THE MIND ON PAPER:
THE ROLE OF INTERPRETIVE MIND AND ICONICITY IN CHILDREN'S
SYMBOLIC DEVELOPMENT

A Thesis in
Psychology
by
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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

May 2008
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ABSTRACT

A defining characteristic of human cognition is the ability to communicate referentially. In order to use symbols to refer to something, one must recognize that other minds do not necessarily share one’s own knowledge of, intentions for, or interpretation of symbols.

The current study examined the development of this component of symbol understanding in 6- to 9-year-old children. Children made a map to communicate to a symbol-user about hidden toys. Additionally, they evaluated whether maps made by other children communicated effectively. In both tasks, the resemblance between the symbol and referent was manipulated – children either received iconic symbols that somewhat resembled the referents, or they received abstract symbols that did not resemble the referents.

It was predicted that children’s success on these symbol-communicative tasks would be related to their awareness that other minds construe meaning in many different but equally valid ways (interpretive mind). In particular, success should depend upon children’s recognition that even when symbols resemble their referents, resemblance alone is not sufficient to convey meaning to a naïve symbol-user. This is particularly true in a context (such as the one used here) in which the same symbol might reasonably have been assigned to represent a different referent.

Results showed that all children relied primarily on notations (words or pictures) rather than symbol resemblance to communicate meaning. Older children were especially sensitive to the information that the symbol-user needed to know, and were more likely than younger children to attempt map keys to communicate this knowledge. Specifically, older children were more likely than younger children to create categorical representations, using one type of symbol to represent one type of toy. Furthermore, interpretive theory of mind predicted children’s success on the symbol-communication tasks above and beyond chronological age, global intelligence, or memory.

Overall, this study shows that 6- to 9-year-olds’ symbolic development is associated with their ability to recognize that people actively interpret and assign meaning to symbols. Elementary school-aged children gradually come to understand that graphic symbols do not have inherent, fixed meaning, but rather reflect the intentions and decisions of the people who create them.
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ACKNOWLEDGEMENTS

This work was partially funded by the Don A. Trumbo Psychology Department Student Research Award, and by the Robert and Ruth Faris Child Psychology Fund of the College of Liberal Arts. The Bruce V. Moore fund has also supported me at various times in my graduate career. I am thankful for all of these sources of support, because although graduate school is rich in knowledge, money is always tight!

I would like to thank the Psychology Department staff members for their assistance over the years in reimbursing, copying, mailing, and all of the administrative duties that are so important to successfully running a study. Special thanks goes to Diane Plummer, Penn State Families Interested in Research Studies (FIRST), and all of the children and families who volunteered their time to participate in the study. I am also thankful to Jean Courter, who can always be counted on for an encouraging word, good advice, and answers to any question about the graduate school process.

I am deeply grateful to my wonderful advisor Lynn Liben for her years of mentorship and dedication to my intellectual and professional development. Throughout her patient guidance and countless hours of work, she has been an inspiration to me as a genuinely curious scientist. After having worked with her, I am a better researcher, writer, teacher and person.

I am also thankful to my undergraduate mentor Sophia Pierroutsakos, who first introduced me to the study of symbolic development and led me to Lynn as a graduate mentor. Under Sophia’s guidance, I became intrigued by the process by which children come to understand symbols, and became increasingly interested in how research could address questions about that process.

I would also like to thank my doctoral committee (Rick Gilmore, Richard Carlson, and Carol Miller) for their many helpful suggestions. Their ideas have greatly improved my research program over the years. I will miss their feedback in the years to come, but I have also internalized their critiques. They have trained me to think critically about my work, and that will be a valuable skill for me as a new Ph.D.

This work could not have been done without the help of my undergraduate research assistants Kelly Hayduk, Megan Bibey, Kimberly Yingling, and Katie Freet. They spent many long hours recruiting participants, testing children, transcribing responses and coding data, and I sincerely thank them for their dedication.

In addition to my colleagues, I would also like to thank my parents, Francie Demby and Harold Myers, for their constant support and encouragement throughout my education, from preschool to the dissertation. My brother Alexander (“Z”) Myers has kept me humble no matter how educated I am, and he has peppered my years in graduate school with his constant humor.

Also, I thank my graduate school colleagues and friends. This process would have been lonely without them to share in our mutual accomplishments and hurdles over the years.
Last but not least, I extend my heartfelt gratitude to my husband Steven Jax, for being my partner in life, love and intellectual pursuits. I came to Penn State with some research ideas and the hope that I could succeed, and I am leaving with a career track, a Ph.D., and a wonderful husband whom I met along the way.
Chapter 1

Introduction

“Pictures are realizations of mentality. We have a glimmer of such a possibility from a comment made by a 7-year-old… ‘That’s a picture, that’s someone’s mind being put on paper.’ That’s perfectly correct… the central fact of depicting is someone’s mind being ‘put on paper.’” (Freeman, 1995, p. 146)

A defining characteristic of human cognition is the ability to communicate referentially, that is, the ability to use arbitrary symbols to refer to something. Symbols allow us to go beyond thinking and communicating about the “here and now” and enable us to refer to the “there and then,” such as the past, the future, things and people that are absent, the hypothetical or fanciful, and abstract ideas. Moreover, exposure to symbolic media fundamentally alters our cognition. Maps, for example, present space from vantage points that differ from human perceptual experiences, allowing us to see and connect spatial relationships that would be difficult from our embodied view of the world (Gauvain, 1993; Liben, 1999; Uttal, 2000). Similarly, graphs can help us see relationships between and among variables that would be difficult to visualize in other formats, and can lead us to ask questions of our data that would not have been possible otherwise (Lehrer & Schauble, 2002).

The development of symbolic understanding is important for children’s comprehension of language, gestures, maps, photos, drawings, and other types of symbolic media that are ubiquitous in our culture. For instance, it is a cognitive challenge to understand that the written word “cat” does not resemble an actual cat, and that a star denoting a city capital on a map does not resemble the actual city capital. Moreover, a symbol is an object in itself, but also refers to a referent, and thus has an inherent duality that can be difficult for children to “see through” (DeLoache, 2002; Potter, 1979). Empirical studies have shown that the more children interact
with a small model room as an object (i.e., by playing with it as a toy dollhouse), the more
difficulty they have in using it as a representation for the referent room (DeLoache, 2002).

Symbols are also inherently social. Goodman (1976) wrote extensively about the need to
understand “the language of symbols,” meaning that we must learn about the cultural
conventions of symbols in order to use and understand them. Specifically, he argued against the
assumption that representations such as photographs, paintings or sculpture show the world “as
is,” and asserts that we must learn about depiction and pictorial conventions in order to see
through the representation to its referent. This underscores another essential component of
symbols – they are selective, and must leave out certain information in order to highlight the
intended portions. Representations are not simply “RE-presentations” of the world (Liben,
1999).

