CHAPTER 14

Developing an Understanding of External Spatial Representations

LYNN S. LIBEN
The Pennsylvania State University

The contributors to this volume have been invited to discuss their uses of the construct of "representation" (see Sigel, chap. 1, this volume). My own work has focused on spatial representation, and here I consider children's developing understanding of a subset of external spatial representations. I first consider their defining features, and then discuss what it means to say that someone has "understood" them. I next propose a six-level developmental sequence that begins with the child's ability to respond to the depicted referential content, and ends with the sophisticated ability to reflect upon how various kinds of representations may be created and used. In my closing comments, I speculate about mechanisms and experiences that facilitate progress through the proposed developmental sequence.

WHAT ARE SPATIAL REPRESENTATIONS?

Space is arguably one of the basic categories of human thought, as evidenced by the attention it receives in the disciplines of philosophy, physics, mathematics, and, of course, psychology (e.g., see Eliot, 1987; Jammer, 1954; Liben, 1981). Space is clearly fundamental to human life at a practical level as well. We—like other species—live in and move about space. Furthermore, we rely upon *representations* of that space for a myriad of reasons. We draw sketch maps to give directions to our home, use diagrams to show how to assemble a piece of furniture, employ satellite images of Earth to study land use and plan irrigation systems, produce architectural renderings to decide about the structure and placement of buildings, create paintings to convey a sense of the beauty of a landscape or even a bowl of fruit. We rely upon cognitive maps to make decisions about which route or which vacation to take, and mentally rotate internal spatial images to make judgments about how to pack suitcases in the trunk of a car or to rearrange the furniture in our living room. In short, representations of space are pervasive and important in human thought, action, and communication.

Within the examples just given are some that fall within the category of what I have elsewhere referred to as *spatial products* (Liben, 1981). These are the external entities that represent space, and may be in any medium, including three-dimensional, concrete objects (as in scale models), two-dimensional graphic representations (as in photographs, paintings, or drawings), verbal language (as in prose descriptions of a landscape), or numerical notations (as in latitude and longitude).

Although all spatial products provide information about space, my discussion here is limited to representations in which at least some information about a spatial referent is carried via the spatial arrangement of the elements of the representation itself, referred to here as "external spatial representations." Prototypical exemplars include maps and drawings in which there is a systematic mapping between the arrangement of the elements of the referent and the arrangement of the elements of the representation. These contrast to representations of space that are in a nonspatial format (such as language) in which the spatial arrangement of the representational components conveys nothing about the spatial arrangement of the referent. For example, the sentences: "The dog is in front of the cat" and "The cat is behind the dog" convey the same information about the spatial referent irrespective of where the animals' names appear within the sentences (see also Liben & Downs, 1992).

With respect to content, representations may stand for spatial or nonspatial referents. Spatial referents are any that have spatial properties, and thus include large geographic places (such as cities) as well as objects (such as a bowl of fruit) that have spatial properties such as shape and size. In contrast, nonspatial referents are referents that have neither extension nor location. The referents "liberty" and "poison" are illustrations. Only abstract concepts fall into the category of nonspatial referents because the moment that a referent has any form or location in space, that form or location is spatial. One might, of course, *spatialize* some aspect of inherently nonspatial concepts, as, for example, creating thematic maps that depict the distribution of democracies or poisonous landfills over the Earth. But now the spatial form of the representation depicts a spatial referent of the spatial distribution of liberty and poisons. It is not that the referents "liberty" and "poison" have themselves become inherently spatial.

Despite the seemingly simple set of defining qualities just discussed, it is not always a simple matter to decide if a particular entity is or is not an external spatial representation of some referent. My own position is that an external spatial representation must not only have spatial features that carry meaning, but, in addition, (a) must *be* something other than the original (referent) thing itself, (b) must be *interpreted as* something other than the referent itself, and (c) must be *used as* something that stands for the referent. With these three simple rules, I have implicitly taken the position that determining whether or not a particular entity is a true external spatial representation rests on an analysis not only of the features of the concrete external entity itself, but also on the way in which an individual sees, understands, or uses it. As such, my analysis is rooted squarely within in a constructivist theoretical orientation.

A failure to meet the first criterion occurs in cases of *identity* (see Table 14.1). The concept of something serving as a representation of itself is an absurdity. This case is illustrated by a passage from Lewis Carroll's *Sylvie and Bruno Concluded* in which a map scale is changed gradually from 6 inches to the mile, to 6 yards to the mile, to 100 yards to the mile, to a scale of a mile to a mile. At last the farmers complain that "it would cover the whole country and shut out the sunlight! So now we use the country itself, as its own map, and I assure you it does nearly as well" (Carroll, 1893, p.169).

The concept of using a thing to represent itself is clearly outside the realm of what anyone would accept as an external spatial representation. However, there may be other slightly less fanciful circumstances under which a viewer might interpret one entity as if it were the original object itself, even though to an out-

TABLE 14.1
Things *Are* Sometimes What They Seem:
The Case of Nonrepresentation

DEFINITION: *Nonrepresentational cases* are those in which phenomenologically the object under analysis functions as an original object itself. That is, irrespective of what the object is, it is *experienced* as the object itself. Nonrepresentational cases occur under conditions of:

- *Identity.* The object under analysis *is* the original object itself (e.g., a country as its own map as in Lewis Carroll quotation in text).
- *Replication.* The object under analysis is a duplicate of the original object itself, indistinguishable by the viewer from the original object. A failure to distinguish may be traced to the precision of the replication in interaction with perceptual or analytic skills of the viewer (e.g., chemical analysis of paint or high expertise may reveal that an artistic forgery is not an original even though it appears so to the untutored or unaided eye).
- *Perceptual equivalence.* The perceptual experience mimics the perceptual experience that would have been experienced by this particular viewer at this particular station point if the depicted object had actually been present. Here the experience is equivalent *not* because the object under analysis replicates the referent object, but rather because the perceptual information mimics that of the original object (e.g., *trompe l'oeil* art). The phrase "by this particular viewer" acknowledges that different viewers (e.g., of different species, maturational levels, or experiential histories) may be differentially sensitive to information in the optic array.
- *Cognitive trickery.* The viewer is tricked into believing that the object in question is the original object. Here (in contrast to *replication* and *perceptual equivalence*) the viewer perceives the object in question as perceptually different from the original object, but is tricked into interpreting it as the original despite the fact that it looks different (e.g., the shrunken room of DeLoache described in text).

side observer, it is in actuality distinct from the original (referent) object. According to the criteria offered earlier, I would argue that if the viewer does not interpret the entity as separate from the original, then that entity cannot function as a representation for the original. Next I consider three conditions under which a viewer might fail to distinguish a second entity from the first: replication, perceptual equivalence, and cognitive trickery (see Table 14.1).

