Imagery, Action, and Young Children's Spatial Orientation: It's Not Being There That Counts, It's What One Has in Mind

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RIESER, JOHN J.; GARING, ANNE E.; and YOUNG, MICHAEL F. *Imagery, Action, and Young Children's Spatial Orientation: It's Not Being There That Counts, It's What One Has in Mind.* CHILD DEVELOPMENT, 1994, **65**, 1262–1278. Young children typically fail when asked to judge how objects would look if they moved or changed shape, and this has been taken to mean that they lack the competencies for dynamic imagery. We used a different approach to study young children's imagination and found evidence of much earlier competence. Across 6 experiments, people were asked to imagine familiar surroundings and anticipate their spatial orientation from different observation points there. In the first 2 experiments, children (2½–9-year-olds) and their parents sat at home and were asked to call to mind knowledge of their (child's) classroom relative to the perspective at their (child's) seat at (pre)school. After this, subjects were asked to judge the perspective at the teacher's seat in each of 2 conditions. In the Locomotion Condition they were asked to imagine walking from their seat to the teacher's seat while physically walking a path that resembled the actual one in the remote classroom. In the Imagination-only Condition the instructions were the same but they were not accompanied with physical walking. Children 3½ years of age and older, like the adults, were accurate and rapid in the Locomotion Condition. In the Imagination-only Condition the children almost never judged perspective correctly; the adults responded accurately but slowly. These findings were replicated and extended across 4 additional experiments designed to clarify the operating principles that link perceiving, imagining, and acting.

People plan their future actions and coordinate their ongoing activities with remembered places, objects, and events. To do this many report calling to mind the relevant situations and imagining the consequences of alternative actions there. Adults and older children imagine things across a broad range of contexts and tasks. For example, consider shoppers calling to mind the layout of a department store to plan an efficient route from area to area (Gauvain & Rogoff, 1989). Consider physics students attempting to understand the trajectories of moving bodies by calling the movements of familiar objects to mind and imagining how they differ across variations in the conditions (Larkin & Simon, 1987). Finally, consider advising friends about how to cope with strained interpersonal relations, when counseling them to imagine the outcomes of alternative ways of behaving (Beck, Rush, Shaw, & Emery, 1979).

Young children, in contrast to adults, traditionally have been thought to be deficient in their use of imagination. For example, Piaget and Inhelder (1971) distinguished reproductive images from anticipatory images. Reproductive images consist of the literal re-presentation of earlier static situations, whereas anticipatory images involve calling to mind either real or hypothetical situations and imagining possible changes in them. To investigate the use of

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images, Piaget and Inhelder typically showed children an object (or array of objects), then removed the object and asked them to judge either how it had looked when they saw it (to assess use of reproductive images) or how it would look if it were moved or changed in shape (to assess use of anticipatory images). They found that children younger than about 7 years of age typically succeeded on the reproductive image tasks but failed on the anticipatory image tasks, whereas children older than about 7 years of age succeeded on both types of task.

We decided to use a different approach to study young children's imagination, expecting to find evidence of much earlier competence. Our approach differs from earlier ones in two ways. First, in most earlier studies young children were asked to imagine objects and anticipate how they would look if they were changed. In ours, young children are asked to imagine familiar surroundings and anticipate their perspective from different observation points there. Second, in most earlier studies young children were asked to imagine changes that were verbally described, out of the context of the relevant actions. In ours, the to-be-imagined change in perspective is physically prompted by walking with children along a path like the one that they are being asked to imagine walking in the remembered surroundings.

The present experiments are designed to demonstrate that young children can use such imagination strategies in the context of spatial orientation tasks. They are also designed to show that action is tightly linked to the imagined surroundings for children and adults alike, just as it is linked to the perceived surroundings. To set the stage for the theoretical issues addressed by the present experiments we review what is known about perceiving and imagining objects and then review what is known about perceiving and imagining spatial orientation.

Perceiving and Imagining Objects

The acts of perceiving and imagining have much in common for adults, who judge objects and changes in objects in similar ways when they are remembering the objects and imagining changes in them and when they are looking at the objects and watching the changes. This is the case when adults are asked to judge how objects would look after many different types of changes, including rotations, translations, expansions, and foldings (Kosslyn, 1980; Shepard & Cooper, 1982).

What about children, and the development of calling objects to mind and imagining changes in them? Consistent with Piaget and Inhelder's results (1971), recent research shows children younger than about 7 years of age typically fail when asked to anticipate how objects would appear if those objects were rotated to a new orientation (Dean, Duhe, & Green, 1983; Kerr, Corbitt, & Jurkovic, 1980; Marmor, 1975). Children who are 8 years of age and older are similar to adults when asked to imagine changes in objects. For example, Kail (1986) asked 8–11-year-olds and adults to judge whether letters presented in varying orientations were actual letters or mirror image reversals of letters. Like the adults, the children succeeded on the task and their latencies, although slower than the adults', were also linear functions of the stimulus letter's orientation away from upright.

Kosslyn, Margolis, Barrett, and Goldknopf (1990) distinguished four components of imagery processing—generating an image, maintaining it in working memory, scanning it, and transforming it. They compared the performances of 5-, 8-, and 14-year-olds, and of adults on four tasks, each intended to assess one of the four components. The results were that older subjects performed better than younger ones in the image scanning, image rotation, and image generation tasks, and the age groups did not differ significantly on the image maintenance task. Their findings fit with others' conclusions that young children use static images but may be deficient at using dynamic images.

Perceiving and Imagining Spatial Orientation

The acts of perceiving and imagining objects seem to be similar for adults and young children alike in the context of spatial orientation tasks. In a study by Rieser, Guth, and Hill (1986), adults were asked to view targets from one observation point in their immediate surroundings and then they were asked to imagine the perspective from other observation points in the room. Finally, they were asked to judge the directions of target locations from the new observation point as if they stood there under two conditions. In one condition (the Locomotion Condition) subjects physically walked to a new observation point; they were equipped with a blindfold and sound system so they could not see or hear the consequences of their walk. In this condition the subjects judged the self-to-object directions rapidly and accurately from the second observation point. According to the subjects' reports, their good performance was mediated by a dynamic imagery strategy, in which they kept their surroundings in mind during the walk and updated their spatial orientation with respect to their remembered surroundings while walking.

In the other (Imagination-only) condition subjects were asked to imagine walking to a second observation point without physical movement. This condition was more difficult, and subjects showed significantly longer latencies and larger errors. Subjects reported using either a static imagery strategy (attempting to "jump" in their mind to the new observation point) or a computational strategy (recalling the actual self-to-object angle and adding a constant to it in an attempt to correct for the change in observation point).