Children must also learn about the relationship between characteristics of the symbol and
characteristics of the referent. *Iconic symbols* resemble their referents in some way (as in the
earlier example of a model room) whereas *non-iconic symbols* do not (as in the earlier example
of a star representing a city capital). However, no amount of resemblance between a symbol and
referent is sufficient to establish a representational link, because the key to establishing
representation lies in a person’s intentional use of a symbol to “point to” a particular referent
(Goodman, 1976). Thus even the most pictorial inscription is not a symbol unless it is created or
used in an intentional way. For example, a map of Italy *resembles* a boot but it is not a *symbol of*
a boot because it was created to map a country, not to represent a referent boot. Consistent with
this idea, children’s understanding of non-iconic symbols was the mark of the semiotic function
for Piaget (Piaget, 1970). The signifier (symbol) and signified (referent) are entirely
differentiated from one another, linked only by the ways in which social groups intentionally assign them meaning.

In this paper, I will address one component of children’s symbolic development – the recognition that other minds do not necessarily share the child’s own knowledge of, intentions for, or interpretation of symbols. This is particularly important for symbols that are created for communication with another person. Maps are one type of symbolic media that are often created to communicate information to others, as when they are produced to guide others along routes or to particular locations. However, maps can be challenging for children to understand because they are often composed of symbols that do not resemble the intended referents (as in a star used to denote city capitals). The assignment of symbolic meaning must therefore be conveyed in ways other than resemblance to a referent. The prototypical means of conveying or communicating the assignment of meaning is via a map key. Map keys are explicit in conveying symbol meaning by providing a precise notation linking the creator’s symbols with the “pointed to” intended referents.

At the broad level, the work reported here was designed to investigate children’s understanding of the mind as a component of symbolic development. Specifically, I examined whether children’s symbol understanding rests in part on their ability to anticipate alternate interpretations of a symbol by the intended audience. I predicted that this ability would be particularly challenging when children were asked to use symbols that resemble their referents in some way (iconic symbols). Under these conditions, children may mistakenly think that the referent of an iconic symbol will be clear to anyone, even if they are generally aware of the need for a map key (or other notation of meaning) when using non-iconic symbols.
Because this study is related to symbolic development, iconicity, theory of mind, and audience assessment in communication, I will review the literature in each of these areas below.

_Literature Review_

*Symbolic Development*

Broadly defined, a symbol is something that someone intends to stand for something else. This definition underscores the idea discussed in the previous section that symbols are *intentional* creations. Notably, this definition is silent about resemblance to a referent, which makes symbols incredibly general and flexible – anything can be used as a symbol for anything else if used intentionally. Drawings, photographs, video, maps, written words, spoken words, and gestures are just a few possible symbolic media. Several of these symbolic media are particularly relevant to the present study – gesture symbols (which may be the first referential symbols an infant is exposed to), drawing symbols (a medium in which symbol resemblance and intentionality are particularly important), and scale models (a medium in which children’s understanding of the duality of symbols has been extensively documented). In the section that follows, I will review these areas.

When can infants begin to understand and use symbols in communicative contexts? Language is certainly a mark of this ability, but some research shows that this ability is evident even before infants begin to use language. A current trend is for parents to use “baby signs” (hand gestures modeled after American Sign Language) to communicate with their infants before the children can speak. Using strict criteria for gestures that qualify as “symbolic,” (as opposed to those gestures that are inextricably linked with the action that they refer to, as in holding up one’s arms as a signal to be picked up), researchers have shown that parent-child use of these early gestural symbols is positively associated with later verbal vocabulary development.
(Acredolo & Goodwyn, 1988; Goodwyn & Acredolo, 1993). Symbolic gestures give parents and infants a vehicle for isolating and referring to actions and objects in an otherwise continuous stream of events, thus bootstrapping infants’ ability to attach a verbal label with those actions and objects.

Although infants can understand some things about symbols, they do not yet understand their dual nature. For example, 9-month-olds grasp at photographs as if they are attempting to pluck the object off the page (Pierroutsakos & DeLoache, 2003). When are children capable of understanding that a symbol is a thing in its own right, but also represents something else? DeLoache and colleagues (see DeLoache, 2002 for a review) have shown a remarkable shift in the toddler years when children begin to understand and overcome the inherent duality of symbols. They designed a model room task in which children watch an experimenter hide a miniature toy in a realistic scale model of a room (the symbol), and are told that the larger version of the object (the referent) is hidden in the corresponding place in the actual room. If children can think of the model room as a symbol for the referent room, they should have no trouble retrieving the toy. This result typically occurs around 3 years of age. However, 2 and 2.5-year-olds have difficulty achieving this “dual representation,” that is, they have trouble conceiving of the model room as a symbol for the larger room. When they enter the referent room, they fail to retrieve the hidden toy because in their minds, the model room is a separate entity in and of itself (instead of a symbol for the room). This duality is especially difficult for toddlers to appreciate when they focus on the model as an object itself. If the model is made less “object-like,” however, by placing it behind a window for instance, children more readily use the model room as a symbol.
The strongest evidence for the idea that children must conquer dual representation to use a symbol comes from a study in which dual representation demands were removed entirely from the task. The researchers introduced children to a “shrinking machine” which allegedly shrunk and expanded the room so that sometimes it was small (the model room) and sometimes it was large (the referent room). Thus, children did not have dually conceive of the model room as a symbol and an object because they believed that the model room and referent room were the same thing, merely shrunk or expanded. Under these conditions, 2-year-olds had no trouble using information from the small room to find where the toy was hidden in the larger room.

Even as they are adept at learning and understanding referential gestures and overcoming symbol duality, infants and young toddlers are not yet aware of the ways in which symbols are assigned meaning by an intentional creator, and that resemblance to a referent is irrelevant if a symbol is not created intentionally. When, then, do children become sensitive to these issues? Research on the development of drawing sheds some light on this question. In early drawing development, children scribble onto the page and name the referent of their drawing after the fact. Gradually they begin to understand that drawings show a particular referent that a creator has intended to represent. Gross and Hayne (1999) showed that 3-year-old children remembered what their own drawings depicted, even when those drawings appeared to be non-representational scribbles. Relatedly, Callaghan (2003) showed that 4-year-old children could select their own drawing from among other children’s drawings of similar referents. This was the case even when children had drawn with a chopstick onto carbon paper and had consequently never seen the graphic result of their intended drawing. Interestingly, children whose previous drawings (with a marker and paper) were classified as representational (as opposed to non-representational scribbles) were more successful at selecting their own drawings. Children also
come to rely on others’ intentions to name ambiguous drawings (Bloom & Markson, 1998), but hesitate to provide an object label for a seemingly identifiable shape if they are told it was created accidentally (Gelman & Ebeling, 1998). Taken together, these findings suggest that preschool-aged children are beginning to realize that resemblance between the shape of a graphic representation and its referent is reasonable but not necessary, whereas the creator’s intention is essential to the assignment of symbolic meaning.

