Seeing through symbols?

The development of children's understanding of symbolic relations

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The ability to use symbols is a hallmark of human cognition. Our capacity to communicate and learn from others depends upon our knowledge that one thing can stand for another. Not surprisingly, almost all theories of cognitive development have stressed the importance of acquiring an understanding of symbols. Initially, young infants are not privy to the information symbols can provide; they learn primarily through interacting directly with the world. The development of symbolic skills fundamentally changes the way children learn and communicate.

The early development of symbolization occurs in the context of a wealth of symbolic representations. In addition to language and symbolic gestures, children in every society encounter numerous cultural artifacts. Virtually all American toddlers and preschool children are exposed to television, and many have experience with home videos as well. Pictures are found everywhere in our culture, from the illustrations in children’s books to the sports heroes on cereal boxes and the advertisements on billboards. Many children learn the meaning of icons in computer games, and what American child does not know the significance of the Golden Arches? In their preschools, young children's symbolic horizons are broadened further, with explicit instruction about numbers, letters, maps, clocks, and calendars. Further, as we discuss later in this chapter, preschool and young elementary school children often encounter a variety of educational materials designed to help them learn complex, abstract concepts.

Given the ubiquity of symbols in the lives of young children and the importance of symbols in human culture and communication, one might suppose that a basic understanding of the nature of symbols would come quite early and relatively easily--that children could readily
"see through" at least some symbols to what they represent. Our research indicates that this is not the case; one can never take for granted that a young child will appreciate the representational nature and role of any given symbol. This is not surprising with respect to abstract, arbitrary symbol systems, such as letters and numbers; however, as our research shows, young children often fail to detect the relation between even highly iconic symbols and their referents.

In this chapter, we will first discuss briefly what is involved in understanding a symbol-referent relation and using information provided by a symbol. We will then describe some of the evidence for the above claims about the non-transparency of symbols to young children. Finally, we will discuss the implications of our research for some aspects of educational practice with young children.

Symbol Understanding and Use

What is involved in understanding and using symbols? First, one must realize that a given entity is a symbol; that is, one must appreciate that it is intended to stand for something other than itself and that it should be responded to and interpreted primarily in terms of its referent rather than itself. Second, one must know what the symbol represents. In other words, one must understand something about the relation between the symbol and its referent. Third, one must know how the symbol and its referent are related, that is, how the symbol is to be mapped onto the referent.

To illustrate these three aspects of symbolic functioning, consider a family on a holiday in Chicago. The parents might want to find the Art Institute, and the children are demanding to see the Shedd Aquarium and the Lincoln Park Zoo. The children win out, and the family decides to head for the zoo. They pull out their city map and note that the zoo is just a few miles to the north. They plan their route and head for the nearest el stop.

To use their map, the family must understand (1) that the map they hold is a symbol—a representation of something other than itself, (2) what it represents (Chicago), and (3) how to
apply the lines, shapes, words and other symbols on the two-dimensional map to the real landmarks in the city. The children, depending on their age and experience, might share their parents' knowledge of all three or none of these features of the map.

These three aspects are always involved in symbol use, but they are not always neatly separable in research addressing children's symbolic understanding. The child's knowledge of them can be explicit and statable, or it can be implicit and inexpressible. Preschool children's knowledge of symbol-referent relations is probably usually implicit. Such children are capable, however, of explicit understanding in some domains, as evidenced by one preschool subject in our lab. When the experimenter admired the Batman logo on his shoes, commenting, "Oh, it's Batman," this child corrected him—"No, it's just a symbol." In this chapter, we will explore the developmental origins of this sophisticated understanding.

Research on Symbolic Understanding

Photographs.

We begin our discussion of research with a symbol-referent relation that seems, at least initially, to be transparent and obvious. As adults, we know that photographs of objects are only representations. Although we may kiss a photograph of an absent loved one, we realize that the photograph is not the actual object of our affection. The results of our research suggest that infants and toddlers may not share this understanding; they do not fully appreciate the representational nature of photographs. As with all symbols, children must learn that photographs are representations and how these representations function.

Our research on this issue was motivated in part by anecdotes reported by parents and some informal accounts by researchers: Infants sometimes treat photographs of objects as if the photographs were the objects themselves. For example, infants sometimes attempt to grasp or otherwise manipulate depicted objects (Murphy, 1978; Ninio & Bruner, 1978).