Rieser (1989) extended the Locomotion and Imagination-only Conditions, systematically varying whether the first and second observation points differed by only a simple rotation in facing direction or only a simple translation in location. As before in the Locomotion Condition, physical walking facilitated adults' use of the dynamic imagery strategy during both the rotation and the translation trials. However, performance in the Imagination-only Condition differed for the rotation and translation trials: It was relatively poor during the rotation trials, and subjects reported difficulty in imagining turning to face a new direction; but it was rapid and accurate during the translation trials, and subjects reported it was easy to judge the directions from other locations in their surroundings as long as they maintained their original heading.

Research on young children's spatial orientation when walking without vision shows that it is similar to adults', although less precise. This is the case for 4-year-olds when they are asked to maintain their spatial orientation with respect to as many as five objects while walking without vision (Rieser & Rider, 1991), for 2-year-olds for single targets (Rider & Rieser, 1988), and for 1-year-olds when they are passively moved relative to a single target (Lepecq & Lafaite, 1990).

Logically, spatial orientation relative to the actual surroundings while walking without vision requires that subjects view their surroundings, close their eyes, and maintain knowledge of their surroundings in working memory even in the absence of visual or auditory information from the surroundings. When walking to the second observation point, subjects need to integrate afferent and/or efferent information related to the biomechanical activities of walking with their remembered surroundings.

But whether "dynamic imagery" is involved really depends on what one means. On the one hand, adults report keeping their surroundings in mind when walking without vision, and they report the images are dynamic, since they are aware of their changing position relative to the remembered objects. Their rapid and accurate spatial orientation performance is consistent with their subjective reports. But, on the other hand, subjects viewed the room from their original observation point, and presumably they would not need to generate an image of their perspective, although they would need to maintain it in working memory and transform it when walking without vision. Furthermore, some may be skeptical about whether dynamic imagery was needed in the Locomotion Condition: The subjects actually walked from the first to the second observation point, so it is correct to say they were perceiving the actual state of affairs, not imagining a possible one.

Young (1989) extended the earlier locomotion and imagination tasks and assessed adults' spatial orientation under "remote site" conditions in order to reduce possible ambiguities about whether subjects are perceiving or imagining their changing orientation when walking without vision. In the remote-site condition, subjects stood in the laboratory and were asked to think about the room where one of their college lectures was held. They were asked to describe salient objects in the remote classroom, imagine standing in a particular observation point there, and point at the objects as if they stood there. After they were induced to generate an image of the perspective of a remote room from one observation point in this way, subjects were then asked to judge the perspective at a second observation point in the remote classroom under the Locomotion and the Imagination-only Conditions, described above.

The results of the Locomotion and the Imagination-only Conditions showed the same pattern in the remote classroom as in the laboratory sites, namely, rapid and relatively accurate responding in the Locomotion Condition and slower and less accurate responding in the Imagination-only Condition. In the actual-site condition subjects were required to keep their actual surroundings in mind, whereas in the remote-site condition subjects were required to generate an image of their classroom. Additionally, in the Locomotion Condition, subjects physically walked a path like the one in the actual classroom, but they were not in the actual classroom, and so they needed to imagine how that walk would change their spatial orientation relative to their imagined surroundings.

Overview of the Experiments

Six experiments were designed to assess young children's spatial orientation relative to their imagined surroundings. There were equal or nearly equal numbers of boys and girls in each experiment; a majority were Caucasian, and the others were African American, Hispanic American, and Asian American. Children were recruited from elementary schools and preschools that served middle-class and lower-middle-class neighborhoods. The aim of the first experiment was to adapt the remote-site method for use with children to see what age range of children could follow the instructions. The aim of the second experiment was to find out whether younger children could follow the instructions and demonstrate competence at using dynamic images in a spatial orientation task. The last four experiments were designed to evaluate a theoretical framework to account for children's spatial orientation relative to imagined surroundings.

Experiment 1: Spatial Orientation Relative to Imagined Surroundings by 5-Year-Olds, 9-Year-Olds, and Adults

Method

The subjects were six 5-year-olds (their average age was 70 months, the range was 69–71 months) selected from a public elementary school kindergarten, six 9-year-olds (their average age was 114 months, the range was 111–118 months) selected from a fourth-grade class in the same school, and six of their parents (we did not ask their ages).

The induction and test procedures consisted of four phases conducted in the subjects' homes, typically in a bedroom or kitchen. First, during the induction phase subjects were asked to call to mind their school classroom as if they stood at their (or their child's) seat in their (or their child's) classroom. Four of the classroom's important objects or features were identified to serve as the target objects for the tests (the targets were familiar things like a window, doorway, light switch, bookcase). In the kindergarten classroom all of the children sat on the carpeted floor and were arranged in a U shape so that the teacher sat facing the open end of the U. In the fourth-grade classroom the children sat in rows facing the teacher, who sat at the front of the room facing the children. The induction phase lasted 5–10 min, until the children said they had their classroom firmly in mind.

The second phase consisted of Induction-check tests. During the tests children were asked to imagine that they sat at their seat in their classroom at school and then were asked to point as rapidly as they could as each of the targets was named. The targets were named in randomly interspersed order, twice each, for a total of eight trials.

The third and fourth phases consisted of tests to assess the children's knowledge of a second perspective, the perspective at the teacher's seat. Half the children were tested first under the Imagination-only Condition, and the others were tested first under the Locomotion Condition. During the Imagination-only Condition children then were asked to imagine walking over to the teacher's seat and turning to face the way their teacher faces. They were given about 4 sec to imagine the walk, and then they were asked to point as rapidly as they could as each of the targets was named in randomly interspersed order, twice each, for a total of eight trials.

During the Locomotion Condition the verbal instructions were exactly the same, but in this case the children physically walked a path like the one they were asked to imagine walking in their classroom. They were guided from behind by the tester. Since the bedrooms and kitchens where the tests were conducted were much smaller than the children's classrooms, it was not possible for the children to walk the actual distance from their own seat to the teacher's seat in their imagined classroom, but it was easy to guide them through the needed amount of change in heading. The walks preserved the actual changes in heading, but the distances were compressed to fit into the constraints posed by the children's homes; whereas the actual distances ranged in the classrooms from 4 to 20 feet, the distances walked in the children's homes ranged from 4 to 8 feet. (This compression of the distances made sense in light of earlier research with adults [Rieser, 1989]. Physical rotation consistent with the to-be-imagined heading greatly facilitated this task, whereas physical translation consistent with the to-be-imagined location did not significantly affect performance.) The walks lasted about 4 sec, after which subjects were asked to point at the targets for a total of eight trials.