In summary, the developmental literature has extensively documented the process by which children come to understand symbols in the first few years of life – gestures, scale models, and drawings, just to name a few. However, relatively few studies have examined how children’s understanding of symbols continues to develop after the age of 5 or 6. Thus, one of many goals of the present study is to examine how symbolic development continues to progress in the elementary school years.

**Iconicity**

Having briefly discussed relevant topics within symbolic development, I will now turn to work addressing adults’ and children’s understanding of a particular facet of symbols – the degree to which a particular symbol resembles (or does not resemble) the object for which it stands. **Iconic symbols** are symbols that share features with or resemble their referents in some way. In order to measure the degree to which a particular symbol is iconic, investigators have assessed adults’ and children’s accuracy in guessing the meaning of a symbol. Using this method, investigators have identified three types of symbols: transparent, translucent, and opaque (see Bloomberg, Karlan & Lloyd, 1990 for a review). **Transparent symbols** are easily guessable with little to no instruction or cues about the array of possible referents. **Translucent symbols** are not guessable, but upon brief instruction, explanation or contextual cues, the
resemblance between symbol and referent is readily evident. *Opaque symbols* are not guessable and must be learned instead, because the link between symbol and referent is entirely arbitrary or abstract.

One might suppose that understanding symbols that resemble their referents would be easier than understanding more arbitrary or abstract representational links, and sometimes this is the case. Luk and Bialystok (2005) have shown that, when asked to choose between two photographs as possible referents, adults can correctly identify the referent of Chinese characters that contain pictorial markings of the symbols’ meanings. In an interesting related study, Packard, Chen, Li, Wu, Gaffney, Li et al. (2006) showed that Chinese reading instruction was more effective when children were taught about the evolutionary link between a Chinese character and its referent. Apparently this newly acquired knowledge allowed children to “see” a link between symbol and referent where they previously saw none, and this helped point them toward the intended referent. This effect has also been found with English-speaking adults who are new to learning a somewhat pictographic language (Muter & Johns, 1985).

Does resemblance between a symbol and a referent always facilitate symbolic understanding for children and adults? Empirical evidence suggests not. In the Luk and Bialystok (2005) study, adults performed much more poorly (indeed, practically at floor level) when they were asked to guess the meaning without the two photograph response choices. Also, Namy, Campbell and Tomasello (2004) have found that 18-month-olds learned arbitrary and iconic gestures equally well. For example, an iconic gesture for a rabbit was a repeated hopping motion with the index and middle finger extended from a closed fist like rabbit ears, whereas an arbitrary gesture for a rabbit was a side-to-side motion with the hand extended as if to shake hands. Only older 4-year-old children remembered the iconic gestures better than the arbitrary
gestures. The authors proposed that iconicity may not facilitate early symbol learning because for very young children, all symbol-referent links may be arbitrary (even those that adults and older children interpret as clearly iconic).

Not only does iconicity not confer a benefit for young children, but in toddlerhood, iconicity can actually harm children’s performance on symbol use tasks. DeLoache and Sharon (2005) have found that three-year-old children perform better using a model room to find objects hidden in a referent room if the two were more dissimilar to one another (i.e., if the referent space was twice the size of the symbol space) than if the two spaces were identical in size. They reasoned if highly salient characteristics of the spaces are shared, children have no impetus to look for deeper symbolic connections between the two spaces. (However, as a caveat, theorists of representation would balk at the idea of two identical things being termed a symbol and a referent, as this undermines the idea that symbols are not RE-presentations of the world as is.)

Even though iconicity can actually impair symbol understanding, children seem to have a strong belief that symbols should share properties with their referents. Beilin and Pearlman (1991) have shown that 3-year-old children were more likely than 5-year-olds to report that a photo of an ice cream cone would feel cold and wet, or that a cut up picture of a rattle would result in damage to the actual rattle. Similarly, Liben and Downs (1989) reported that although most preschoolers understood that road maps and aerial photographs stood for places, these children expected the symbols to share qualities with their referents. For example, a line for a road was “not fat enough for two cars to go on,” and children had trouble finding grass depicted on a black-and-white aerial photograph because “grass is green.” First graders also declared that using an asterisk to represent a file cabinet on a map of their classroom was absurd, because an asterisk does not look like a file cabinet. In general, these results show that 3- to 6-year-old
children tend to focus on the physical correspondence between the referent and the symbol. They fail to recognize that although symbol-referent resemblance may be helpful in identifying the referent, ultimately anything can be used as a symbol for anything else if its meaning is assigned intentionally.

In fact, even emphasizing the symbol-creator’s intention may not be sufficient evidence for children to overcome their beliefs in iconicity. Myers and Liben (in press) report that the overwhelming majority of 5- and 6-year-olds insisted that red dots must stand for red firetrucks, even when they also understood that those same red dots had been placed on the page for a non-symbolic purpose. It was not until 7- and 8-years of age that children began to consistently grasp that the intention with which a symbol was produced should override mere color resemblance, and universal understanding was still not achieved until ages 9 and 10.

Lehrer and Schauble (2002) report that one way to help children overcome these beliefs in iconicity is to allow them to come to the realization that the representation is insufficient for a goal. First grade children insisted that graphs representing flower stem growth should be green like stems, with a flower bud at the top. However, when they were asked to draw conclusions from the graphs (i.e., which type of flower is growing the fastest?), children quickly realized that their representations were insufficient for this purpose and were more willing to compromise resemblance in favor of conveying the more important information about flower height. The authors call this approach problematizing, a way of setting up a question or task so that children realize that their current solution is insufficient and needs to be amended.

Alternative and augmentative communication. Researchers who work with developmentally delayed individuals have extensively studied the properties of graphic and manual symbols that make them most readily understandable to individuals who use visual-
graphic or manual sign systems as alternatives to verbal communication. Specifically, the degree of arbitrariness versus iconicity has been consistently identified as an important factor in selecting an ideal symbol communication medium. One possibility is that symbols that resemble their referents should be readily learned by individuals with developmental delays because a highly iconic symbol should be more guessable than a non-iconic symbol. However, this is a controversy among clinicians because one’s ability to “see” the iconicity of a symbol is dependent on culture, context and experience (Dunham, 1989). That is, individuals bring their own cognitive capacities, histories and semantic concepts to the task of understanding symbols, and it is an error to assume these are invariant across individuals. Sevcik, Romski and Wilkinson (1991) say of this issue, “if individuals do not have a particular semantic concept within their linguistic repertoires, then that meaning would not be able to be employed to facilitate the learning of a symbol” (p. 163).