We designed a series of studies to determine whether these reports could be validated in a controlled setting. In our first study (DeLoache, Uttal, Pierroutsakos, & Rosengren, 1993), we examined 9-month-old infants' manual responses to pictures, focusing particularly on behaviors
that appeared to be attempts to grasp or pick up the depicted objects. We presented the infants with specially constructed picture books with a highly realistic color photograph of a single object on each page. The pictured objects were small enough (ca. 3.8 x 2.5 cm) that a 9-month-old could have picked them up, had they been real objects.

The results were surprisingly clear. As shown in Figure 1, every infant attempted, at least once, to manually investigate a pictured object, by grasping at, hitting, or rubbing the depicted object. Some infants were remarkably persistent, making repeated and concerted efforts to pluck the objects from the pages. Thus, these infants did not comprehend fully the representational nature of the photographs. Instead they treated the photographs as if they were the objects themselves.

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Insert Figure 1 About Here
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In subsequent studies, we have shown that children's confusion of photographs and represented objects declines in the second year of life. As Figure 2 shows, older children (15-month-olds and 19-month-olds) attempt to grasp or otherwise manipulate the photographs substantially less than 9-month-olds do. Instead, older infants tend to point to the pictures, often vocalizing to another person as they point. They show substantial interest in the photographs and attempt to communicate their interest, but they rarely attempt to manually explore the represented objects.

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It is important to note that the younger infants' frequent attempts to grasp or manipulate the photographs do not stem from difficulty distinguishing perceptually between objects and photographs of objects. Several prior studies have shown that even young infants can reliably distinguish between two- and three-dimensional objects and photographs of stimuli (e.g.,
DeLoache, Strause, & Maynard, 1979). Hence we believe that the problem for the young infants is not perceptual, but rather conceptual; the infants can perceive the difference between objects and photographs of objects, but they do not yet know the implications of this perceptual difference.

In the next section, we document that problems with understanding symbols continue well beyond infancy. In addition to understanding that something is a symbol, and should be responded to as such, one must understand the specific symbol-referent relation and how to use it. Like infants, young children often respond to a symbol more in terms of the object itself than in terms of what it represents.

**Scale Models.**

Much of our research on the development of early symbolic functioning has focused on very young children's understanding of scale models as representations (DeLoache, 1987, 1989, 1991; DeLoache, Kolstad, & Anderson, 1991; Marzolf & DeLoache, 1994). Specifically, we have investigated young children's ability to use a scale model as a representation of a larger space (i.e., a full-sized room). To do this, we use an object-retrieval task in which children are required to find a toy hidden in a room based on where they see a miniature version of the toy hidden in a scale model of the room. Success in this task indicates that the children appreciate something about the symbolic relation between the model and the room.

There are several benefits to this scale model paradigm. First, very young children (such as the 2.5- to 3-year-olds that we study) are relatively unfamiliar with scale models as representations of specific entities. While they frequently play with dollhouses and farm sets, they typically do not relate them to specific houses or farms that exist in the real world. Thus, we are able to observe children's developing appreciation of scale models as specific representations from their very first exposure to them. Two additional benefits of the scale model paradigm stem from the object retrieval aspect of the task. Because finding a toy in a room requires little verbal skill on the part of our young subjects, we avoid confounding
symbolic understanding and verbal competence. Also, most children find the “hide and seek”
nature of the task very enjoyable, so even notoriously uncooperative toddlers remain highly
motivated throughout testing.

The room used in the standard model task is furnished with familiar objects, such as a
couch, a chair, and a dresser. The objects in the model are very similar to their counterparts in
the room (e.g., same color and texture), with the obvious exception of size. Further, the objects
in both spaces are arranged in the same way, and the model is always aligned with the room.
The model is always located outside of the room so that the children cannot see the interior of
both spaces at the same time.