Except for the physical walk, the Imagination-only and the Locomotion Conditions were exactly the same—verbal instructions, time available to imagine walking from their own seat to the teacher's seat, and tests to assess knowledge of the second perspective were all the same.

The dependent measures to assess performance were the frequency of correct responses and the frequency of rapid responses. Responses were scored by marking on a sketch of the situation the direction pointed and classifying each as falling into one of the front/back/left/right quadrants. We selected targets that fell near the center of their respective quadrants to make the classifications of the subjects' correct responses relatively easy. Furthermore, during preliminary work it was our impression that subjects' latencies were bimodal—the trials in some conditions seemed difficult and subjects took much longer than 2 sec to respond, whereas the trials in other conditions seemed easier and took less than 2 sec. To capture this, the tester simply classified the response latencies as slower or faster than 2 sec by using the second counter of her digital stopwatch to count the seconds silently from the time she named the target until the subject attempted to point at it. Both the directions and response times were classified very reliably. An independent observer watched the 24 repeated trials (eight each in the Induction, Locomotion, and Imagination-only Conditions) with each of four 5-year-olds. The two independent observers agreed on 100% of the front/left/back/right classifications and on 95% of the response latency classifications.

A Note on Random Responding and Chance Levels of Success

The frequencies of correct responses were analyzed to decide which individual subjects exceeded chance levels of success. Chance levels of performance can be defined in different ways, depending on what assumptions are made about the performance of a subject who selected responses at random. In the present experiments, the six subjects in each age group were asked to point toward target objects in each of three test conditions (the Induction-check, Locomotion, and Imagination-only Conditions). In each condition, four target objects were used (one in each of four quadrants), and the frequencies of correct responses were tallied.

Briefly consider levels of chance responding that would result from three different models of random responding. The first model fits a random responder who did not realize that all four possible responses were used in the first block of trials and then again in the second block. For this model, the probability of success on each trial is .25; the probability that an individual would be correct on all eight trials is .00002, on seven or more .00052, on six or more .01052, on five or more .031052, and on four or more .14052. Thus, on this model scores of 5/8 or better would all exceed chance.

The second model fits a random responder who realized that each of the four possible responses was used only once in each block of four trials. For this model, the probability of success on the first trial of the first block is .25, on the second trial .33, the third .50, and the fourth 1.00; the same probabilities apply to the second block. The probability of scoring 8/8 is .002. For missing the first of the eight trials the probability is .005; for the second .003; for the third and fourth .002; and these repeat for missing the fifth through eighth trials. For this model, a conservative estimate for the probability of a score of 7/8 or 8/8 correct is .012.

Finally, the third model fits the random responder described in the second model, who understood that the target-response pairings in the second block were the same as in the first block. In addition, this model's random responder would memorize the responses he gave during the first block of trials and simply repeat them during the second block of trials. If the random responder was correct (or incorrect) on the four trials of the first block she would also be correct (incorrect) on the second block. In this case, the second block should not be counted. For the third model, the probability of 4/4 correct would be .04.

According to the first model a score of 5/8 or better is significantly better than chance; according to the second the cut-off score is 7/8 and according to the third, and most conservative, model the cut-off score is 4/4 for the first block only.

Results and Discussion

It was easy to induce the children and adults alike to bring the classroom to mind from the perspective of their seats. One 5-year-old failed the Induction-check tests; this child was tired and was not tested further, so his performance is not reflected in the summary statistics described below. For another 5-year-old, the kindergarten classroom was new so we switched to her previous year's preschool classroom and the summary statistics reflect the switch. With these qualifications, the performance in each age group was 100% correct and 100% rapid on the Induction-check tests.

Performance in the Locomotion Condition was similarly good, whereas in the Imagination-only Condition it was poor. For the Locomotion Condition, even using the most conservative model of random responding, all but one of the 9-year-olds exceeded chance levels of success. The 5-year-olds were correct and rapid on 100% of the trials, the 9-year-olds were correct on 98% (SD = 0.4) of the trials (one boy made one error) and rapid on 100%, and the adults were correct and rapid on 100% of the trials. The age groups did not significantly differ on their numbers of errors or slow responses by F test.

In the Imagination-only Condition the numbers of correct responses and of rapid responses showed statistically significant differences, $F(2, 15) = 58.1$ and 28.0, respectively, both $ps < .001$. The 5-year-olds were correct on 2% (SD = 0.4) of the trials; the 9-year-olds were correct on 27% (SD = 2.2), which was significantly better than the 5-year-olds, $t(10) = 2.16$, $p = .05$; and the adults were correct on 100%. The 5-year-olds were rapid on 100% of the trials, the 9-year-olds on 23% (SD = 2.8), and the adults on 29% (SD = 0.8).

In the Imagination-only Condition a majority of every 5-year-old's responses was classified as "no-shift" responses, defined as fitting the perspective available at the observation point they were first asked to imagine (their classroom seat); overall, this was the case for 88% (SD = 2.0) of the trials. Unlike the older children, the young children responded rapidly and gave no indication they understood the task. The 9-year-olds, on the other hand, appeared to struggle to think of the correct response, although they failed much of the time as evident from the fact that 52% (SD = 3.0) of their responses fit the "no shift" category.

Striking individual differences were evident as well. For example, one 9-year-old responded like the 5-year-olds, producing "no shift" responses on all eight trials, six of which were rapid. Others appeared to understand that the instructions called for a change in responding from the induction tests, but were uncertain about how to figure out the needed change. For example, one girl responded slowly on each trial, but inaccurately on each as well, producing a mixture of "no shift" and other errors. Finally, one boy appeared to understand that a change was needed and knew how to figure it out. He responded slowly on all eight trials, but was correct on six of them. Furthermore, after the tests he observed the informal testing of a classmate who produced rapid "no shift" responses on each trial in the Imagination-only Condition. The observing 9-year-old was flabbergasted by this and finally intervened by explaining to his friend how and why he needed to change his responses; although his explanation seemed exactly right to us, the friend did not understand the point.

Experiment 2: Testing Younger Children

The methods provide a convenient way to assess whether young children can bring familiar settings to mind and imagine alternative actions there. They show that even 5-year-olds can be induced to generate images of familiar surroundings and readily imagine changes in the imaged perspective under some conditions. The purpose of Experiment 2 was to see if younger children could be conveniently tested with the same methods. To do this, the same procedures were used with children ranging from 2 through 4 years of age in order to identify the youngest age range where more than half of the children can succeed at the Induction-check tests. We report the results of this study, and then outline some of the alternative processes that might account for the findings, setting the stage for Experiments 3 through 6.