Theory of Mind

As discussed previously, symbols are intentionally assigned meaning by a symbol-creator, and a symbol cannot be a symbol without this essential intentional link. Therefore, an understanding of the mind is of central importance to children’s symbolic development. The following section provides a review of the literature on the development of “theory of mind” throughout the lifespan.

The term “theory of mind” is typically used in the developmental literature to refer to preschool children’s understanding of their own and others’ mental states. However, I will argue here that developmentalists should use the term instead to refer to early emergence and late mastery of this concept, consistent with the position espoused by many investigators (see Chandler & Carpendale, 1998 for a review). The rudiments of theory of mind are evident in
infancy, as when infants begin to jointly attend and point to objects along with their caregivers (Tomasello, Carpenter, & Liszkowski, 2007). However, even adults can fall short in understanding others’ minds.

*Preschool leaps and bounds.* Around the age of 3 and 4 years, children begin to develop a “theory of mind.” Broadly, theory of mind refers to the knowledge of one’s own mental states as well as the awareness that other people have different thoughts, desires, intentions, feelings and beliefs. One common measure of a child’s theory of mind is the false belief task. In this task, the child and a first puppet both see chocolate hidden in location A (Wimmer & Perner, 1983). After the first puppet leaves the room, another character moves the chocolate to location B. The child is then asked to predict where the first puppet will look for the chocolate when the puppet returns. Typically, 3-year-olds fail these types of tasks, answering incorrectly that the puppet will look where the child knows the chocolate is currently hidden, in location B. Another common measure is the unexpected contents task (Wellman, Cross & Watson, 2001). Children are shown a container (e.g., a crayon box) and are asked what they think will be found inside (they answer crayons, of course). Then the experimenter and child open the box to find unexpected contents, band-aids. Before the theory of mind milestone, children will say that they always knew there were band-aids in the box and that a naïve person would know this as well. After achieving theory of mind, children are able to maintain two representations of the same reality (i.e., their uninformed initial belief, and their informed later belief) and they correctly report that naivety (of themselves or another person) causes incorrect initial beliefs about the contents of the crayon box.

Flavell and colleagues (see Flavell, 2004 for a review) have also used the appearance-reality task to assess theory of mind. Children are shown an object that looks like a rock but
when touched, it is evident that it is actually a sponge. Before the theory of mind milestone, children respond that they knew it was a sponge all along and a naïve person (who has not been privy to the rock-sponge demonstration) would also know it is a sponge. Alternatively, children exhibit theory of mind if they can maintain that they first thought it was a rock, that a naïve person would also think it is a rock, and generally that their current informed knowledge is different from their previous ignorant belief.

These results have been discussed in terms of preschool children’s poor understanding of mental states. Specifically, young children may assume that their own mental state is accessible to and equivalent to that of other people, and are unable to differentiate between their present and past beliefs. Citing these and numerous other studies as evidence, researchers have suggested that children younger than approximately 4 years of age fail to recognize, value, and consider that other people may have beliefs, desires, and intentions that are different from their own. Around age 4, it appears that children begin to understand and appreciate that others may maintain different mental representations from reality or from oneself (see Wellman, Cross, & Watson, 2001 for a meta-analytic review).

Interpretive theory of mind. The development of children’s interpretive theory of mind (Carpendale & Chandler, 1996) is a later step in the process of understanding others’ minds that develops in the elementary school years. Whereas the theory of mind research on preschool children has shown that 3- and 4-year-old children begin to understand that people may hold beliefs that are false, naïve, or otherwise differ from the true state of affairs, interpretive mind is the ability to recognize that two or more beliefs about the same event or stimulus can be equally valid. For instance, John and Mary could see the same movie but come away with different
evaluations of its quality – Mary may think the movie was great, whereas John may think it was bad. Both of these interpretations of the movie are equally legitimate; neither is right or wrong.

In an interpretive mind framework, there is no dichotomy of a “true” belief opposed to a “false” belief, but importantly, this dichotomy is a common characteristic of tasks used to assess younger children’s theory of mind. Furthermore, Chandler and Carpendale (1998) emphasize that interpretive mind is more of a constructive process of knowing (i.e., individuals construct their own knowledge of and beliefs about their experiences), whereas “traditional” theory of mind is more of a copy theory of knowledge construction (i.e., someone is exposed to a particular event and thus believes in that event, with no interpretation or constructive process necessary).

There is a tension in the literature between copy theories of the mind and constructive theories of mind, which is illustrated by the following quote:

The theories-of-mind enterprise suffers under a series of self-imposed limitations that have…rendered it more a champion of the permanent than an advocate of development…[have] cost it any measured concern with the likely causes and natural consequences of cognitive growth, and so truncated the meaning of belief that much of what is most promising about children’s changing conceptions of mental life ends up being left lying on the cutting room floor…False-belief understanding is only an early way station en route toward an increasingly interpretive view of mental life, and an essential part of this developmental course ordinarily involves a growing appreciation of the constructive ways in which minds routinely and characteristically shape the subjective nature of their own experiences. (Chandler & Carpendale, 1998, p. 183-184).

Thus, Chandler and colleagues propose that the benchmarks of childhood theory of mind have unnecessarily become the false belief, unexpected contents and appearance-reality tasks. These are certainly important starting points for children’s understanding of the mind, but children continue to expand their understanding of the mind well past the age of 4 or 5. There is currently a paucity of work in the literature that addresses this continuing development.
This theoretical distinction between traditional theory of mind and interpretive mind is supported empirically. Specifically, 4- through 6-year-old children who readily pass false belief and appearance reality tasks and are thus credited with a theory of mind in the traditional sense nevertheless fail on interpretive mind measures (Lalonde & Chandler, 2002). Presumably they falter because although they are beginning to understand some things about the mind, they cannot yet simultaneously consider as equally valid multiple interpretations of the same stimulus (Carpendale & Chandler, 1996; Chandler & Carpendale, 1998).