During an extensive orientation, the experimenter emphasizes the correspondence between
the model and the room by directly comparing each miniature object from the model with its
counterpart in the room. On each of the subsequent trials, the children watch as the
experimenter hides a miniature toy in the model. The toy is hidden behind or under one of the
items of furniture (e.g., behind the chair), and a different hiding place is used on each trial. The
experimenter then tells the child that she is going to hide a large toy in the “same place” in the
room. When the experimenter returns, she reminds the child that the large toy is hidden in the
same place as the miniature toy. The child then searches for the large toy in the room. This
Symbol-based Retrieval is the key dependent variable. If the child is consistently able to find
the large toy, we conclude that he or she appreciates the relation between the model and the
room. Without this awareness, the child has no way of knowing where to search for the large
toy in the room. After retrieving the large toy, the child returns to the model and retrieves the
miniature toy that he or she had seen hidden. This Memory-based Retrieval is important for
interpreting the performance of children who have difficulty finding the large toy in the room. If
children remember where the miniature toy is hidden, yet still fail to find the large toy in the
room, then we conclude that they do not appreciate that the two spaces are related.

The analysis of symbol use that we presented above is relevant to understanding what
children must do to succeed in the model task. First, they must understand that the model is a
symbol; they must know that it represents something and is more than simply an object. Second, the children must understand what the model represents; they must know that the model represents the room. Third, the children must understand how the model-room relation works; they must know that the toy can be found in the room by searching in the location corresponding to the one that was indicated in the model. Our research suggests that children can have problems with each of these three aspects.

The results of the standard model task are quite dramatic, and have been replicated several times in our own lab as well as by others (DeLoache, 1987; Dow & Pick, 1992). As shown in Figure 3, three-year-old children are very good at retrieving the large toy in the room. They clearly appreciate that the model and the room are related and they use what they know about one to make an inference about the other. In contrast, 2.5-year-old children are very unsuccessful at finding the large toy in the room. In assessing their poor performance, it is important to note that they do understand several key components of the task. First, they understand that they are to find the large toy in the room, as evidenced by their enthusiasm during the Symbol-based Retrieval. Second, they are very good at remembering where the original toy was hidden in the model. Their Memory-based Retrieval performance is always near ceiling, on par with that of the 3-year-olds. Thus, their inability to find the toy in the room is not because they fail to remember where the miniature toy is hidden in the model. Finally, 2.5-year olds can match the corresponding objects (e.g., large and small chairs) in the two spaces. In a recent study (Troseth & DeLoache, in preparation), children were presented with an item from the model and told: “Show me the one in the big room that looks like this.” They were quite successful at doing this (79% correct). Nevertheless, the same children subsequently failed to exploit those object correspondences in the standard model task (Symbol-based Retrieval = 21%). We believe that the 2.5-year-old children who fail the standard model simply do not realize that the model and the room are related, and therefore they have no basis for using what they know about one to make an inference about the other.
Why is it so difficult for these young children to understand the model-room relation? Our research has revealed several factors that influence children's appreciation of symbol-referent relations. Three factors are particularly relevant to this chapter: the salience of the symbol as an object, instruction, and experience. We consider each of these in turn.

Salience of the symbol as an object. DeLoache (1987, 1991; DeLoache & Marzolf, 1992) has proposed that young children find the model task difficult because it requires thinking of the model in two different ways—as an object in its own right and as a representation of something else. To succeed, the child must interact with the model as an object (i.e., hide and retrieve toys in it) and at the same time regard it as a representation of something other than itself (i.e., the room and its contents). Although the younger children obviously treat the model as an object, they have difficulty simultaneously thinking of it as a representation of the room. In other words, they have difficulty realizing that the model is a symbol and/or understanding what it represents.

According to the dual representation hypothesis (DeLoache, 1987, 1991, in press), the salience and attractiveness of the model as an object makes it difficult for 2.5-year-olds to simultaneously think of it as a representation of the room. Several counterintuitive predictions follow. One is that making the model more salient as an object should make it more difficult for 3-year-olds to think of it as a representation of the room. In one study (DeLoache, in press), the salience of the model as an object was increased simply by allowing children to play with it for five to ten minutes before the standard model task. As predicted by the dual representation hypothesis, the 3-year-olds who participated in this study performed significantly worse than children their same age who did not have the extra experience with the model.

Another prediction that follows from the dual representation hypothesis is that decreasing
the salience of the model as an object should make it easier for children to think of it as a representation of the room. The standard model task was altered by placing the model behind a plastic window (DeLoache, in press). Neither the experimenter nor the child ever touched the model or its contents. Rather than hiding a miniature toy to indicate the hiding place, the experimenter simply pointed to the relevant hiding place in the model. As predicted, the children in the window condition performed significantly better than children their age typically do in the standard model task. Thus, decreasing the salience of the model as an object made it easier for our young subjects to think of it as a representation of the room. (We know that performance in the standard model task is the same regardless of whether the experimenter points to the hiding place in the model or hides a miniature toy. Thus, the superior performance of the children in the window condition is not due to the manner in which the hiding place was indicated.)