Method

The subjects were 31 additional children (15 were boys) ranging from 33 to 64 months of age. The children were tested on their knowledge of their preschool classrooms via procedures that were the same as those in Experiment 1. Unlike Experiment

1, the tests were not conducted in the children's homes but instead were conducted in a mobile research laboratory, a modified school bus, parked outside their schools. An internal wall separated the driver's area of the bus from the back area, which was outfitted as a 5 × 8-foot playroom. In the playroom, the floor, ceiling, and sides (windows included) were walled over, covered with sound insulation, and carpeted to create a small playroom that was sound attenuated and, when the lights were turned out, completely dark. The playroom was equipped with infrared lights and video cameras. These were controlled from the driver's area of the bus, where a second experimenter viewed the action (whether lighted or in darkness) on a video monitor. In addition, the tester could view the children even when the lights were out by using a hand-held infrared monocular scope.

Results and Discussion

The proportions of rapid and of accurate responding appear in Table 1 for each subject in each condition. Some 3-year-olds succeeded at the Induction-phase tests with these methods, but others did not: only half of the 3-year-olds scored 50% correct or better in the Induction-check tests. Most of the 4-year-olds performed easily and well, as did the 5-year-olds in Experiment 1. There are further similarities to the results of Experiment 1. Many of the present 3-year-olds and all but one 4-year-old performed accurately and rapidly in the Induction-check tests and in the Locomotion Condition tests. They also performed inaccurately but rapidly in the Imagination-only Condition tests and most produced mainly "no-shift" responses that fit with the perspective at their own seats, not the teacher's seat.

As is apparent from Table 1, different patterns of individual differences seem to pertain for the Induction-check and Locomotion Condition tests on the one hand, versus the Imagination-only Condition tests on the other hand: Children who performed well on the Induction-check tests also tended to do well on the Locomotion Condition tests but not on the Imagination-only Condition tests. To estimate the magnitude of these associations, we computed the partial correlations, controlling the effect of age, of proportions of correct responses across the three test conditions, combining the scores of the 26 children who completed participation in the present experiment with the 12 5- and 9-year-olds who participated in Experiment 1. The partial correlation was statistically significant for errors on the Induction-check tests and the Locomotion tests, $r = .40$, $t(35) = 2.58$, $p < .01$. For the errors on the Imagination tests, the partial correlation was not significant for either the errors on the Induction-check tests ($r(36) = .13$) or the Locomotion tests ($r(36) = .05$). These results indicate that the children used similar strategies in the Induction-check and the Locomotion Condition tests, and quite different strategies in the Imagination-only Condition tests. This is consistent with Experiment 1 reports from the 9-year-old and adult subjects that the target directions in the Imagination-only Condition needed to be figured out, whereas in the Locomotion and Induction Conditions the target directions seemed directly "perceptible."

General Discussion of Experiments 1 and 2

The results indicate that even the 3½-year-old children used dynamic imagery when prompted by physically walking in the context of a spatial orientation task. The 2-year-olds and some of the younger 3-year-olds did not understand what we wanted them to do and failed to point appropriately even during the Induction-check tests.

Except for the 2- and young 3-year-olds, children and adults alike responded rapidly and accurately in the Locomotion Condition and performed either inaccurately or with more difficulty in the Imagination-only Condition. Although we could not coax meaningful explanations from the younger children, the explanations of the 9-year-olds and adults are informative about this. For the Locomotion Condition, each reported that responding was easy, as if they had actually walked to the teacher's seat and almost as if they could "see" the perspective there. For the Imagination-only Condition, however, each reported needing to "do something" in order to figure out how to respond (this was not the case for one 9-year-old, the only one who responded rapidly and incorrectly on every trial).

Age-related differences were not found for the Locomotion Condition. But although subjects at all ages experienced significantly more difficulty in the Imagination-only Condition than in the Locomotion Condition, there were significant age-related differences as well. In the Imagination-only Condition every adult performed correctly and more slowly than in the Locomotion Condition; they needed to think about how to re-

TABLE 1

THE RESULTS OF STUDY 2 FOR EACH INDIVIDUAL SUBJECT ORDERED BY AGE

Age (Months)	Gender	Induction Phase		Locomotion Condition		Imagination-only Condition		
		Correct	Rapid	Correct	Rapid	Correct	Rapid	No-shift
33	M	0	0	...	...	...	...	...
36	M	0	0	...	...	...	...	...
37	F	.75	1.00	.50	1.00	0	1.00	1.00
37	M	.75	1.00	.75	1.00	0	1.00	1.00
38	M	.33	0	.25	1.00	0	0	0
38	F	.25	1.00	.38	1.00	.12	1.00	.12
39	F	.88	1.00	.25	1.00	.50	1.00	0
44	M	0	1.00	...	...	...	...	...
47	M	1.00	.50	1.00	1.00	0	0	1.00
48	F	0	0	...	...	...	...	...
49	M	.58	.67	1.00	.88	0	1.00	1.00
53	M	1.00	1.00	1.00	1.00	0	1.00	1.00
53	F	1.00	1.00	1.00	.88	0	.75	1.00
54	M	1.00	1.00	1.00	1.00	0	1.00	1.00
56	F	1.00	1.00	1.00	.50	.50	.50	.50
56	M	1.00	1.00	1.00	.88	.50	.50	.50
56	F	1.00	1.00	1.00	.88	.50	.50	.50
60	F	1.00	1.00	.75	0	0	0	1.00
60	F	1.00	1.00	1.00	1.00	.12	0	.88
60	M	1.00	1.00	1.00	1.00	.50	1.00	.50
60	F	1.00	1.00	.50	0	0	0	1.00
60	F	1.00	1.00	.75	.75	.25	1.00	.75
60	M	0	0	...	...	...	...	...
60	F	1.00	1.00	1.00	1.00	.25	0	.75
61	F	.67	.67	1.00	.88	0	0	1.00
61	F	1.00	1.00	1.00	1.00	.50	0	.50
61	M	1.00	1.00	1.00	.88	0	0	1.00
62	F	.67	.67	.75	1.00	0	0	1.00
63	M	1.00	1.00	1.00	1.00	0	1.00	1.00
63	F	1.00	1.00	1.00	1.00	0	1.00	1.00
64	M	1.00	1.00	1.00	1.00	0	1.00	1.00

NOTE.—The numbers are the proportions of the eight repeated trials that were classified as correct (in the appropriate quadrant) and rapid (faster than 2 sec) in the Induction Condition, Locomotion Condition, and Imagination-only Condition. Children who did not master the Induction Condition were not tested further as indicated by ellipses (. . .).

spond. Every 3–6-year-old responded incorrectly and rapidly; it was as if they did not understand the verbal instruction "to imagine walking to the teacher's seat and point as if you stood there," since most of their incorrect responses "fit" with their initial perspective.