The case of *replication* is that in which the original is reproduced in every detail. In actuality, a perfect replication is impossible. Even if the same types of materials as found in the original are used to create a second, the particular set of materials is necessarily different. Perhaps we might disassemble the original and then reassemble the pieces elsewhere, as one might do, say, in creating a "reconstructed Colonial village." But the reconstructed object is still different from the original insofar as its geographic location and thus also its surrounding context are different. (This would be true for biological clones as well.) What if we now move it back to its original location? Can we claim to have a replica if the original no longer exists? In essence, the "replica" has *become* the original.

Although these kinds of questions hold great philosophical interest (see Goodman, 1976), it is perhaps less fanciful and psychologically more useful to focus on less extreme cases in which the viewer cannot distinguish the replica from the original, even though some other more privileged observer knows that the replica is not the original. Consider, for example, the case of an identical twin who might be mistaken for his or her sibling, or an artistic forgery that might be mistaken for an original. In these cases, although there is a differentiation between the original and the replica in the physical world, there is no psychological differentiation by the viewer. Rather, the replica is interpreted *as* the original. Note that erroneously interpreting a replica as the original stems from characteristics of the objects (i.e., the similarity of the original and replica) as well as characteristics of the viewer (i.e., the viewer's perceptual and cognitive skills and knowledge). For example, a viewer who is ignorant of a twinship would be more likely to think mistakenly that the replica was the original than would someone who knew of the existence of identical twins. Similarly, an artistic novice would be more likely to mistake a forgery for an original painting than would an expert, particularly one with access to analytic aids that augment human perceptual capacities (e.g., X rays or chemical analyses of paint). Or, a young child who had not yet developed an understanding of classes might have difficulty in individuating members of a class, mistakenly thinking each (in fact new) instance is the original. For example, Piaget (1951) reported that at about 2.5 years, Jacqueline used the term *the slug* for the slugs they saw every morning during their walk along a particular road. "At 2;7 (2) she cried: '*There it is!*' on seeing one, and when we saw another ten yards further on she said: '*There's the slug again*'" (p. 225). This is a case in which the child has interpreted a replica as the original, and thus cannot be credited with having understood the second slug as separate from the first.

However, it need not be only cases in which the original and copy are physically alike in substance and structure that one may fail to differentiate a representation from the original. There are also perceptual conditions that lead the viewer to *perceive* a representation as if it were an original object, even though the physical qualities of the two are very different (*perceptual equivalence,* see Table 14.1). The best example of perceptual equivalence is *trompe l'oeil* art. As the English translation—"fool the eye"—implies, this art form fools the viewer into thinking that the referential subject of the painting (such as a hat hanging on a hook) is actually physically present. Here the mistaken interpretation is only momentary, however, because as soon as the viewer moves, the perceptual information differs from what would have been available if the real objects had been present (see J. J. Gibson, 1979; Hagen, 1986). Movement thus enables viewers to realize that they have been fooled. At the moment of this realization, the painting begins to function as a representation.

Perceptual equivalence may be achieved through newer media such as holograms, three-dimensional computer displays, and virtual realities (see Liben, 1997; Wilson, 1997). Although with these media, viewers are undoubtedly aware that they are looking at a representation, now and then they respond as they would to the object itself (e.g., by reaching out to touch an apparent object and being surprised that they cannot feel it; by flinching at a looming image). At these moments, the "representational" entities are functioning as real or original objects rather than as representations of referents.

The cases discussed so far are rooted in physical similarity or perceptual mimicry, but the viewer might also be fooled by some higher level *cognitive trickery* (see Table 14.1). A clever demonstration of this case is found in the work of DeLoache. In her initial work, DeLoache (1987) showed that very young preschoolers (2.5 years) have difficulty finding analogous locations across two rooms that are alike except for size. In her paradigm, a big toy dog is hidden under the big couch in the big room and the child is asked to then find a small toy dog hidden in the same place in a scale model of the room. Young children were unable to do so, apparently unable to use one room as a representation for the other. When she later fooled preschoolers into thinking that the big room (again containing the dog under the couch) had been reduced in size by a "shrinking machine," children were able to find the small toy dog without difficulty (DeLoache, 1995). As in *trompe l'oeil,* albeit for different reasons, what we (as outside observers) know is a representation is interpreted by the viewer as the thing itself.

In summary, I take the position that we have not tested viewers' understanding of external spatial representations under conditions in which viewers have a phenomenological experience that is psychologically undifferentiated from that experienced when they encounter the referential object itself, that is, under any of the cases summarized in Table 14.1.

It is not sufficient, however, to recognize that one object is distinct from another object to qualify as representation. In addition, the viewer must *use* all or part of the object in a "stand-for" or symbolic relation to the original object. That is, following the third criterion offered earlier, it is necessary for the viewer to appreciate that things are not only what they seem (that they are entities in and of themselves), but also that they have a *second* existence as representations of something else (that they are symbolic). This quality has been referred to as the "dual nature of symbols" or "duality" by both philosophers and psychologists (e.g., DeLoache, 1989; Langer, 1942; Liben & Downs, 1992; Potter, 1979; Sigel, 1978). Unless this "stand-for" condition is met, the viewer interprets the second object as distinct from, but not informative about, the first.

The recognition of the existence of a second object provides the *potential* for its representational use. Thus, although replicas do not *necessarily* serve a representational function, they *can* do so once they are recognized as separate from the original. For example, engineers and astronauts on Earth used a replica of the space capsule during the Apollo 13 mission to devise and test solutions to deal with damage to the spaceship. In this case, the replica served as a representation because it was used to stand for the original.