The dual representation hypothesis was investigated further by examining young children's understanding of pictures (DeLoache, 1987; DeLoache & Burns, 1994). Although pictures are physical entities, they are very uninteresting as objects. Thus, the dual representation hypothesis predicts that pictures should be relatively easy for young children to understand as representations. Hence, 2.5-year-old children, an age group that typically fails the standard model task, should succeed in an object retrieval task in which information about the location of the toy is conveyed via a picture. This prediction is counterintuitive in light of extensive research that suggests that better cognitive performance is achieved with real objects than with pictures (e.g., Daehler, Lonardo, & Bukatko, 1979; DeLoache, 1986; Sigel, 1953; Sigel, Anderson, & Shapiro, 1966).

In a series of studies, the experimenter pointed to a picture of the hiding place and told the child that was where she was going to hide the toy in the room. In one study, the experimenter pointed to the hiding place on a wide-angle color photograph of the room. In another, we used four photographs of the individual hiding places, pointing to the appropriate one on each trial. In yet another study, we used a line drawing of the entire space. As predicted by the dual representation hypothesis, the 2.5-year-olds who participated in these studies were very
successful, regardless of the type of picture used. Thus, while children this age typically do not appreciate the relation between a scale model and the space it represents, they clearly understand the relation between a picture and what it represents. These results support the dual representation hypothesis: Young children understand pictures as representations, because they do not have to think of them as objects and as representations at the same time.

In the most stringent test of the dual representation hypothesis to date, we sought to remove the need for children to think of the model as a representation of the room (DeLoache, 1993; DeLoache, Miller, Rosengren, & Bryant, 1993). To do this, we convinced a group of 2.5-year-old children that we were shrinking the room. Our reasoning was that if the children believed that the model actually was the room after being shrunk, then they should be able to reason between the two spaces without thinking of the model as a representation of the room. Thus, no dual representation would be required.

We used a tent-like portable room (a 1.85 x 2.57 x 1.88 m structure constructed of opaque white fabric and a plastic pipe framework) and a scale model of that room, both of which have been used in numerous other model studies. During an orientation phase, the children were introduced to a troll doll, the “troll’s room,” and a “shrinking machine.” The child was told that the machine could shrink toys and then make them big again. To demonstrate this, the experimenter placed the troll doll in front of the machine and turned it on. The child and experimenter waited in an adjacent room, listening to the “sounds the machine makes while it’s shrinking the troll.” When they re-entered the room, they found a much smaller troll in front of the machine. The experimenter then demonstrated how the machine could make the troll “get big again.”

The experimental trials followed this orientation. On the first trial, the child watched as the experimenter hid the troll somewhere in the portable room. The experimenter told the child to remember where the troll was hiding so he or she could find it later. They then waited in the adjacent room while the machine shrunk the troll’s room. When the machine was done, the child discovered the model where the large room had been. She was encouraged to find the
troll, which was, of course, hidden in the same place in the model that the experimenter hid the large troll in the room. After finding the troll, the child watched as the experimenter hid it in a different place in the model. They then waited in the adjacent room while the machine "made the room big again," after which the child searched for the large troll in the room. Subsequent trials alternated between the shrinking and enlarging events.

In order for this manipulation to work as expected, children had to believe that we were indeed shrinking and enlarging the same space. Based on the children's behavior, as well as independent ratings from two experimenters and the children’s parents, we concluded that the children were convinced that our shrinking machine worked as advertised.

As predicted, the 2.5-year-olds who participated in this study were quite successful at finding the toy in one of the spaces based on where they saw the other toy hidden in the other space (see Figure 4). They performed significantly better than children in two different control conditions using the same artificial room and model. The children did everything necessary to solve the standard model task; that is, they used their knowledge of the location of the toy to figure out where the second toy was hidden. The only difference is that in the shrinking room task, children did not have to think of the model as a representation of the room.