Why might the younger children have failed so completely in the Imagination-only Condition? Perhaps they rarely went to the teacher's seat and therefore did not know the perspective there. However, this is easily ruled out given their excellent performance in the Locomotion Condition, where they judged the perspective at the teacher's seat almost perfectly. Alternatively, perhaps they did not understand the verbal instructions to imagine walking to the teacher's seat and then to point toward the targets "as if" they stood there at the teacher's seat. This fits with the fact that all of the adults asked questions about the instructions in this condition, to make sure they understood what we wanted them to do.

It seems clear that the young children did not understand what we wanted them to do in the Imagination-only Condition, since their responses were uniformly rapid, incorrect, and fit their initial perspective. However, it is equally clear that the instructions per se were "understandable," since the same instructions were given in the Locomotion Condition and every subject followed them! The context provided by physically walking made the instructions sensible even to the young children. The older children understood the instructions without the physical context provided by the walk, but most failed to devise a workable strategy, and the adults understood the instructions and devised a workable strategy.

Three Operating Principles

What processes might account for the ease with which the children switched from their own to the teacher's perspective in the Locomotion Condition and their difficulty in the Imagination-only Condition? We devised a theoretical framework to help make sense of these findings. The three operating principles of this framework are described below, together with relevant features of Experiments 3 through 6, which were designed to evaluate them.

Principle 1.—Knowledge of spatial layout in long-term memory is (*a*) functionally viewpoint independent (organized so that children can call it to mind from all of the familiar observation points), and (*b*) generative (so that they know the perspective at all of the observation points, including wholly novel ones that they have never experienced).

Consider an alternative to the first part of the principle. During the induction, children were asked to imagine standing at their own seat in their classroom. This would likely be the most familiar perspective of their classroom. Perhaps children can initially bring to mind only the most familiar perspective of a remembered place, in which case children's long-term memory of spatial layout would be viewpoint dependent. Experiment 3 was designed to evaluate this possibility. Children were asked initially to call their classroom to mind from the teacher's seat and then switch to the perspective at their own seat via the Locomotion and Imagination-only Conditions. If children's long-term knowledge of spatial layout is functionally viewpoint independent, then they should perform equally well in the Locomotion and Imagination-only Conditions, whether they are asked initially about a more familiar or less familiar perspective.

Now consider the second part of Principle 1, which says that long-term knowledge is generative, in the sense that children can view a place from one observation point and "know" the perspective at other, novel observation points. Since in Experiments 1 and 2 children would likely have seen both the perspectives they were asked to judge, Experiment 4 was designed to evaluate the issue. Children viewed a small novel room from one and only one observation point. Then they were asked to judge the perspective at a diametrically opposed observation point (they had never viewed it from the novel point) under both the Locomotion and Imagination-only Conditions.

Principle 2.—Working memory, in contrast to long-term knowledge, is functionally viewpoint dependent. That is, when people have a particular place in mind from one observation point additional processing is needed to switch to the perspective at a different observation point. The evidence for this is that even the older children and adults found performance in the Imagination-only Condition somewhat problematic, and the younger children failed at the task completely. Why might performance in the Imagination-only Condition have been problematic? The preceding experiments show that the children "knew" the perspective at the teacher's seat since they judged it so well in the Locomotion Condition, and that the instructions were understandable as well. Despite this, they had difficulty bringing the knowledge to mind while they were imagining a different perspective of the same room.

Principle 3.—Action, imagination, and perception are tightly linked, so that actions can be perceived and represented relative to imagined surroundings in working memory in the same ways that they are represented relative to one's actual surroundings. The preceding experiments support this, since even the young children performed rapidly and accurately in the Locomotion Condition, as if perceiving their changing position relative to their imagined classroom.

Consider two alternatives to Principle 3. One is that children's good performance in the Locomotion Condition was mediated by their use of a "mapping" strategy and does not demonstrate anything about whether action and imagination are linked. To use a "mapping strategy," children might map features of their remembered classroom onto spatially corresponding features of the visible test room. If they did this, then they would not need to keep in mind the locations of the remembered classroom targets. Instead, they would need to keep in mind which features of the test space corresponded to the target objects and then simply point at the visible objects that corresponded to the named target.

This "mapping" strategy could, in principle, account for the easiness of the Locomotion Condition as well as the Induction-check tests, since subjects could simply point at the visible objects mapped onto the targets. Experiment 5 was designed to evaluate whether or not children used a mapping strategy. The ability to use a mapping strategy in this situation depends on the opportunity to view the test space, in order to pick features of the actual test space that correspond spatially to the targets in the to-be-imagined classroom. In Experiment 5 children were tested in a totally dark laboratory room, in which none of the features could be seen or heard.

The second alternative is that physical locomotion is not tightly linked to imagination but, instead, plays the more general role of a "dump" function. According to this alternative, performance in the Imagination-only Condition is difficult because working memory is already "occupied" with a perspective of the test space. Physical locomotion may work to "dump" the original perspective from working memory, thereby making room for a new perspective.

If this is the case, then locomotion in any direction should serve to clear working memory. If, on the other hand, action and imagination are tightly linked, then one would expect the geometry of the imagined perspective to be updated in ways that fit with the geometry of the physical locomotion. The three conditions of Experiment 6 were designed to contrast these alternatives. In the Relevant Walk Condition the children walked a path like the one from their seat to the teacher's seat; in the Full Circle Condition, subjects walked completely around a full circle, while being asked to imagine walking to the teacher's seat; and in the Opposite Direction Condition subjects were guided on a path that was opposite in direction from the path to the teacher's seat and faced about 180° away from the teacher's facing direction. If physical walking facilitates performance by serving a nonspecific "dump" function, then children should perform similarly well in all three test conditions.

Experiment 3: Initially Imagining the Teacher's Perspective

Method

The subjects were six 5-year-olds who averaged 61 months of age (ranging from 52 to 70 months). The children were tested in the same situations and under the same conditions as those described in Experiment 1. The only change was that the children were asked initially to imagine standing at the teacher's seat (instead of their own). During the induction trials children were asked to point at the targets as if they occupied the teacher's seat. Then, during the Locomotion and Imagination-only Condition tests they were asked to point at the targets as if they occupied their own seats in the classroom.