Replicas thus can serve a representational function, but these anchor one end of an important continuum of physical similarity between the referent and representation, as depicted in Fig. 14.1. Representations that bear high similarity to their referent primarily serve what might be called a "re-presentation"

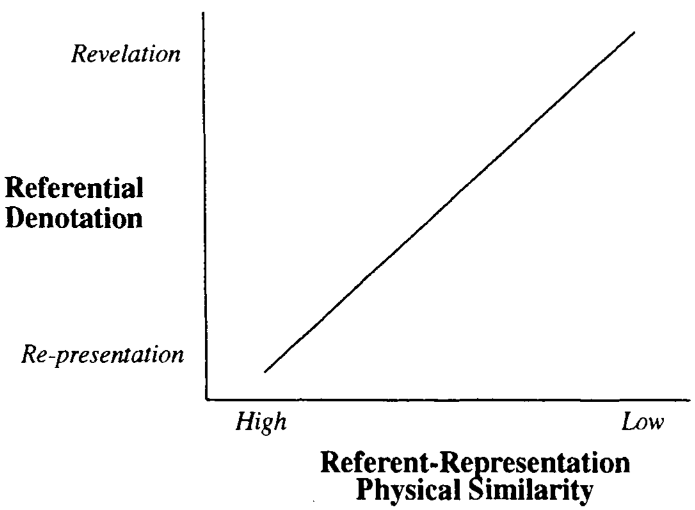

FIG 14.1. Kinds of referential information conveyed in relation to physical similarity between representation and referent.

function. That is, they re-present information about the referent that is much like the original. The extreme case, of course, is a reproduction or replica (within the limitations discussed earlier) that can be a useful re-presentation because it is convenient (as in the Apollo 13 example). A slightly less extreme case, still highly similar to the original, is a working scale model such as one that might be used by engineers to test equipment more quickly or cheaply than would be possible if they had to build a full-scale prototype. But representations of these kinds are useful primarily because they enable the viewer to construct knowledge about the referent that is like the knowledge that could have been gained by interacting with the referent itself, and are thus primarily re-presentational.

As the representation moves further away from providing an experience that mimics what would already have been accessible from direct interaction with the original referent, the representation provides increasing potential for achieving new insights or revelations about the referent. If the referent is large enough, scale reduction alone may allow revelation because the representation can permit the viewer to see relationships that would be otherwise unobservable. For example, a scale model of a city would allow the viewer to see spatial relationships among areas of the city that might otherwise go unnoticed.

But representations may also communicate some new insight or vision by presenting highly processed and transformed information about the referent. This revelation function of representations is generally recognized in painting and drawing, but is often overlooked for other art forms such as sculpture and photography. The latter are often naively assumed to show the world "as it is" (see Goodman, 1976), a misconception also found in people's naive beliefs about maps (e.g., see Downs, 1981; Downs & Liben, 1988; Liben & Downs, 1989, 1992). The general point holds for any medium: Representations do not merely reproduce the world as it is, but rather are artifacts that communicate or construct new visions or insights that would have been difficult and often impossible to achieve from direct interaction with the real, physical world. In some cases, the insight may precede the creation of the external representation, so that the process is primarily one of creating an external spatial representation to record or communicate that insight; in other cases the insight may be revealed in the act of producing or viewing the external representation as when a computer-generated map, graph, or model allows the viewer to "see" a relation among variables that had not been previously understood. But in either case, the external spatial representations are more than denotations of the external world that simply re-present that world in another form. Given this interpretation of external spatial representations, the task of understanding them is naturally more complex than simply identifying their denoted referents. In the next section, I discuss this richer view of what it means to understand external spatial representations.

UNDERSTANDING WHAT WE MEAN BY "UNDERSTANDING" EXTERNAL SPATIAL REPRESENTATIONS

In this section I discuss what it might mean to say that someone has used and understood external spatial representations. One possible interpretation, that might be called a "transparency" view of understanding (see Downs & Liben, 1988), is depicted in Figure 14.2. Here the viewer sees through an external spatial representation directly to the referent (here necessarily depicted by yet another external spatial representation). The disembodied eye is used to imply that information is extracted from the representation via perceptual processes much like those used in picking up information from the three-dimensional world itself. Under this model, it is assumed that the translation from the three-dimensional world to the two-dimensional representation is a relatively straightforward one, made possible through perceptual skills already available from infancy.

Because the transparency view suggests a phenomenological experience much like that which would be achieved by interacting with the referential world itself, I believe that it is more re-presentational than representational. Not surprisingly, then, I argue for a more complex view of what it means to understand external spatial representations—the "embedded" view that is depicted in Fig. 14.3. Here the understanding of external spatial representations is embedded within the context of understanding the referent itself, as well as within the context of understanding representational strategies (the means by which representations can be created). Note that the prior two sentences (and the graphics of Fig. 14.3) present a strong stand that "understanding external spatial representations" is *not* limited to "identifying the referent for which the representation stands." In the discussion that follows I highlight some of the major

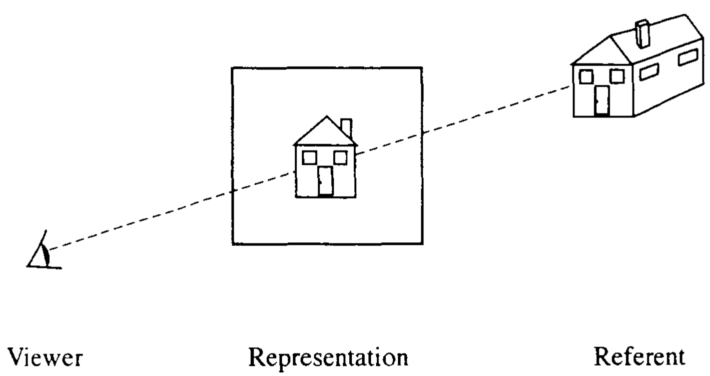

FIG 14.2. A depiction of the "transparency" interpretation of understanding external spatial representations.

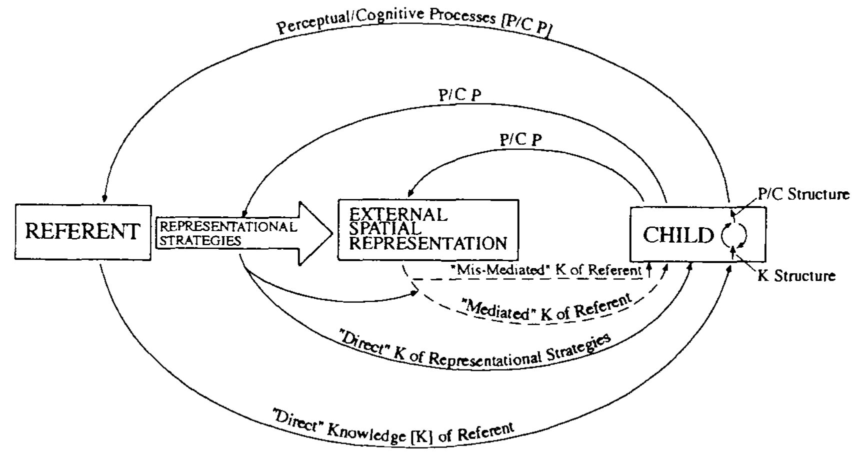

FIG 14.3. A depiction of the "embedded" interpretation of understanding external spatial representations.

components of this model which I am in the process of developing in more detail (Liben, 1998).