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These studies demonstrate one factor that influences young children’s appreciation of symbol-referent relations: salience of the symbol as an object. When a symbol is very salient as an object, it is difficult for young children to appreciate it as a representation of something else.

**Instruction.** Another factor that influences whether young children detect symbol-referent relations is the instruction they receive concerning that relation. In our standard model task, we provide a significant amount of information about the correspondence between the model and the room. During the orientation, for example, we demonstrate the object correspondences by taking each miniature object from the model and directly comparing it to its counterpart in the
room. Three-year-old children typically succeed following these instructions. In another study, none of the object correspondences were pointed out (DeLoache, 1989). After showing children both spaces separately, the experimenter immediately began the test trials. Even though the 3-year-old children in this study were told that the toys were hidden in the same place, they were very unsuccessful at finding the large toy in the room. Thus, the amount of instruction that children are given about a particular symbol-referent relation has a dramatic affect on whether they appreciate that the two are related.

Experience. A third factor that influences children’s appreciation of the relation between a symbol and its referent is the experience that they have with other symbols. We have proposed that insight into specific symbol-referent relations contributes to a child’s symbolic sensitivity or basic readiness to appreciate that one object or event can stand for another (DeLoache & Marzolf, 1992; Marzolf & DeLoache, 1994). Thus, more experience with one kind of symbol makes a child more likely to detect other symbol-referent relations.

A series of easy-to-hard transfer studies illustrates this point (DeLoache, 1991; Marzolf & DeLoache, 1994). In these studies, children were first given an object-retrieval task that involved a symbolic relation that children their age typically understand. On the following day, the same children were given a task involving a relation that children their age typically do not appreciate. Our rationale was that insight into the easy relation on the first day would help children appreciate the difficult relation on the second day. This hypothesis was supported in all of the transfer studies that we have conducted to date. In one study, for example, 2.5-year-old children who first experienced an easy picture task subsequently succeeded on the standard model task, a task that children their age typically fail. Thus, insight into the picture-room relation helped children notice the model-room relation.

The transfer effects in these studies are quite robust. Transfer has occurred within and between symbol types (as in the picture-to-model transfer study described above). In some of the studies, the easy task was conducted in one space and the difficult task was conducted in a different space, demonstrating transfer across contexts. Finally, we have reported transfer
effects for both 2.5- and 3-year-old children. Thus, we believe that previous experience with symbol-referent relations is an important factor determining whether children subsequently detect more difficult relations.

Understanding that a symbol and its referent are related, however, is often not enough to allow use of a symbol; the child must still know how to use the information. In the model tasks described so far, for example, the child has to map the relation between the miniature toy and its hiding place in the model to the room in order to infer the location of the large toy. In other words, the children must know how the information in the model specifies the location of the toy in the room. The 3-year-olds in our model task are very capable of mapping this relatively simple information. Would they be able to map more complex relational information in this task?

To investigate this issue, we have conducted a number of model studies in which we used four identical white boxes as hiding places (Marzolf, 1994, 1995). In most of these studies, the boxes were located directly on top of or immediately next to distinctive landmarks (i.e., items of furniture). To succeed at this task, children have to encode the hiding relation between the toy and the box as well as the relation between the box and a landmark, and map this entire set of relations from the model to the room. Thus, this seemingly trivial manipulation increases the complexity of the information that children have to map.

Three-year-old children, who would succeed in the standard model task, were surprisingly unsuccessful at locating the large toy in the room (43%). They always looked in a box, but did not know which one was correct. Interestingly, the same children were very good at retrieving the miniature toy they had seen hidden in one of the boxes in the model (77%). This indicates that they did encode and remember the entire set of relations, but failed to map them across the spaces. Thus, these 3-year-old children are clearly limited in their ability to map a set of relations between a symbol and its referent in this task. These results demonstrate that even when a child appreciates that something is a symbol and knows what the symbol represents, understanding how to map information between the two may still be quite difficult.
Dolls.

Another case in which the dual representation hypothesis leads to a counterintuitive prediction concerns young children’s use of a doll as a symbol for themselves. Adults generally assume that a doll is such an obvious representation for a person that even very young children would appreciate the relation between themselves and a doll. This assumption is bolstered by the fact that very young children’s doll play is meaningful.