Results and Discussion

The children responded in the same ways in this experiment as in the earlier experiments. During the Induction-check tests the children were correct and rapid on 100% of the trials. During the Locomotion Condition trials, they were correct on 96% (SD = 0.5) of the trials and were rapid on 100% of the trials. All but two subjects, who each missed one trial, exceeded chance levels of success even by the most conservative model of random responding. During the Imagination-only Condition trials, subjects were correct on 6% (SD = 0.8) of the trials (one subject was correct on two of the eight trials and one subject was correct on one trial) and rapid on 96% (SD = 0.4) of them. The subjects in this experiment performed similarly to the 5-year-olds in Experiment 1.

Consider the three main findings and their implications for spatial representation. First, the 5-year-olds in the present experiment judged the target objects from the perspective at the teacher's seat as well as the 5-year-olds in Experiment 1 judged them from the perspective at their own seats. It appears to have been similarly easy for them to access their classroom knowledge from the familiar perspective at their own seat and the less familiar perspective at the teacher's seat. In other words, their long-term spatial knowledge is functionally viewpoint independent.

Second, the subjects judged the target objects from the perspective at their own seat very poorly in the Imagination-only Condition. Clearly, the subjects "know" the perspective from their own seat, and their difficulty here does not indicate a lack of knowledge in long-term memory. Instead, it indicates that they were unable to access that knowledge in long-term memory and call it to mind in working memory. And third, the present subjects judged the perspective at their own seat very well in the Locomotion Condition. As in the other experiments, the acts involved in locomoting facilitated calling the perspective at their own seat to mind.

On the one hand, the results show that spatial knowledge in working memory is organized so that it is functionally viewpoint dependent; and, at least under the conditions of the present experiments, the perspective in working memory tends to fit the changes in perspective that go with the geometry of the locomotion. On the other hand, the results show that in long-term memory spatial knowledge is organized so that it is functionally viewpoint independent.

Experiment 4: Judging the Perspective at Imagined Observation Points That Were Never Experienced

How generative are the spatial encoding processes serving long-term memory? One might suppose that encoding processes are literal, in the sense of storing the perspectives on a place that have been seen. However, the system might be generative, so that experience of seeing a single view of a place would lead to knowledge of its different possible perspectives. Experiment 4 was designed to contrast these alternatives.

Method

The subjects were six 3- and 4-year-olds (they averaged 51 months of age and ranged from 45 to 58 months). The procedures were adapted from those used in the earlier experiments in order to show children an unfamiliar playroom from one and only one observation point, and then assess their knowledge of the novel perspective at the diametrically opposed corner of the playroom under both the Locomotion and the Imagination-only Conditions.

Tests were conducted in the mobile laboratory. Toys were placed in the corners of the 5 × 8-foot play area, and two points of observation were defined: one very near to the room's entrance and the other in the diametrically opposed corner. The procedures consisted of a learning phase with the lights turned on, learning-check tests with the lights turned off, Locomotion Condition tests with the lights turned off, and Imagination-only Condition tests with the lights turned off. The learning phase lasted about 5 min. Children walked with the experimenter directly to one or the other point of observation. The experimenter used her hand to cover the subject's eyes during the short walk. Standing at the first observation point, the experimenter pointed out the four target objects and asked the children to point rapidly as each was named. During the learning-check tests the lights were turned off and children were asked to point rapidly as the target objects were named for a total of eight trials as in the earlier experiments.

The Locomotion and the Imagination-only Condition tests were the same as those used in the previous experiments. Half of the subjects underwent the Locomotion Condition first and half the Imagination-only Condition first. Within each condition, half viewed and learned the targets from one of the observation points and half from the other.

Results and Discussion

The young children's pattern of responding in this experiment, in which the second observation point was wholly novel, was the same as in the earlier experiments, where it was familiar. During the Induction-check tests the children responded correctly and rapidly on 100% of the trials. During the Locomotion Condition tests, conducted after they were guided in the dark to a wholly novel observation point, they were correct on 100% of the trials and rapid on 83% (SD = 1.9). All subjects exceeded chance levels of success. And during the Imagination-only Condition tests they were correct on 0% of the trials, rapid on 100%; 83% (SD = 2.3) of their responses were classified as "no shift" responses.

Although the pattern is the same, the children were slightly worse in the present experiment when asked to judge a novel perspective than in the earlier experiments when asked to judge a familiar perspective. We wished to evaluate this statistically and so used t tests to compare performance in each condition of this experiment with Experiment 3 in which the second observation point was the very familiar one at the their own seat. None of the ts approached statistical significance for either the percentages of correct or of rapid responses for the Induction-check test, the Locomotion Condition tests, or Imagination-only Condition tests.

Experiment 5: Evaluating Use of a "Mapping Strategy" to Account for the Good Performance in the Locomotion Condition

Method

The subjects were six 3- and 4-year-olds, drawn from preschools in middle-class neighborhoods (age averaged 51 months and ranged from 45 to 58 months). The tests were conducted in the mobile laboratory parked outside their schools. The procedures for the induction phase, Induction-check tests, Locomotion Condition, and Imagination-only Condition tests were exactly the same as those in the earlier experiments, except for the change in lighting. The lights were left on during the induction phase, since the children became nervous when in the dark for more than a few minutes at a time. After the induction phase, the lights were turned off until the Induction-check tests were completed. Then the lights were turned on again, children were reminded to keep the perspective of their classroom at their seat in mind, the lights were turned off, and the Locomotion and the Imagination-only Condition tests were given—half the subjects completed the Imagination-only Condition first and the others completed it second.

Results and Discussion

The subjects responded the same way in this experiment in which the lights were turned off as they did in the earlier experiments where the lights were turned on. During the Induction-check trials, the subjects were both correct and rapid on 100% of the trials.

During the Locomotion Condition trials, the subjects were correct on 100% and rapid on 100% of the trials. All subjects exceeded chance levels of success. During the Imagination-only trials, the subjects were rapid on 100% and correct on 0% of the trials; their errors were systematic, however, and 88% ($SD = 2.4$) of them were "no shift" responses. We wished to know whether the young children tested in the dark in this experiment reliably differed from children of similar ages tested in the light. To assess this, we selected six comparably aged children from Experiment 2 for statistical comparison; the six averaged 53 months of age and ranged from 47 to 56 months. In the Induction-check tests they averaged 100% correct and 92% ($SD = 0.2$) rapid; in the Locomotion Condition they averaged 100% correct and 100% rapid; and in the Imagination-only Condition they averaged 17% ($SD = 0.3$) correct, 98% rapid, and 83% ($SD = 0.3$) of the responses fit the "no shift" pattern. None of these Experiment 2 scores differed reliably from the corresponding Experiment 5 scores by t test.

The children performed as well in the dark as they did in the light. There is no evidence that they used a "mapping" strategy. Instead, we believe the findings show that the physical walk was tightly linked with the imagined surroundings: The children followed instructions by bringing their classroom to mind from the perspective at their own seat in the induction tests and imagined physically walking from their seat to the teacher's seat in the Locomotion Condition tests.