It is useful to begin by pointing out two major contrasts between the model shown in Fig. 14.3 and the earlier Fig. 14.2. First, the "eye" has been replaced by the construct "child." This substitution reflects my constructive theoretical orientation noted earlier. We are not simply sensation-recording devices, but instead we are active explorers and creators of our own knowledge. We proactively reach out with our "perceptual/cognitive processes" to interact with the world (outward arrows from the child in the top half of Fig. 14.3). The products of these interactions in turn lead to various kinds of knowledge (incoming arrows to the child in the bottom half of Fig. 14.3). The child is a biologically prepared, self-regulating system that at any moment is the consequence of prior constructive history, and is prepared to reach out for new and developmentally progressive experiences.

The second major contrast between the models shown in Figs. 14.2 and 14.3 is that there are now three major external constructs with which the child is concerned. In addition to the constructs of the referent and the representation (instantiated in Fig. 14.2 as the depiction of the referent house and the depiction of the representation or drawing of the house), there is also now the construct labeled "representational strategies." The idea is that strategies or techniques for producing external spatial representations are also a kind of content that must be explored for a full understanding of representations. Thus, the embedded model posits that perceptual-cognitive processes are addressed to the strategies or techniques for producing external spatial representations as well as to the products that result from applying those techniques.

The purpose of including external representational strategies in the model is to depict the role of understanding the multiple (indeed, infinite) ways that a referent can be represented. When—as here—we are concerned with *spatial* representations, these strategies include the spatial or geometric systems by which representations can be created. In cartography, for example, any given representation is at a specific scale, uses a particular projection (e.g., Mercator), and has a particular orientation. Likewise, representational art may use alternative geometries. As Hagen (1986) reminded us, the projective geometry used in Western art allows the artist to convey different information than that conveyed by, say, the affine geometry of Asian art.

Strategies also include media-specific processes. Understanding at least some components of these processes may be essential in understanding the referential meaning of particular representations. An extremely dark photographic image might indicate something about the light in the referent room, but it might indicate something about the size of the lens aperture or the exposure length. Or a blurred image might indicate something about the referent (e.g., movement of a person in the photograph), but it might instead indicate something about the photographer (e.g., camera shake). Knowing something about the photographic process can allow one to distinguish between which is the case in a given photograph. Without understanding these strategies, the viewer runs the risk of inappropriately assigning *referential* meaning to a *representational* quality.

Empirical illustrations of overextending representational qualities to referential qualities come from earlier work on children's understanding of representations of place (Liben & Downs, 1989) in which we interviewed preschool children to explore their understanding of road maps and aerial photographs. Although preschoolers typically had no difficulty in understanding that the maps and photos stood for places, they often gave responses suggesting they sometimes misunderstood the relation between specific qualities of the representation and the referent. In some cases, they inappropriately overextended an attribute of the representation to an attribute of the referent. For example, a red line on the map was thought to indicate a red road in the real world, and yellow areas (standing for built-up areas) were thought to indicate "eggs" and "firecrackers." Relatedly, they often had difficulty accepting something as a representation of a referent if its attributes did not match the attributes of a potential referent. For example, one preschooler rejected a line as showing a road because "it's not fat enough for two cars to go on," and rejected a rectangular shape on an aerial photograph as his father's office building because "his building is *huge!* It's as big as this whole map!" Others said they were unable to find grass on a black-and-white aerial photograph because "grass is green." These examples illustrate the kinds of misconceptions that can occur if the child does not appreciate the strategies by which one creates representations of referents. This point is made in Fig. 14.3 by showing that in the absence of knowledge of representational strategies, the knowledge derived from representations will be *"mis-mediated"* knowledge of the referent.

Having taken the position that the understanding of external spatial representations goes beyond identifying the denoted referent, it is not surprising that I take the position that the mastery of this understanding is a protracted and multifaceted developmental process. In the next section, I suggest a sequence of accomplishments in this process.

CHARACTERIZING THE DEVELOPMENT OF REPRESENTATIONAL UNDERSTANDING

As implied by the arguments made in the prior sections, any developmental account of the course of understanding external spatial representations is heavily dependent on what is meant by *understanding.* If we mean simply that the viewer can recognize qualities of the spatial referent by examining the depiction—even a depiction that shares high physical similarity with the referent—then understanding may be said to occur very early. If, however, we mean that the viewer can interpret even abstract representations and can appreciate the variety and power of representations and use them for new insights, then understanding may be said to occur considerably later. In this section I suggest six levels of understanding that are anchored by these two extremes (see Table 14.2). Given the arguments made earlier, I prefer to take a conservative position, and credit children with true understanding only once they have acquired "representational insight" (DeLoache, 1995; see Table 14.2). Others, however, may well prefer to be more inclusive, and consider all six of these levels as demonstrations of representational understanding. Indeed, it is likely that disagreements about where to place the boundary of "understanding" underlie past controversies about when children can understand aerial photographs and maps (see Blaut, 1997a, 1997b; Downs & Liben, 1997; Liben & Downs, 1997). Irrespective of where one places definitional boundaries, however, the levels can be used to describe a sequence that characterizes ontogenetic development. (This sequence may also characterize changes that occur in the course of skill acquisition as individuals move from novice to expert performance within particular domains, although I have not made any attempt to evaluate this possibility here.)

Before asking whether the viewer can use information from a spatial representation to reveal information about a spatial referent, it is relevant to ask whether the viewer can appreciate spatial information in the actual physical world itself. How early this appreciation is accomplished is itself controversial. Piaget (1954) argued that the infant's understanding that objects—as well as self—are located in a three-dimensional world (or even exist permanently at all) is a very gradual accomplishment that takes place over the course of infancy as a consequence of complex interactions with the physical environment. Others

TABLE 14.2
Progressive Competencies in Understanding External Spatial Representations

I. **Referential Content.** The viewer begins to identify the referential meaning of the representation, with varying ease depending on the physical similarity of representation and referent. Thus, the viewer "understands" the representation in the sense of identifying the denoted referent, but appears to confuse them (as in trying to pick up a depicted object).

II. **Global Differentiation.** The viewer identifies the denotative meaning of the representation, distinguishes the representation and referent, and responds to them differentially. The viewer does not, however, reflect upon the correspondence between the two. The "stand for" relation is implicit in identification, but not generally subject to intentional manipulation.