The assumption that children readily understand dolls as symbols for themselves underlies the extensive use of dolls in the forensic arena. Clinicians, social workers, and police often use anatomically-explicit dolls to interview children who are suspected victims of abuse (Boat & Everson, 1988). The claim is that dolls should be particularly useful with very young children whose verbal skills may not be adequate to describe their experience (Yates & Terr, 1988).

In fact, dolls are not a transparent symbol to very young children. A study by DeLoache and Marzolf (in press) explored 2 1/2- to 4-year-olds’ ability to recount their experiences with a male experimenter in a lab setting. The children were asked to tell about and show on a doll where the experimenter had touched them during a “Simon Says” game. Results indicated that the children provided just as much information verbally as they did using the dolls.

A second study (DeLoache, Anderson, & Smith, 1995) further investigated young children’s ability to use a doll as a self-symbol. In an attempt to have a better analog of a real abuse situation, children were questioned about an event in their everyday lives in which someone had done something to them that they did not like and about which they became emotionally upset. Preschool teachers provided crucial assistance in this study; they recorded every incident in which a child became upset because of something another child had done to him or her. The children were then questioned about the incident. All children heard the same questions, but the interviewer asked half of the children to use a doll to answer the questions. The results were the same as in the earlier lab study: Using the dolls did not confer an advantage. The children provided the same amount of information when they were simply questioned as they did when they were also asked to use the dolls to demonstrate what had
happened to them.

These two studies are consistent with our laboratory research on scale models and with the dual representation hypothesis: One reason that the presence of the dolls failed to enhance the children's memory reports could be that they did not fully appreciate that the doll was supposed to represent themselves or they were not sure how to map between themselves and the doll.

In a recent series of studies (Smith, 1995), we investigated in more detail young children's use of a doll as a self-symbol. In this research, an even simpler task was used. We asked children to place a sticker on a doll in the location analogous to where the experimenter had just placed a sticker on the child. This task had no memory requirement, as the sticker on the child remained in view while he or she placed the smaller sticker on the doll. Nevertheless, the children in this study correctly placed the stickers only 52% of the time. Even in this very simple task, young children had difficulty using the relation between themselves and a doll. These results provide a strong challenge to the common assumption that children can easily use a doll as a representation of themselves.

**Application of research on early symbolic development to educational practice**

In the final section, we consider the application of our theory to education. Our focus is the use of **manipulatives** to teach arithmetic to young children. Manipulatives are concrete objects, such as blocks and rods, that are designed to help children understand complex mathematical concepts. Many teachers believe that children learn more effectively when they can work through problems with concrete objects that they can hold and touch. The assumption has been that making problems tangible makes the mathematics concepts tractable (Kennedy & Tipps, 1994; Boling, 1991).

There is much enthusiasm about the use of manipulatives. Journals for teachers are filled with articles praising their virtues for teaching several subjects, but particularly mathematics. The faith in the value of manipulatives crosses the entire spectrum of abilities: claims have been made both that manipulatives are particularly helpful for advanced subjects such as calculus and
that they are especially beneficial for students who experience difficulty in mathematics (Peterson, Mercer, & O'Shea, 1988; Threadgill-Sowder & Juilfs, 1980). Manipulatives have also been touted as a cure for mathematics anxiety (Martinez, 1987). Deborah Ball (1992), a mathematics education researcher and elementary school teacher has captured well the current enthusiasm for manipulatives:

In much of the talk about improving mathematics education, manipulatives have occupied a central place. Mathematics curricula are assessed by the extent to which manipulatives are used and how many "things" are provided to teachers who purchase the curriculum....Parents and teachers alike laud classrooms in which children use manipulatives... Manipulatives--and the underlying notion that understanding comes through the fingertips--have become part of educational dogma: Using them helps students; not using them hinders students (p. 16).

Unfortunately, research on the effectiveness of manipulatives has lagged far behind the enthusiasm for their use (Ball, 1992). Moreover, the studies that have been conducted have yielded mixed results (see Scott & Neufeld, 1976; Suydam & Higgins 1977). Meta-analyses have failed to document a consistent advantage of manipulatives (Sowell, 1989). Put simply, current research does not support the unqualified and widespread belief in the magical power of manipulatives. (See Sowell, 1989 for a discussion of the limited conditions under which manipulatives can be helpful.)