But, alternatively, it may be the case that the physical walk was not tightly linked to the imagined surroundings and, instead, that the walk served a general function of "dumping" the original perspective from working memory, clearing the way for the children to bring the second perspective to mind. Experiment 6 was designed to evaluate this possibility.

Experiment 6: Does the Locomotion Exert a Specific or General Effect?

Method

The subjects were six 5-year-olds (they averaged 61 months of age and ranged from 56 to 65 months). The tests were conducted individually in quiet areas of the children's homes. The procedures for the Induction phase, Induction-check tests, and Locomotion Condition tests (now it is called the Meaningful Locomotion Condition) were exactly the same as in Experiment 1. However, the Imagination-only Condition was not used. Instead, two new conditions were designed to assess whether physical locomotion facilitates performance because it is tightly linked to imagined surroundings or merely plays a general "dump" function.

Both new conditions were very similar to the original Locomotion Condition—subjects were physically guided along a path while being asked to imagine walking from their seat in class to their teacher's seat. But in both cases the path was geometrically different from the to-be-imagined path. In the Full Circle Condition, children walked a full circle that was about 1 meter in diameter and faced the same way as when they started. In the Opposite Direction Condition children walked a path that was opposite in direction to the one needed to move from their seat to the teacher's seat, and they ended facing as they did at the start of the walk. All six of the possible orders of the three test conditions were used, one with each of the children tested.

Results and Discussion

As in the earlier experiments, the children were 100% correct and rapid during the

Induction-check tests, and 92% (SD = 0.8) correct and 96% (SD = 0.5) rapid on the Meaningful Locomotion Condition tests. Four of the subjects exceeded chance levels of success. Performance in the other two conditions was poor, similar to performances in the Imagination-only Conditions in the earlier experiments. In the Full Circle Condition the children were 6% (SD = 0.5) correct and 88% (SD = 0.5) rapid, and 81% (SD = 1.1) of their responses fit the "no shift" pattern. In the Opposite Direction Condition the children were 6% (SD = 0.5) correct and 96% (SD = 0.5) rapid, and 83% (SD = 1.0) of their *incorrect* responses fit the "no shift" pattern. The errors significantly differed across the repeated trials of the three conditions, $F(2, 10) = 184$, $p < .001$. Follow-up *t* tests showed significantly fewer errors in the Meaningful Locomotion Condition than in the other two conditions (for each analysis, $t(5) = 14$, $p < .001$), which did not significantly differ from each other.

Since small differences in performance were observed across these two conditions and the Imagination-only Conditions used in the earlier experiments, we wished to assess whether the small differences were statistically reliable. To do this *F* tests were calculated for the percentages correct and percentages of rapid responses for the children's performances across three conditions—the Full Circle Condition, the Opposite Direction Condition, and the 5-year-olds' performances in the Imagination-only Condition from Experiment 1. None of the *F*s approached statistical significance (they were all smaller than 1.0, with $ps > .20$). The findings indicate that the physical walk is tightly linked with children's imagined surroundings under these conditions.

General Discussion

For adults and young children alike, these experiments show ways that perceiving, acting, and imagining are coupled in the context of spatial orientation tasks. James Gibson (1979) complained of "the false dichotomy between present and past experience," noting that "it has not been possible to find out when perceiving stops and remembering begins" (p. 253). Gibson believed that perceiving consisted of the pick-up of information specifying the properties of organisms, objects, and events and the observing self's relation to them. In many cases such properties are detected over time—for example, the expression of an emotion, the three-dimensional shape of opaque objects, or the arrangement of rooms within a house. He felt it was wrong to dichotomize the pick-up of information in an instant of time as "perceiving" and the pick-up of information over time as "remembering."

The present demonstrations follow Gibson's lead by emphasizing the similarities and codependencies among the three activities while blurring the functional distinctions among them. Action and perception are tightly linked in spatial orientation tasks: When walking without vision, young children and adults keep up to date on their changing perspectives relative to remembered features of their actual surroundings. Action and imagination are linked in a similar way: When walking without vision, children and adults keep up to date on their changing perspectives relative to imagined surroundings. The experiments were designed to help evaluate three operating principles of the underlying system linking both long-term and working memory with perceiving, imagining, and acting. These principles and relevant supporting evidence are considered below.

The Findings and the Empirical Status of the Three Operating Principles

Across all six experiments, the subjects included seven children ranging from 2 to 3.5 years of age, 53 ranging from 3.5 to 6 years, six who were 9 years, and six adults (see Table 2). A few of the young children seemed not to understand what we wanted them to try to do (these included all seven of the 2–3.5-year-olds and three of the 3.5–6-year-olds). For all other subjects, those who did understand what we wanted, performance in the Locomotion Condition was very good. For example, 49 of the 50 3.5–6-year-olds were correct on 75% or more of their trials, and on 382 of their total of 400 repeated trials their responses were correct. Performance in the Imagination-only Condition, on the other hand, was very poor. For example, all 50 of the 3.5–6-year-olds were correct on 50% or fewer of the trials, and on only 31 of the total of 400 repeated trials were their responses correct. Although incorrect, the 3.5–6-year-olds erred by systematically producing "no shift" responses. For example, 47 of the 50 children produced "no shift" responses on at least half of their repeated trials, and for a total of 341 of the 400 repeated trials their responses were "no shift" responses.

TABLE 2

SUMMARY OF THE 4–6-YEAR-OLDS' PERFORMANCE IN THE LOCOMOTION AND THE IMAGINATION-ONLY CONDITIONS

	LOCOMOTION		IMAGINATION			
	Total Correct/ Total Trials	No. of Subjects with ≥ 75% Correct	Total Correct/ Total Trials	No. of Subjects with ≤ 50% Correct	Total "No Shift" Errors/Total Trials	No. of Subjects with ≥ 50% "No Shift" Errors
Experiment 1	48/48	6/6	1/48	6/6	42/48	5/6
Experiment 2	150/160	19/20	25/160	20/20	135/160	20/20
Experiment 3	46/48	6/6	3/48	6/6	43/48	6/6
Experiment 4	46/48	6/6	0/48	6/6	40/48	5/6
Experiment 5	48/48	6/6	0/48	6/6	42/48	5/6
Experiment 6	44/48	6/6	Full Turn Condition 2/48	6/6	39/48	6/6
Totals	382/400 96%	49/50 98%	31/400 8%	50/50 100%	341/400 85%	47/50 94%

Principle 1: Children's Long-Term Knowledge of Spatial Layout Is Viewpoint Independent and It Is Generative

During the Induction phase children were asked to tell us about their classroom and then bring it to mind either from the perspective at their own seat (in Experiment 1) or at the teacher's seat (in Experiment 3). No matter which perspective they were asked to bring to mind first, they were similarly successful in the Induction tests (100% in Experiments 1 and 3), similarly successful in the Locomotion Condition tests (100% and 96%, respectively), and similarly unsuccessful in the Imagination-only Condition tests (2% and 6% correct, respectively). The small differences in performance across corresponding conditions of the two experiments did not approach statistical significance by t test (the t values were less than 0.5, $ps > .2$). Thus, the children were able to think about the perspective either at their own seat or the teacher's seat similarly well. They were not limited to only a single viewpoint when initially recalling familiar places from long-term memory.