III. **Representational Insight.** The viewer distinguishes between representation and referent, and intentionally interprets or assigns "stand for" meaning to the representation. Representational insight occurs first for objects that are inherently representational (as a photograph) and only later for objects that do not normally function as representations, but rather are most salient as objects in their own right (as a scale model).

IV. **Attribute Differentiation.** The viewer comes to appreciate that some, but not all attributes of the representation are motivated by attributes of the referent, and that some, but not all attributes of the referent motivate graphic attributes of the representation. Until doing so, the viewer inappropriately expects that attributes of the representation necessarily mimic attributes of the referent (as in inferring that a red line means a red road) and that attributes of the referent will necessarily be mimicked by attributes of the representation (as in expecting that a large building will appear large in the representation).

V. **Correspondence Mastery.** The viewer extends the prior understanding of attribute differentiation to develop understanding of the formal representational and geometric correspondences between representation and referent. The former allows the viewer to understand the referential content of symbols; the latter allows the viewer to understand the referential meaning of graphic space.

VI. **Meta-representation.** The viewer is able to reflect upon the mechanisms by which, and the purposes for which, graphic representations are created, including understanding that different correspondence rules and conventions are used in different media (as in maps vs. graphs), different traditions (as in Western vs. Asian art), and different renditions (as in a world map in a Mercator vs. a Peters projection). As a result, the viewer is able to understand representations not simply as convenient substitutions for referents, but rather as cognitive tools that enrich understanding of the referent, and to select among them appropriately for particular purposes.

hold that human infants are prewired to pick up information about space far earlier, perhaps even in the first month of life (e.g., see E. J. Gibson, 1987; Spelke, 1991).

In either case, it appears fairly clear that sensitivity to spatial information in the dynamic three-dimensional physical world occurs before sensitivity to spatial information in the static two-dimensional representational world (e.g., Adolph, Eppler, & E. J. Gibson, 1993). This is not to suggest that there is necessarily a terribly long lag before babies appear to respond to spatial information in static representations. For example, habituation studies have shown that by about 5 months, infants recognize objects pictured in photographs (e.g., DeLoache, Strauss, & Maynard, 1979; Dirks & E. J. Gibson, 1977), and are sensitive

to depth information in pictures by about 5 to 7 months (e.g., see Yonas, Arterberry, & Granrud, 1987). Even monkeys and other nonhuman species show considerable ability to respond to photographs (e.g., see review in Beilin & Pearlman, 1991) and to pictorial depth (e.g., Gunderson, Yonas, Sargent, & Grant-Webster, 1993). Thus, the first level of competence—extracting *referential content*—appears to occur early, at least with some kinds of representations.

What is less clear is whether babies who are able to extract meaning from representations are also able to *distinguish* between the representation and the referent. Some investigators have reported that differential responding to photographs versus objects occurs within days of birth, whereas others have placed this accomplishment later (e.g., DiFranco, Muir, & Dodwell, 1978; Rose, 1977). Even after babies seem to be able to pick up cues that distinguish two-dimensional representations from three-dimensional objects in the real world, they appear to confuse representations and referents. There are informal accounts of young infants trying to pick up patterns drawn on fabric or paper (Liben & Downs, 1992; Ninio & Bruner, 1978) or other kinds of flat images such as light patterns on the floor (Church, 1961). More formal research has also revealed instances in which infants appear to be acting upon two-dimensional representations as if they were the three-dimensional objects they depict. DeLoache, Pierroutsakos, Uttal, Rosengren, and Gottlieb (1998), for example, found that 9-month-old infants grabbed at objects shown in photographs, even adjusting their hand shape appropriately to the depicted object, and persisting when they were unable to lift the object the first time. Of course, it is difficult (or perhaps impossible) to know whether the repeated attempts to grab depicted objects imply that the infant "believes" that the object is truly there, or whether instead these behaviors are efforts at testing qualities of the representation itself (i.e., that indeed it is flat and cannot be grasped in the same way that three-dimensional objects can be grasped). Thus, at this point in development, it appears that either there is some confusion of representation and referent, or at the very least, there is a struggle to confirm and test the boundaries between representation and referent. But in either case, it seems reasonable to conclude that the developmental task during this level of development is coming to master the differentiation between the representation and referent at some general level (i.e., that there are, in fact, two different kinds of entities).

Probably by toddlerhood, and certainly by preschool, children can recognize and name representations of a wide variety of objects in a wide variety of representational media (e.g., Potter, 1979), without giving signs that they are confusing the representation with the depicted object at the global level. That is, young children do not really try to eat pictures of food, or play with depicted toys, or put on represented pieces of clothing (although they may pretend to do so in play). At this point, then, children are making a *global differentiation* between the representation and the referent (see Table 14.2).

There are, however, still some indications that surface features of the representation may inadvertently intrude into the conceptualization of the depicted object. Sigel (1971), for example, reported that at least some groups of preschool children categorized real objects differently than they categorized photographs of those same objects. More recently, Melendez, Bales, and Pick (1995) reported that 4-year-olds sorted toys by function more often when they were sorting the real toys than when they were sorting drawings of the identical toys, and further, sorted line drawings by color or size more often than by function. Similarly, Deák and Bauer (1995) found that preschoolers categorized three-dimensional objects differently than they categorized line drawings. These data suggest that representations are not yet understood completely in a stand-for relation to the referent such that their role as representations (rather than as things in and of themselves) has not yet been fully understood.

It is not until the child achieves *representational insight* (see Table 14.2) that the child is able to *assign* referential meaning. As described earlier, DeLoache (1989, 1995) has shown that representational insight appears at about the age of 3 years, such that information provided by one object (the representation) may be used to provide specific information about the other (the referent).

Interestingly, the child's ability to employ a particular representation symbolically is affected by the extent to which the qualities of the representation make it salient as a thing in its own right. Representations that are more "thinglike" and thus useable in and of themselves are *less* likely to support representational insight than are representations that have little nonrepresentational use (see DeLoache, 1995). For example, representational insight that a location shown in a representational room can stand for a location in the referent room is more difficult when the representation is a scale model of the room than when the representation is a photograph of the room. The representational role of the scale model is more obscure because the primary use of a miniature room is as a toy for dollhouse play. In contrast, the representational value of the photograph is more salient because the primary use of a photograph is *as* a representation. Children are usually asked or told what photographs are "of" (as when looking through the family photo album), and are discouraged from using them as nonrepresentational objects. For example, children are cautioned to treat photographs carefully, not to draw on them, fold them, rip them, and so on, all of which diminish the salience of the photograph as a piece of paper, and increase its salience as a representation. In short, children initially show representational insight with objects that they already think of as representations, and only later extend this insight to objects that are not already viewed as inherently representational.