Why has research failed to confirm an advantage for manipulatives? Part of the problem is with the research; many of the studies have suffered from serious methodological flaws, such as a lack of appropriate control groups (Sowell, 1989). In addition, making comparisons across the studies is difficult, because many different types of manipulatives have been used. In addition, numerous factors, such as ability level, age, and previous instructional experiences can affect dramatically whether a manipulative will be effective (Sowell, 1989).

We believe, however, that the failure of research to identify a clear advantage of
manipulatives extends beyond methodological issues. The central problem may stem from the assumption that manipulatives will help because they are concrete (e.g., Fennema, 1972). That is, teachers assume that because the manipulatives are solid objects, they reduce the cognitive effort that children must exert to understand the underlying concept (Scheer, 1985). In Ball’s (1992) words, “Concrete is inherently good; ‘abstract’ is inherently not appropriate—at least at the beginning, at least for young learners.” (p. 16). This assumption is derived in part from Piaget’s theory. It has been argued that abstract, symbolic thought requires formal operations (Fennema, 1972). Manipulatives are assumed to make information accessible for the younger, concrete-operational child (Marzola, 1987; Williams & Kamii, 1986). Hence, the Piagetian-based assumption is that manipulatives provide an important bridge from the concrete to the abstract.

Our research and theoretical perspective lead us to a different conclusion: Concrete manipulatives may be quite difficult for young children to understand as representations of abstract mathematical concepts. We believe that concrete manipulatives are symbols, and that using a manipulative is thus similar to using our model. To succeed, children must realize that the manipulative, like the model, is not just an object, but also a symbol. Just as in our previous discussion of photographs and models, one cannot assume that children can simply “see through” the manipulative to what it represents. Making something concrete does not make its relation to a referent necessarily transparent or even clearer (See Gentner & Ratterman, 1991). In the remainder of this section, we discuss how our theoretical perspective leads to conclusions and suggestions about manipulatives that run counter to many commonly-held beliefs.

Understanding that manipulatives are symbols. A brief review of some of the literature on children’s use of manipulatives demonstrates clearly that children often have difficulty grasping that a concrete manipulative is intended to be a symbol. The results of several studies and anecdotes strongly suggest that children often have difficulty realizing that a manipulative is intended to represent something (Goswami, 1992). For example, Hughes (1986) asked 5- to 7-year-olds to use simple bricks to represent sums, such as $4 + 3 = 7$. The children were told to
use the bricks to show the experimenter what was written in the problem. Thus, children were asked to translate the abstract, symbolic representation of the written problem into the concrete representation of the bricks.

On average, children’s performance was poor; most could not use the bricks to represent the written problems. More importantly, children’s errors shed light on the source of the difficulty. Many of the children took the instructions literally; they used the blocks to copy the written problems. For example, some children arranged the bricks as shown in Figure 5. They did not understand that the bricks were intended to represent a mathematical concept; they did not understand that the bricks were symbols or what the bricks were intended to represent. Just as children in our model task sometimes fail to grasp the relation between the model and the room, the children in Hughes’ experiment did not realize that the bricks were more than objects, that they provided an alternate format for representing the numbers.

Insert Figure 5 About Here

Figuring out what a manipulative represents may be particularly difficult for young children because they may not understand the underlying concept (e.g., fractions, addition, multiplication, etc.). For example, if they do not yet understand fractions, then it may be quite difficult for them to use manipulatives to learn about fractions. In contrast, teachers understand the concepts so they can appreciate fully how the manipulative stands for those concepts. Ball (1992) provides an example of the difficulties children may encounter when they are asked to use a manipulative that is intended to represent a concept they have not yet grasped completely. The children (third-graders) were attempting to use fraction bars to figure out the concept of parts and wholes. The teacher asks, “Which is more--three thirds or five fifths? A student moved two of the fraction bars and stated, “Five fifths is more...because there are more pieces.” (p. 17). The child did not understand fractions and hence he was unable to use the fraction bars as a symbol. Instead, he resorted to what he knew: counting. This example demonstrates
clearly that children's understanding of the relation between manipulatives and their intended referents may be quite different than what the teacher expected.

Are interesting manipulatives the best manipulatives? A second implication of our theoretical perspective is that interesting or novel manipulatives may be more difficult to use as symbols. This runs counter to the common belief that exciting and engaging manipulatives are best for young children (DeLoache, Uttal, & Pierroutsakos, in press).