Moreover, a new study shows that interpretive mind is important to social-cognitive development across domains. Children who were trained in constructive conflict resolution with their siblings showed social-cognitive gains as measured by interpretive mind tasks (Smith & Ross, 2007). Interpersonal conflict resolution is interpretive in nature because conflict can arise from different people’s divergent understandings of the same event. The authors use the example of two siblings who are asked by their mother to clean up their blocks. John has built a tower he is proud of and resists cleaning it up, but his sister Maggie destroys the tower and cleans up the blocks. This story and others used in the study were designed so that each sibling could blame the other – John could blame Maggie for knocking down his tower, but Maggie’s actions are justified because she was obeying their mother. If siblings understand that another person’s construal of the same event may be justified from that person’s perspective, conflict can be lessened and understanding the other person’s perspective can be enhanced. Thus, children’s practical experience of recognizing and appreciating their siblings’ perspectives in disputes can contribute to a more general interpretive understanding that other people may have equally valid perspectives of a single stimulus (Ross, Recchia, & Carpendale, 2005; Smith & Ross, 2007).
Notably, as interpretive mind gains ground in the literature, it is important that theory of mind not turn from a “one-miracle view” (theory of mind comes online at age 4) to a “two miracle view” (theory of mind comes online at age 4, followed by interpretive mind around age 8). Thus, next I will turn to theory of mind development into adulthood.

Theory of mind throughout the lifespan. Do adults simply achieve an endpoint in theory of mind, never to develop or change again? Although developmental psychologists have largely ignored theory of mind development past childhood, there is new evidence suggesting that we continue to refine our understanding of the mind throughout adulthood.

One recently identified link is between hindsight bias in adults (the “I knew it all along” phenomenon) and theory of mind in childhood. In hindsight bias, knowledge of the eventual outcome biases adults’ decisions or beliefs about a past event. For instance, Bernstein, Atance, Meltzoff and Loftus (2007) give the example that, “armed with the knowledge that New Orleans suffered a devastating flood, we are more apt to think that we knew it would happen all along” (p. 1374). The authors point out that hindsight bias and theory of mind share the necessity of having to ignore or override one’s current knowledge. To support this claim, they show evidence of a remarkable overlap between children’s performance on traditional theory of mind tasks and hindsight bias tasks, a relationship that is not accounted for by language ability or inhibitory control. Most interestingly, they put forward the idea that perhaps hindsight bias persists into adulthood because the mechanism underlying it allows us to easily update our memories with new relevant information, “but also allows us to fall prey to hindsight bias (the updating prevents gaining full and easy access to our past beliefs)” (p. 1390).

In a related series of studies, Birch and colleagues (Birch, 2005; Birch & Bernstein, 2007; Birch & Bloom, 2007) have investigated adult theory of mind in terms of the curse of knowledge,
a difficulty appreciating a more naïve perspective as the result of being biased by one’s current own knowledge. The naïve perspective can be one’s own earlier perspective (as in the hindsight bias) or someone else’s perspective (as in false belief). Birch and Bloom (2007) showed that when adult participants had a plausible rationale for why someone might behave in accordance with the participants’ own belief (in a modified false belief task for adults), they selected the biased response more often than the correct response. Importantly, although adults in all conditions had a plausible reason for why the naïve actor might return to the original location (i.e., the desired object was moved to the red box, which resided in the area of the room where the correct blue box originally resided), only adults who had knowledge of the hiding outcome used this fact as justification for their answer. The authors reason that just like children (though under slightly different circumstances), an adult’s own knowledge can compromise their ability to make predictions about others’ behavior.

Even though adults may have the ability to explicitly reflect on the differences in what they and others know (whereas children may not), adults do not always recruit this knowledge to interpret what others mean (Keysar, Linn & Barr, 2003). The authors of this study set up a circumstance in which Person B knows that there is scotch tape hidden in an opaque bag, but Person A does not. However, when Person A refers to a cassette tape, Person B is slower to identify Person A’s intended referent relative to a control condition in which both people are naïve to the contents of the bag. Most strikingly, some participants actually identified the hidden object as the referent of Person A’s utterance and self-corrected shortly after making this choice, aware of their fumble. Thus, even when adults can explicitly identify what others know, they still show implicit (or sometimes overt) egocentric biases.
These results dovetail nicely with studies in other domains showing continuity between childhood and adulthood cognition. For instance, in the Dimensional Change Card Sort task (DCCS), preschool-aged children show difficulty in switching from the rule that they use first to sort cards (i.e., sort by color – blue bunnies and blue boats are sorted together) to a second rule (i.e., sort by shape – blue bunnies and blue boats are sorted into different groups). Although children can verbally state the new rule, behaviorally they persist in sorting by the first rule (Zelazo, Muller, Frye & Marcovitch, 2003). When Diamond and Kirkham (2005) examined adults’ reaction times to the same task, they found an identical pattern but with less overt behavioral consequences – adults could complete the task correctly, but their reaction times to do so were much faster when the trial was consistent with the rule they had learned first.

In summary, there is not the discontinuity between childhood and adult cognition in general, or in cognition about the mind specifically, as an examination of the developmental literature would suggest. As a concluding point, academic psychologists are more informed about their research content areas than are their students in the classroom (one would hope they are, that is). However, unclear messages in teaching can occur when an instructor fails to deliver a lecture at an appropriate level for their students’ more naïve standpoint – the instructor’s own expertise makes it difficult for her to take the perspective of the student (the curse of expertise, see Hinds, 1999). Clearly, children and adults of all stripes (even academics who study such effects) are not immune to fumbles in theory of mind.

*Audience Assessment in Communication*

*Referential communication.* Using symbols to communicate with others is an area in which understanding the mind of one’s audience is particularly important. Callaghan (1999) has examined whether even younger children alter their symbols when told that their drawings are
inadequate for communicating information to someone else. Children were asked to draw a picture to tell an experimenter which toy to grab, and 3- and 4-year-old children improved and elaborated on their original drawings when it became evident that their audience member (a second experimenter) did not understand which toy the drawing represented.

In a classic experiment on the development of referential communication, Krauss and Glucksberg (1969) asked elementary school children to take the roles of speaker and listener in a block-building task, and to develop names to refer to novel forms used in the task. The two children were situated on either side of a barrier, and the speaker’s job was to verbally instruct the listener to build a block structure to match his own by describing novel shapes that labeled each block. The authors observed the following: “When a child calls one of our figures “Mommy’s hat,” a name which does not enable listeners to select the correct referent, he is demonstrating his lack of appreciation of the fact that a good name must take into account the knowledge his listener possesses.” (p. 264). The fifth grade children and adults in the study were less likely to make these errors of shared knowledge than were the kindergartners and first graders, indicating that audience sensitivity in communication is refined with age.

More recently, Lehrer and Schauble (2002) have observed similar occurrences when small groups of elementary school-aged children design graphs and maps. Within their own groups, children insist that their presentation is superb and transparent to anyone who might use their representation, and they are shocked when someone else has difficulty using it to draw conclusions about the data represented. Just as in Krauss and Glucksberg’s (1969) work, one particularly common error in these contexts was that the children relied too much on shared group knowledge, seemingly unaware that someone outside the group would not have access to that same information. Taken together, these studies show that a rudimentary sensitivity to one’s
audience is apparent as early as toddlerhood, but it continues to be refined and elaborated throughout the elementary school years.