Even after achieving representational insight, the child has not yet fully mastered the details of the relation between the representation and referent. Children must also develop an appreciation of the boundaries between the two or what I call *attribute differentiation* (see Table 14.2). That is, children must come to understand that only some of the many attributes of the representation carry

meaning about the referent and some do not, and similarly, that some of the many attributes of the referent are reflected by attributes of the representation, and some are not.

There is evidence that children are confused about the boundaries between qualities of representations and the qualities of referents in a variety of domains. Piaget, for example, reported spontaneous comments by young children that suggested confusion in differentiating the representational world from the referential world, as when at 2;8 (14), Laurent said spontaneously: "It's very heavy [a picture book] because there's a little girl in it," (Piaget, 1951, p. 225). Vygotsky (1962) noted that preschoolers appeared to believe that qualities of referents cling to their labels as evidenced by their explaining the assignment of names by appealing to the referents' attributes. For example, he reported that one preschooler reasoned that: "an animal is called 'cow' because it has horns, 'calf' because its horns are still small, 'dog' because it is small and has no horns" (p. 129). Preschoolers likewise rejected the possibility of interchanging names, refusing to "call a cow 'ink,' and ink 'cow' . . . because ink is used for writing, and the cow gives milk" (p. 129). And, when asked to use the word *dog* for *cow*, the child then insisted that the animal, so named, *must* have horns: ". . . if it is a cow, if it's called cow, it has horns. That kind of dog has got to have little horns" (p. 129).

Confusions about attribute boundaries are also evident in research on children's understanding of external spatial representations. In research on children's understanding of photographs, for example, Beilin and Pearlman (1991) found that young preschoolers showed evidence of what they termed "iconic realism" (see also Beilin, 1991). In particular, they found that preschoolers (especially 3-year-olds and less often 5-year-olds) confused physical properties of photographs and referents. For example, when asked: "If you shook this picture would you hear the rattle?" 3-year-olds not infrequently answered in the affirmative, or when asked "If you touched this picture [of an ice cream cone] here, how would the picture feel?" they not infrequently answered "cold." Although young preschoolers also sometimes gave iconic realism responses to questions that asked about function (e.g., "Can you eat this picture of an ice cream cone?"), they never maintained these iconic responses in the face of countericonic challenges (e.g., inviting the child to actually eat the cone). In contrast, many of the younger children *did* maintain iconic responses to questions about the physical properties, even after testing them (e.g., asserting that when they felt the photograph, the ice cream did, indeed, feel cold). The data reported by Beilin and Pearlman (1991) are thus consistent with the conclusion that even after children are able to differentiate between representations and referents, they may still confuse their attributes.

As noted earlier in this chapter (and described in more detail elsewhere, see Liben & Downs, 1989, 1991, 1992), similar kinds of boundary confusions have been found in research on young children's understanding of graphic representations of place. Preschool children often assume, first, that a quality of a referent should be seen in a quality of the representation (as in rejecting a small rectangle on an aerial photograph as a large building because the rectangle is too small, or rejecting a line as a road because it is too narrow for two cars), and second, that a quality of the representation must be extended to a quality of the referent (as in reasoning that a red line indicates that the referent road is red as well).

Once having understood the general concept that there is not a perfect match between the attributes of the representation and the attributes of the referent, the child must still come to understand the systematic correspondences between the representation and referent, or what I call *correspondence mastery.* That is, the next developmental challenge is to understand the formal or informal rules by which some attributes of referent and representation come to be shared and others do not. Thus, for example, children must learn that on maps, color choices are arbitrary (as in using red lines for two-lane highways), whereas depiction of size is not (once one has selected a particular scale and projection). Or, to put it differently, the challenge of the prior level of attribute differentiation is for the child to recognize that there is not a one-to-one correspondence between attributes of the representation and attributes of the referent; the challenge of the current level of correspondence mastery is for the child to come to understand how the correspondences between referent and representation work for various types of representational media (e.g., maps, photographs) and for various instances within each (e.g., this particular map or this particular photograph). More specifically, two kinds of correspondences between the referent and representation must be understood—representational and geometric (see Liben & Downs, 1989).

Representational correspondences refer to the links between the "things" in the actual in the referent world, and the symbolized entities included in the representation. Even representations such as photographs that have high referent-representation similarity (see Fig. 14.1), cannot re-present all information about all referents available in any particular referent world. They must, for example, be taken from a particular viewing angle (thereby necessarily obscuring some parts of the referent objects), with a particular film (thereby recording some but not all light), with a particular lens and focal length (thereby recording sharply only objects at a particular distance), printed in a particular way (thereby affecting color and contrast), and so on. And of course graphic representations that share even less physical similarity with the referent involve even more selectivity and abstraction. On a map, for example, only some information is represented (e.g., all population regions greater than some size), at a particular level of categorization and generalization (e.g., grouping populations into, say, five groups), using particular symbols (e.g., different-sized circles corresponding to different populations).

Geometric correspondences refer to the links between the space of the actual referent world and the symbolized space in the representation (see Downs, 1981, 1985). The same referent space may be represented by a virtually infinite array of representations that vary along geometric qualities of viewing angle (e.g., an elevation vs. a nadir view), scale, and viewing azimuth (e.g., looking north vs. west). In maps (see MacEachren, 1995; Muehrcke, 1986), as in paintings (see Hagen, 1986; Kubovy, 1986), different geometries are used to represent the three-dimensional world on the two-dimensional surface, and these result in strikingly different representations.

The correspondences between referent and representation are differentially systematic in different representational genre. Some representational forms allow the viewer to recover precise spatial information about the referent on the basis of the representation as, for example, in an architect's blueprint or a surveyor's map. Others are far less precise, as in a painter's still life that might preserve the general arrangement, but not the sizes of different pieces of fruit. The process of mastering an understanding spatial correspondences thus includes learning the conventions of the genre, and when appropriate, understanding the precise meaning of representational space (as in "reading" distances on a scaled map). Empirical work suggests that the mastery of these precise geometric correspondences is particularly challenging, presumably because the specific spatial concepts on which they draw are developing over a relatively long period during childhood (e.g., see Liben & Downs, 1993; Liben & Yekel, 1996).