Additionally, their long-term spatial knowledge is functionally generative, that is, the experience of seeing one view of a place lets them know what the other perspectives look like. In Experiment 4, children viewed a novel room from one and only one observation point. In the Locomotion Condition, they were guided in the dark to the diametrically opposed observation point. They localized the targets as accurately from this wholly novel second observation point in Experiment 4 as from a familiar second observation point in Experiment 3.

Principle 2: Children's Working Memory of Spatial Layout Is Functionally Viewpoint Specific

Subjects were asked to bring to mind their knowledge from one perspective and then shift to a second perspective. The research supporting Principle 1 shows that both perspectives were available from long-term spatial knowledge, but the data show that having one perspective of the remembered place in mind interfered with bringing a second perspective of the same place to mind. It did not matter whether the initial perspective was from a more familiar (Experiment 1) or less familiar (Experiment 4) observation point. Subjects had to "do something" to bring a different perspective of the same place to mind. In the Locomotion Condition physically walking was effective for young children and adults alike. In the Imagination-only Condition the adults and some of the 9-year-olds, but none of the younger children, devised a strategy to switch perspectives.

Other investigators have noted viewpoint specificity when adults are asked to judge spatial orientation (e.g., Levine, Jankovic, & Palij, 1982; Presson, DeLange, & Hazelrigg, 1989). They have suggested that it means that in some situations people encode the locations of objects in a specific way in long-term memory. Contrary to this, the present findings show specificity only at the level of working memory, not long-term memory.

Principle 3: Children's Action, Imagination, and Perception Are Tightly Linked

In the Locomotion Condition children judged their changing spatial orientation rapidly and accurately whether they were asked to point toward objects in their actual surroundings or remembered surroundings. In Experiment 5 the children did this when walking in the dark, which shows they were not using a simple "mapping" strategy. In Experiment 6 the children did this when asked to localize the targets when they were physically guided along a route that fit with the actual rotation in heading needed, but not when they simply walked in a circle or walked in an irrelevant direction. This indicates that the locomotion did not serve to merely "dump" the contents of working memory. Apparently, children perceived their walk relative to their imagined surroundings.

Age-related Differences in the Perceiving-Imagining-Acting System

Three developmental differences seem important. The first involves the 2–3.5-year-olds' failure on the induction task tests. The second involves the 3.5–6-year-olds' failure on the Imagination-only task. And the third involves the 9-year-olds' failure on the Imagination-only task. These are discussed in order below.

Why might the 2–3.5-year-olds have failed on the Induction task tests? Did they fail because they lacked one or more of the underlying competencies or simply because they did not understand what we intended for them to try to do? While testing the children, our impressions were that they simply did not understand—they wanted to please us but did not understand what we wished them to do. If this is a correct interpretation, they still might have been unable to perform even if they had understood. Given this, what might their specific deficiencies be? We know from earlier research that even 24-month-olds can maintain their spatial orientation relative to their actual surroundings when walking without vision (e.g., Garing & Rieser, 1990; Rider & Rieser, 1988). This shows that they can maintain knowledge of their actual surroundings in working memory and update their spatial orientation relative to their remembered surroundings when walking without vision. But in the earlier research children viewed their actual surroundings, closed their eyes, and were asked to keep them in mind. They did not need to "pretend" anything, and they did not need to draw on their long-term knowledge to generate an image. It could be that very young children are too much "realists" to pretend or that they are unable to generate an image from long-term knowledge when asked to do so.

Why might the 3.5–6-year-olds have failed on the Imagination-only tasks and yet also have responded so rapidly? Again, the children seemed eager to please. After the first experiment, the tester tried to explain the Imagination-only Condition to the 3.5–6-year-olds. They simply did not understand. They failed to grasp the logical possibility of an alternative perspective of a place once they already had the place in mind from a different perspective. It is important to note that their difficulty is a specific one: In the Induction phase young children readily understood that they could call to mind a different perspective from their own, as long as the different perspective related to a different place.

Why might the 9-year-olds have responded slowly but inaccurately in the Imagination-only Condition? Five of the six 9-year-olds responded more slowly in the Imagination-only Condition than in the Locomotion Condition, and they varied their responding. Unlike the younger children, they understood that the instructions required something different from the "no shift" responses. Either they did not know how to figure out the appropriate responses, or perhaps they knew how but were unable to figure it out when trying to respond rapidly.

Conclusions: Can Young Children Imagine Changes in Things or Not?

The present studies show that by 3.5 years of age children easily use dynamic imagery when they are asked to imagine their physical walks relative to imagined surroundings. Why is it that earlier studies, where children were asked to imagine changes in objects, have failed to discover competent use of dynamic imagery? Our approach differed from earlier ones by asking children to imagine surroundings instead of objects, and the findings may reflect a fundamental difference in how children imagine objects compared to how they imagine surroundings. But we do not believe this is the case. It is important to note that the methods used to induce children to imagine changes in objects have been analogous to our Imagination-only Conditions, where the to-be-imagined change was not prompted by physical action. And the results are that young children fail to demonstrate dynamic imagery in both cases.

We believe the physical action makes the critical difference. This leads to a strong prediction. In the current studies children readily imagined the change in perspective that corresponded to their physical actions. Analogously, we suppose that young children can readily imagine how objects look when they change when the to-be-imagined changes correspond to their physical actions.

Finally, we believe that young children's capacity to readily imagine changes in perspective that correspond to their physical actions reflects perceptual learning (Rieser, 1990; Rieser, Pick, Ashmead, & Garing, in press). The theory is that, while walking with vision, young children have learned how their biomechanical activities while walking covary with perceptible changes in their perspective. Earlier studies show that very young children act on these learned covariations to remain oriented relative to their actual surroundings when walking without vision (Garing & Rieser, 1990; Rider & Rieser, 1988). The present study shows that they can act on this to know changes in perspective relative to imagined surroundings as well as actual ones.

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