*Linguistic pragmatics.* The fields of linguistic pragmatics and sociology have contributed significantly to our understanding about how speakers and listeners work together to convey and comprehend meaning in conversation. Listeners have a repertoire of tools termed *back-channel responses* that signal their understanding of the message being conveyed by the speaker (head nods, saying “uh huh”), and when they do not understand, they can interrupt for correction or clarification. Clark and colleagues (Clark & Bangerter, 2004; Clark & Wilkes-Gibbs, 1990) have been especially influential in examining the ways in which turn-taking between speakers and listeners establishes mutual responsibility for ensuring the listener’s understanding.

The principal difference between linguistic and graphic symbol communication is that in verbal communication, listeners can give signs to the speaker if they do not understand, and speakers can adjust to these misunderstandings online by altering their message based on the feedback they receive from the listener (Clark & Wilkes-Gibbs, 1990). However, this sort of adjustment in the moment is often not possible in graphic symbol communication – the message is written at one time by the symbol-creator and understood at another time by the symbol-user. Therefore, it is important for the symbol-creator to anticipate the symbol-user’s state of knowledge (i.e., does she know what I know?) when writing a message. Conversely, the symbol-user may more readily understand the message if she thinks about the state of mind of the symbol-creator.

*Connecting Symbol Development, Iconicity and Intentionality*

*Intersection between iconicity and communication.* The intersection between iconicity and communication is particularly interesting. Because iconic symbols retain some measure of
similarity with their referents, it is possible that a symbol-creator could come to believe that the referent will be clear to anyone. In order to communicate effectively, the creator must take the perspective of the symbol user, anticipate how a naïve or other-informed mind might construe the symbols differently than oneself, and provide additional information that is not immediately clear otherwise. When efforts fail to maximize symbol transparency and a communication attempt fails, how do children respond? Robinson and Robinson (1976) found that 5- and 6-year-olds attributed all communication failures to the listener (regardless of whether the message had been insufficient), but 7- and 8-year-olds recognized that communication can fail because of an inadequate message (and that it is not necessarily the fault of the listener).

*Symbol intentionality understanding as a mechanism of overcoming iconicity beliefs.*

Myers and Liben (in press) examined whether 5- to 10-year-old children could understand creators’ intentions, and whether they could use this knowledge to distinguish between marks that either did or did not carry symbolic meaning. They tested these questions under two conditions that varied with respect to the iconic resemblance relationship between the referent and symbol. Children viewed the symbol-creation process by watching videos of two people drawing. One person demonstrated a *symbolic intention*, verbally and physically expressing their intention to represent real-world referents onto a map, using green dots as symbols, whereas the other person demonstrated an *aesthetic intention*, decorating the paper with red dots to make it more colorful. Children were moderately successful at describing what each of the people was trying to do.

However, when asked which person’s drawing would help to find toy fire trucks (a red referent that matched the color of the aesthetically-created dots), even the 5- and 6-year-olds who had described the creators’ intentions correctly were “seduced by color.” That is, they insisted
that “the red dots would help you because fire trucks are red.” Children performed moderately better in the condition in which the referent did not share iconic color resemblance with either drawing, but 5- and 6-year-olds still showed very low levels of success. However, 9- and 10-year-olds were consistently successful at calling upon knowledge about the creators’ intention to select the symbolically informative map, regardless of whether the apparent iconicity conflicted with the creator’s intention.

The authors proposed that interpretive theory of mind is a process developing between the ages of 6 and 9 that could be partially responsible for this shift in performance. Specifically, they argue that,

The identical marks can carry entirely different meaning (or even no referential meaning at all) depending on how those marks were created. Marks do not have inherent or automatic meaning by sole virtue of their color or other incidental similarities to a referent. This recognition, along with the knowledge that symbols mean what they are intended to mean by a creator (not what they happen to resemble) may rely on the more general appreciation that others’ minds can construe meaning in many possible different, but equally valid ways. (Myers & Liben, in press, ms. p. 37).

Thus, a main goal of the present study was to directly test children’s interpretive theory of mind and examine its relationship with children’s use of iconic and non-iconic symbols to communicate with another person.

Research Questions

The preceding literature review shows that children have a belief in symbol iconicity, that 7- to 8-year-olds begin to appreciate their audience in communication tasks, that theory of mind continues to develop after the preschool years, and that interpretive mind may be a mechanism of how children begin to understand that symbol meaning is intentionally assigned by different individuals. For purposes of this paper, by “symbol,” I mean a graphic representation that stands
for a real-world referent. Symbols can also be pictures, gestures, scale models, and the like, but the symbols used in the present study were on paper and were therefore graphic symbols.

The present study builds on these findings by examining several aspects of elementary school children’s symbolic development in the context of producing a particular kind of graphic symbol – a map. The first aspect of interest is children’s ability to overcome reliance on iconicity to convey symbol meaning. Do children erroneously believe that iconic symbols will be obvious to another person who attempts to use the map they have created? The second aspect is children’s awareness of the need to communicate meaning to another person, and their capacity to invent a strategy to do so. Do children believe that iconicity will carry meaning so completely that a map key is unnecessary? When they realize that meaning must be conveyed in some way other than iconicity, how do they do so? Do they use pictures or words? Do they use categorical notations (i.e., use one type of symbol to represent a category of referents) or do they specify the same symbol-referent link multiple times?

This investigation was also designed to examine the contribution of developing an interpretive theory of mind to symbolic development. This link is theoretically important given that both constructs involve recognizing that meaning is not intrinsic to any stimulus, event, or symbol. Specifically, the study was designed to investigate whether children who score high on interpretive mind tasks would be better at anticipating other people’s likely interpretation of map symbols.

To address these questions, 6- through 9-year-old children were asked to make a map of hidden toys in a room. The task was designed to provide children with the opportunity to notate which toys were selected, what symbols were used to represent each toy, and where they were hidden.
Critically, the iconicity of the available symbols was manipulated between children. Some children were provided with symbols that were abstract and bore no surface resemblance to the referent toys. Other children were provided with symbols that shared features with several of the toys. Of interest was whether these two kinds of symbols would be differentially conducive to children recognizing the need to convey symbolic meaning to the map-user. Thus, it was predicted that children would be more likely to create a map key in the abstract symbol condition than in the iconic condition. Because the abstract symbols looked nothing like the referents, it should be obvious to children at this age that abstract symbol meaning needs to be communicated in some way.