The accomplishments of the correspondence mastery just discussed are medium-specific. It is not until the next level, which we have termed *meta-representation* (Liben & Downs, 1992), that the focus is on the coordination of understanding the variations among, as well as within, different representational media. With meta-representation, the individual comes to appreciate how different correspondence rules and systems provide different means of communicating different visions to others, or of supporting different kinds of revelations or realizations for self. It is by recognizing that different goals require different kinds of representations and that new representations can lead to new insights that the full power of external spatial representations can be appreciated.

To summarize, understanding external spatial representations develops gradually, and proceeds through the six-level sequence of competencies defined in Table 14.2. The developmental pattern of emergence is depicted in Fig. 14.4. It should be clear from Fig. 14.4 that although I have suggested an age-related progression, I am not suggesting that there are abrupt, discrete phases through which individuals pass in some chronologically precise manner. For example, even adults may fail to show global differentiation under some circumstances, and children who fail to differentiate in one setting, may nevertheless do so in another. But I would argue that in general the infant is not aware of the dual nature of representations whereas in general adults are, and when cognitively normal adults are lulled or fooled into equating a representation with its referent (as in *trompe l'oeil*), they quickly and easily recognize the foolishness of their initial response. In general, the very young preschooler is likely to confuse representational and referential attributes, whereas the adult does so only occasionally (as

AGE GROUP	COMPETENCY					
	Referential Content	Global Differentiation	Representational Insight	Attribute Differentiation	Correspondence Mastery	Meta-Representation
Infants	■	○				
Toddlers	•	■	○			
Preschoolers	•	○	■	○		
Young Children	•	•	○	■	○	
Older Children	•	•	•	○	■	○
Adolescents +	•	•	•	•	○	■

FIG 14.4. Developmental progression in understanding external spatial representations. Shaded cells indicate the focal competency under development. Cells marked with a large open circle indicate that considerable development in that competency is continuing or beginning. Cells marked with a small closed circle indicate that the basic competence has been achieved, although further minor development may still be occurring. Blank cells indicate that little development is yet under way. Definitions of competencies are given in Table 14.2.

in the "Greenland effect" in which adults often believe that Greenland is larger than Brazil because it appears to be so on the Mercator projection).

If it is not age, or age alone, that controls progression in understanding, what mechanisms are responsible for progress in understanding? It is this topic that I consider in the concluding section of this chapter.

FACILITATING REPRESENTATIONAL DEVELOPMENT

Factors that facilitate development through the six levels summarized in Table 14.2 may be organized into three major groups: (a) general perceptual and cognitive achievements, (b) factors that enhance knowledge of referents, and (c) factors that enhance understanding of external spatial representations per se.

The first means by which representational understanding develops is through the general cognitive structures or strategies that develop over the life course. Although theorists may disagree about the specific characterization of these developmental changes, all would agree that there are age-linked advances in the knowledge and reasoning skills that may be brought to bear on any particular cognitive task. Clearly it is impossible to review these developmental changes here—they comprise the entire corpus of work on cognitive development. But by way of illustration, I note that children's developing spatial skills (e.g., see Eliot, 1987) should be relevant for children's understanding of geometric correspondences, that children's developing analogical reasoning skills (e.g., Gentner, 1988) should be relevant for developing representational insight, and that children's growing understanding of appearance–reality distinctions (e.g., Flavell, 1986), should be relevant to understanding attribute differentiation.

The second category concerns understanding the referent itself. As discussed

earlier, understanding that there are objects in a three-dimensional world occurs sometime during infancy (earlier or later depending on one's theoretical perspective). However, many other kinds of knowledge of the referential world develop later and are relevant for understanding representations. To illustrate, consider what happens when viewers are shown an external spatial representation of a cat (e.g., a drawing). To interpret the cat-drawing as showing a cat, they must have some concept of the referential cat to which the representation may be linked, a concept that may have been formed slowly on the basis of experience with real cats, or built by other kinds of experiences such as verbal descriptions, perhaps paired with earlier images. (The latter route is important for representations of imaginary referents such as unicorns, as discussed at length by Goodman, 1976.) They must, for example, perceive cats as coherent objects moving as a whole; come to recognize cats as distinct from, say, dogs; recognize cats from the side, back, and front; appreciate that cats may appear in many different colors and patterns; and so on. As long as the child has knowledge of the referent cat, asking the child to interpret a cat-representation challenges the child's *representational* skills. But the referential knowledge base is not necessarily well developed for all referents. Consider, instead, asking the child to interpret an aerial photograph of a city. If the child has difficulty interpreting a pattern that shows a clover-leaf intersection of an interstate highway, the child's difficulty may reflect ignorance about clover-leaf intersections or about how they look from overhead even in the physical world (as from an airplane), rather than necessarily reflecting inadequate understanding of how to interpret the representation. One implication of this observation is to acknowledge that much prior research (including my own) has not differentiated clearly between the two sources of difficulty. A second implication is to recognize that developmental progress in understanding spatial representations may be based on an expanding knowledge and understanding of the referent world itself, quite apart from expanding knowledge and understanding of representations.

The third category concerns factors directly tied to representations per se. Interestingly, although as a discipline we have conducted extensive research on everyday experiences that foster children's comprehension and production of language (e.g., the role of motherese, the impact of hearing stories read aloud, exposure to early reading-related curriculum such as letter-recognition drills on "Sesame Street"), with few exceptions (e.g., Sigel, 1978) we have done relatively little to study the everyday experiences that might foster children's understanding of spatial or graphic representations. Most extant research has been addressed to understanding unusually skilled performance in individuals (such as artistic prodigies; see Winner, 1996) or in cultures (as in China, where instruction in drawing begins very early; see Gardner, 1989). Given the scarcity of research, there is little empirical work on which to formulate and test hypotheses. Thus, the suggestions that follow about what may enhance development are necessarily presented as "speculations."

First, I would speculate that competencies in understanding external spatial representations should be enhanced by exposure to many different kinds of external spatial representations (e.g., drawings, paintings, photographs, models, maps, graphs). Consistent with this conjecture is work by Sigel (1971) suggesting that early limitations in preschoolers' experience with representational materials are linked to difficulty in using conceptual criteria to categorize pictures even when these criteria can be used successfully to categorize actual objects.