First consider how symbols are often presented on the popular television show, Sesame Street. Numbers dance and letters sing. On one program, a map of Australia transformed into a kangaroo and then a fish, a display intended to illustrate the fauna that can be found in Australia. Our favorite segment was a beauty show for letters. The letters first appeared in magnificent evening gowns, bedecked with jewelry. They participated in a talent contest and then a swimsuit competition. The curvaceous shape of the letter "S" helped her win the swimsuit competition. The letter "E" was crowned the overall winner, because "E" appears in so many words.

What should a child learn from this show? The producers hope that it helps children acquire a better understanding of the characteristics and functions of letters, maps, and other symbols. But is this true; do exciting and dynamic symbols help children understand what the symbols represent? Again, our research leads us to wonder whether making symbols "come alive" is a good idea.

Our studies have demonstrated that appreciating a symbol-referent relation requires that children treat the model (or any symbol) as more than an object; they must treat it as a representation of something else. To this end, highlighting the characteristics of the object as a thing in itself may undermine the goal of helping the child use the object as a representation of something else. Thus, children may find the dancing letters interesting because of the dancing, not because the letters represent sounds. Highly attractive educational symbols may focus children's attention on the symbol itself and away from where it needs to be—the relation of the symbol to what the child is supposed to learn.
Interestingly, the belief that manipulatives should be engaging and entertaining is not universal. In Japan, children begin first grade with a small set of manipulatives, including blocks and other shapes. The children continue to use the same manipulative for multiple tasks throughout the lower elementary grades. We would expect that these objects become highly familiar and hence less interesting, thereby freeing the children to focus instead on what the manipulatives represent. Support for this claim comes from Sowell’s (1989) meta-analysis, which revealed that manipulatives were most effective when they were used consistently over extended periods of time.

In the United States, however, teachers place great emphasis on the use of a variety of objects in a variety of contexts. An unintended result of this practice may be that children attend to the objects rather than what the objects are intended to represent. Stevenson and Stigler (1992) have noted:

> Japanese teachers... use the items in the math set repeatedly throughout the elementary school years...American teachers seek variety. They may use Popsicle sticks in one lesson, and marbles, Cheerios, M&M’s, checkers, poker chips, or plastic animals in another. The American view is that objects should be varied in order to maintain children’s interest. The Asian view is that using a variety of representational materials may confuse children, and thereby make it more difficult for them to use the objects for the representation and solution of mathematics problems. Multiplication is easier to understand when the same tiles are used as were used when the children learned to add. (pp. 186-187).

**Instructions matter.** Another relevant lesson from our research is that instructions about the relation between a symbol and its referent are very important. In our model task, we have found that children must be told explicitly that the model represents the room. Moreover, they must be given specific examples of the correspondences between the two. Deleting the instructions dramatically lowers performance (DeLoache, 1989).
Instructions are also critical when manipulatives are used. Studies by Ball (1992), Fuson and Briars (1990) and others have shown that instructions help to focus children's attention on the relevant aspects of the manipulative. Instructions also help to constrain the multiple (and often incorrect) ways that children can interpret the manipulative (Larson & Slaughter, 1984). Resnick and Omanson (1987) suggested that math pedagogy should concentrate on the verbalization of quantities, rather than counting on transference of understanding directly from manipulatives. Teachers cannot assume that because manipulatives are concrete, their relation to the underlying concept is transparent and does not have to be taught.

Conclusion

Our research and analysis indicate that no symbol, no matter how simple it appears to an adult, is necessarily transparent to young children. There is an interesting developmental story to be told even for children's understanding of highly iconic symbols, such as photographs and scale models. We hope our examples have illustrated why it is necessary to study and pay attention to this story.
References


Figure Captions

Figure 1. Manual investigation of color photographs by 9-month-old infants.

Figure 2. Manual investigation and pointing to photographs as a function of age.

Figure 3. Percent of errorless retrievals by 2.5- and 3-year-old children in the scale model task.

Figure 4. Performance in the standard model task versus the shrinking room version of the task.

Figure 5. Children’s use of blocks to represent “4 + 3 = 7.” (Adapted from Hughes, 1986.)
Problem: Use small bricks to solve $1 + 7$

Children did this:

Rather than this:

(Adapted from Hughes, 1986)