However, a more sophisticated interpretive mind should lead children in the iconic symbol condition to realize that an additional notation is necessary, because the assignment of symbol meaning is not entirely communicated by iconic resemblance. That is, although iconic symbols look somewhat like their referents, interpretation is still involved and necessary. The symbol and many possible referents share the iconic elements of shape, but the intentional assignment of meaning is different depending on the intended referent. Of interest was whether children would realize that although the iconic symbols communicate some information about the toys, resemblance alone would not help a symbol-user to know what symbols were assigned to represent specific toys.

Children’s responses to questions about information that the map user needs to know were evaluated in order to assess whether children understood the need to communicate symbol meaning. Additionally, the strategies with which children communicated this information (i.e., map keys) were scored. Also of interest was whether children would be able to recognize when a map has effectively communicated information (even if they could not do so in their own
representations). To assess this, children were asked to select another child’s map that would be useful.

The 6- to 9-year-old age range was selected because it spans the ages in which interpretive mind emerges and solidifies. That is, 6-year-olds should be well beyond the theory of mind benchmark (i.e., easily solving classic theory of mind measures such as the false belief and appearance-reality tasks described earlier). However, children of this age are beginning to develop an interpretive theory of mind (iToM), which should be relatively sophisticated by 9 years. Thus, there should be considerable variability in children’s interpretive mind abilities between age 6 and 9, making it possible to examine the relation between iToM and performance on the various symbolic map measures. Children’s interpretive mind abilities were measured by two tasks that required the understanding that different people may come to different assessments when viewing the same stimulus.

As a means of testing whether any associations obtained might be more simply attributed to more general measure of cognitive functioning, children were also given the vocabulary and matrix reasoning sub-scales of the Weschler Intelligence Scale for Children, Fourth Edition (the WISC-IV, Weschler, 2003), and a memory measure related to the map-making task.

In summary, this study was designed to examine three sets of hypotheses concerning (1) children’s symbol-communicative performance using a map, (2) the relation of performance on the symbol-communicative tasks to interpretive theory of mind, most especially for iconic symbols, and (3) whether any effects found in (1) and (2) could be attributed to more general cognitive functioning, as measured by a standardized intelligence test and a memory task related to the map task used in the study. Specifically, with regard to (1), it was predicted that older children would show greater awareness of the information that needed to be communicated to the
symbol-user, and that they would be more successful in formulating and enacting a strategy to do so (using words, pictures, or a key). It was also predicted that younger children would rely more on symbol resemblance (especially in the iconic condition) and less on notation strategies to communicate meaning to the symbol-user. Second, with respect to (2), it was predicted that a more sophisticated interpretive theory of mind would result in better performance on the map-symbol-communicative tasks. This should be especially true in the iconic symbol condition, because although iconic symbols convey some information about their referents, children with a more refined interpretive mind should be able to recognize that resemblance alone is not sufficient for the map-user. Finally, regarding (3), it was predicted that intelligence and memory may account for some, but not all, effects otherwise attributed to age and interpretive theory of mind.
Chapter 2

Method

Participants

Families living within 50 miles of a university child research center, who had either agreed to be part of a university database or who had announced their children’s birth in the newspaper 6 to 9 years earlier, and whose addresses could be located in public records were sent letters inviting their 6- to 9-year-old children to participate in the study. Approximately 35% agreed, resulting in a total sample of 80 children, divided approximately equally by sex and age. The sample consisted of 20 six-year-old children ranging in age from 72 to 83 months, $M (SD) = 76 (3.4)$; 20 seven-year-old children ranging in age from 84 to 95 months, $M (SD) = 89 (3.7)$; 21 eight-year-olds ranging in age from 96 to 107 months, $M (SD) = 100 (3.7)$; and 19 nine-year-olds ranging in age from 109 to 119 months, $M (SD) = 114 (4.0)$. The sample was 90% white and predominately middle-class and rural, with most parents having had at least some college and some having advanced degrees. Although this sample is representative of the local volunteer population, it is not representative of the country at large, and thus caution is needed in generalizing to more diverse populations. Participants were tested individually in the Moore Building on the University Park campus of The Pennsylvania State University. The experimenter for a given session was one of three total female experimenters (the author or two highly trained research assistants).
Procedure

Overview

The broad goal of the map-making task was to evaluate whether children could use symbols to communicate to a map-user which toys had been selected to hide, what toy was represented by each symbol, and where the toys had been hidden. Conversely, the goal of the map-evaluation task was to test whether children could recognize and explain when another person had achieved these communicative and representational goals. The iconicity validation task was designed to corroborate the greater iconicity of the iconic symbols as compared to the abstract symbols. The droodle task and the ambiguous figures task were designed to assess children’s recognition that different people can come to different conclusions even after being exposed to the same stimulus. Finally, the WISC-vocabulary and matrix reasoning tests provided well-validated measures of verbal ability and general intelligence (respectively), and the memory for hidden objects task assessed children’s memory after a delay.

Table 1 presents a hierarchical list of tasks and the variables that were coded from them, and the full experiment script can be found in Appendix B. As part of the informed consent procedure, parents agreed for their children to be videotaped for the study, and for their children’s responses to be transcribed and coded. Additionally, parents could consent to (or deny consent to): (a) archive the records for use in other research projects beyond the purpose and goals of the original study, and (b) to allow their child’s recording to be shown in professional settings. While the parent completed the consent form and a family information form for demographics, verbal assent was obtained from the child. The parent informed consent form can be found in Appendix C, and the child verbal assent is a part of the script in Appendix B.
**Map-Making: Using Map Symbols to Communicate**

Children were instructed to make a map for a symbol-user (referred to as “Lynn”) so that she could later replicate the hiding game for another child. That is, the child’s task was to create a map that would enable Lynn to hide the same toys in the same places as the child had seen the experimenter hide them.

*Introduction to the map.* The goal of the map-making task was to test the symbolic and communicative aspects of map making. Thus, steps were taken to make the room-to-map correspondence as easy as possible to avoid taxing children’s ability to solve the spatial components. Children were provided with a scaled plan-view map of the basic layout of the room showing the walls, entry door, and location of furniture. Because many investigators (e.g., Bluestein & Acredolo, 1979) have shown that map misalignment can be difficult for children to overcome, the map was aligned with the referent space. It was also taped to the table to ensure that children did not turn or misalign the map in the process of their map-making. Furthermore, in order to facilitate children’s ability to see the correspondence between the symbols and the actual furniture, the symbols for the couch, desks, and other objects in the room were presented in the same shape, relative position, and color as the actual furniture.