Second, and relatedly, I would speculate that competencies should be enhanced by exposure to many different examples within any one particular medium, particularly those providing alternative representations of the identical referent. For example, as argued elsewhere (e.g., Downs & Liben, 1988), one likely reason that many people—even adults—often seem to hold rigid, naive (and incorrect) beliefs about the "proper" form of maps is that they have been repeatedly exposed to very limited exemplars in which north is always at the top, water is always shown in blue, the projection is invariably Mercator, and so on. Given these restricted experiences, it is perhaps not surprising that even adults find it difficult to believe (for example) that red shows vegetation (as in false-color GOES satellite images), or become confused when using maps in which north is not at the top of the page (as in strip maps produced by the Automobile Association of America), or have trouble interpreting a map when water is not in blue (as when a New York City subway map had to be recalled because users were confused by the use of brown to symbolize the Hudson River). Seeing that the same referent can be depicted in different forms should help people decouple referents from particular representational instantiations.

Third, I would speculate that understanding should be enhanced by experiences in which the child's attention is drawn explicitly to representational strategies in the context of referential meaning. As an example, consider the opening page of *The Travels of Babar* (De Brunhoff, 1934), in which Babar and Celeste are first shown drifting away in a hot-air balloon. One parent might focus the child's attention exclusively on the story line of the departure of Babar and Celeste, but another might direct the child's attention to the graphic representation of distance by the tiny size of the balloon, perhaps also using this as an opportunity to point out that things only appear smaller from a distance. Or, consider a parent and child examining a family photo album. One parent might comment exclusively on the referential content, but another might also draw attention to the photographic process (e.g., "Look at how blurred the baseball bat looks in this picture—you must have been swinging at the ball really quickly!"). In short, just as we have decades of evidence showing that richer linguistic environments are associated with children's more advanced language skills, so too, we may find that richer "graphic representational environments" are likewise associated with children's enhanced understanding of external spatial representations.

Fourth, I would speculate that understanding external spatial representations should be enhanced by explicit practice in creating and interpreting alternative

external spatial representations. Thus, for example, understanding should be better in individuals who learn to produce representations as an end in themselves (e.g., painters or photographers), who routinely produce representations in the service of some other goal (e.g., engineers or architects), or who frequently manipulate external spatial representations in their work (e.g., geologists who use scientific visualization tools to display seismic data in new ways). To the extent that children are taught how to produce and manipulate representations, their understanding should be facilitated as well.

Finally (and most speculatively of all), I would suggest that understanding may be affected by familiarity with a class of representations that I label *ego-deictic*. The term is meant to denote representations that point to (hence "deixis") themselves (hence "ego"). These are representations that in some way make their status *as* representations salient to the viewer. In other words, ego-deictic representations are those in which surface features are intentionally brought to center stage. There may be any one of a number of ways in which ego-deixis may be accomplished, presumably each having somewhat different psychological consequences.

One of the most direct means of drawing attention to the representational nature of the representation is by including a representation of the creator of the representation within the representation. Examples include Escher's *Drawing Hands* (see Escher, 1992), or the *Purple Crayon* series in which the crayon draws objects that then become "real" (Johnson, 1956).

A second means of effecting ego-deixis is by layering representational world inside representational world, or by playfully shifting the referential meaning of the representation. The former is illustrated when Mary Poppins enters the Match-Man's chalk drawing to spend a day in the park (Travers, 1934). The latter is illustrated by the books *Zoom* and *Re-Zoom* (Banyai, 1995a, 1995b) in which viewers are led to interpret a pictorial representation in one way, only to turn the page to discover that the prior interpretation was wrong (e.g., we first see a farm yard from overhead, only to discover that it is really a toy farm set being played with by a child, only to discover that it is really a picture on the cover of a toy catalogue, and so on).

In the cases of ego-deixis just described, the reinterpretations are sequential, with a reevaluation of referential meaning occurring because the viewer is given an alternative context. One can instead begin with graphics that are referentially opaque as in droodles (e.g., see Price, 1953) and are made meaningful by providing information external to the original representation (by word or graphics). In still other cases, ego-deixis may be achieved by representations that simultaneously support more than one referential interpretation. Well-known examples include ambiguous figures such as the face/vase drawings (e.g., see Block & Yucker, 1989), upside-down drawings that take on entirely different meanings depending on which direction they are held (e.g., a drawing that shows a bird in one direction, but an island, fish, and boat when the drawing is turned upside down; see Ernst, 1986); and, of course, the group of spatially impossible drawings in which components of the representation can support two conflicting meanings simultaneously (e.g., the ascending and descending ramps and staircases found, respectively, in Escher's *Waterfall* and *Ascending and Descending*, see Escher, 1992; or in the impossible representations created by Shepard, 1990).

Another way in which representations may be made ego-deictic is by juxtaposing the presentation of information through symbolic and nonsymbolic means. An illustration is provided by the classic children's book, *Pat the Bunny* (Kunhardt, 1940). The story line is given representationally with words and pictures, but interspersed throughout the book are objects that convey meaning through their actual, rather than their representational, properties. For example, "Daddy's beard" is described as rough. But rather than simply depicting the roughness by graphic techniques (such as stippling), it is conveyed physically by including a piece of sandpaper for the child to feel. Of course, the sandpaper is still a metaphorical representation of the roughness of Daddy's face, but there is nevertheless an interesting interplay of representational and actual physical qualities. In the realm of spatial relationships, a similar interplay between representational and actual space may be found in "Pop-Up" books, as, for example, when a pop-up dog is physically located behind a pop-up house. In such cases, at least some of the spatial relations defined by station point can be experienced directly, and may support the child's ability to understand the spatial relations shown representationally on another page.

To my knowledge, there has been no systematic empirical work on children's understanding of these kinds of representations, or on how exposure to ego-deictic representations may affect children's representational competencies. One might hypothesize that exposure to ego-deictic representations may promote children's understanding of the boundaries between representations and reality because these boundaries are made salient. An equally plausible possibility is that exposure to ego-deictic representations may confuse children by reinforcing the notion that representations and referents share qualities. It is also possible that either outcome may occur, depending on the contexts in which ego-deictic representations are encountered (e.g., whether an adult draws explicit attention to the representational devices).

In closing, I observe that whereas earlier sections of this chapter demonstrate that we already know a considerable amount about children's developing understanding of external spatial representations, the final section makes it clear that many important questions remain virtually unexplored. This observation leads me to end with the more general point that as a society (and as a discipline) we often view instruction (and research) on external spatial representations as an expendable luxury, aimed "merely" at developing aesthetic appreciation (or as an interesting extension of research on language). I hope that the arguments presented here are convincing in demonstrating that external spatial representations are a major part of our human symbolic lives, and as such, should take a

central place in our educational curricula and in our scholarly pursuits on the development of representational thought. It is not only children to whom the title of this chapter applies.

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