There was also a brief familiarization to help children begin to see the correspondences between the map and room, during which the experimenter and child pointed to places in the room and then to their corresponding places on the map. For instance, the experimenter first pointed to the places at the actual table where she and the child were sitting, and then pointed to these places as they were represented on the map. Then the experimenter pointed to the windows above the air conditioner in the room, and asked the child to point to the same place on the map. Only places that were not later used as hiding places were used in the familiarization phase.
Symbol selection. As described previously, a major between-subjects manipulation was the iconicity of the symbols children received for the map-making task. The iconic symbols offered some resemblance to the referents (e.g., Iconic Symbol V, the predicted symbol for the target referent toothbrush, was a long line with three shorter lines extending from it, which resembled a toothbrush handle and bristles). The abstract symbols were limited to several colors and patterns that were not systematically linked to the physical appearance of the referents.

In order to select the iconic and abstract symbols to be used in the children’s map-making task, a separate set of adult data were collected first. Adults were shown a set of objects and a set of potential symbols, and were asked to select the “best symbol” for each object. In the case of abstract symbols, the data showed no single “best symbol” for any of the objects. That is, for any specific pairing between an object and an abstract symbol, the proportion selecting the modal choice (32%) was not much higher than the proportion selecting the second and third most popular choices (25%, 17%, respectively). Furthermore, for abstract symbols, agreement across participants was low (11–32%) for those pairings. In contrast, for iconic symbols, there was a clear “best symbol” for any specific pairing between an object and an iconic symbol. Agreement across participants for that best symbol was moderate (44–80%) for those “best symbol” pairings.

It was important that agreement across participants not be 100% because unanimous agreement would imply that the symbols were completely transparent to a potential symbol-user. Accordingly, the aim was to offer children symbols that shared some resemblance with the referents, but were not completely transparent or agreed upon by individuals. Thus, adult testing validated the a priori division of symbols into iconic and abstract groups.
Symbol iconicity. Children received either the iconic or abstract set of symbols during map-making. As described more fully in the map-making section, the symbols were on half-inch round stickers, and were presented to children in a box with 12 divided compartments. Each of the 12 compartments contained several identical stickers so that children could select several of the same symbol if they wished to do so. Figure 1 presents the two sets of symbols available to the children (between subjects) for the map-making task, Figure 2 presents photographs of the target referents and distracter referents, and Figure 3 presents a photograph of the entire toy box as presented to the children.

Importantly, the iconic symbols could also be iconically linked to alternate “distracter referents” in the toy box that were not selected to be hidden. That is, the iconic symbols also bore some resemblance to another toy in the box. This was an important feature of the task to ensure that iconicity alone could not completely convey which toys were selected. For example, Iconic Symbol G (a circle with lines extending out from it, the predicted symbol for the koosh ball referents) could also be a reasonable iconic symbol for its corresponding distracter referents, the centipede bugs. The symbol and both referents were round and spiky, and thus Iconic Symbol G could reasonably be used to stand for either the koosh balls or the centipede bugs. Symbol iconicity could convey roundness and spikiness, but resemblance alone was not sufficient to convey to a map-user which round and spiky referent it represented. Thus, because the symbol resembled both the target and distracter referents, the child should not solely rely on symbol resemblance to communicate to the symbol-user, but should also make use of additional notations (such as words, pictures or a map key).

Selecting the toys to hide. In order to highlight the selection process from the full set of toys (i.e., which toys were selected), the experimenter placed a large, transparent toy box onto
the table and remarked, “I have a big box of toys here, see? There are all sorts of toys in here. Look at all of these toys! I’m going to pick a few of them for us to use in the hiding game today.” The toy box (see Figure 3) contained the 12 target referents, 12 distracter referents, and several other types of miscellaneous toys (e.g., dice, dreidels, silly putty, etc). The experimenter then selected 12 target referents from the box and placed them on the table at random. There were 3 similar objects for each of the 4 categories: 3 koosh balls (orange, yellow, and pink), 3 slinkies (big silver, small silver, and polka-dotted red), 3 tubes (blue, yellow, and pink), and 3 toothbrushes (purple, green, and blue). In order to further highlight the selection process (i.e., which toys were selected), the toy box remained on the table throughout the entire map-making task.

Next, children were told that the experimenter would hide the toys in the room and he/she would watch and make their map to “show Lynn how to set up things in the same way as we set them up today.” The experimenter emphasized that it was important that Lynn know which category of toy (i.e., koosh ball, slinky, tube, or toothbrush) was hidden in each place, but it was not necessary for her to distinguish between exemplars of the same type of object. For instance, children were told that “she’ll just need to know what kind of thing was hidden in each place,” and the experimenter demonstrated an example by saying, “it won’t matter which tube she uses (the blue or yellow one), she’ll just need to put a tube where a tube was.” Children were told that all the toys would be back in the toy box when Lynn began this process, thus lending credence to the importance of communicating to her which toys were selected.

Map-planning. Next, children were given markers and a box that contained 12 types of stickers (either iconic or abstract symbols). They were told, “your job is to use these, the stickers and the markers, to make the map tell Lynn how to set up the hiding game tomorrow the same
way we are doing it today. Make sure the map tells her what she needs to know.” Children were
given time to select the stickers they wanted to use to stand for the toys and alerted the
experimenter when they were finished. During this time, the experimenter unobtrusively noted
children’s questions and spontaneous comments.

It is noteworthy that children were not instructed to use any particular symbol-referent
pairing (i.e., Iconic Symbol G for the koosh balls). Rather, they could select any of the 12
symbols to represent any of the 12 target referents. However, as explained later in the iconicity
validation task results (see p. 51 – 52), many children (but not all) selected the predicted iconic
symbols to stand for the target referents.

Knowledge probes. Children’s responses to the knowledge probes assessed whether they
recognized the need to communicate their assignment of meaning to the symbols, and that this
assignment of meaning would not be transparent to map-users. These questions were
administered twice – after map-planning and after map-making. Children were allowed to make
changes to their map at any point during the questions. Knowledge probes consisted of the
following questions:

(1) Are you done planning for your map? [For the second administration after map-
making, this question read: Are you done making your map?]
(2) Will Lynn know what kinds of things were hidden?
(3) What will she need to know to set up the finding game the exact same way as we
have?
(4) Will she know what the stickers mean?
(5) In case she has trouble knowing what the stickers mean, is there anything you can do
on your map to tell her what the stickers mean? [Or past tense if key was already
made: Is there anything you’ve done on your map to tell her what the stickers mean?]

Map-making. The experimenter emphasized the where component of map-making before
she began to hide the toys, saying, “Make sure to put the stickers in the exact same place as I put
the toy in the room. Remember, we want to help Lynn set up the next hiding game in the same
way as we have.” As the experimenter picked up each of the 12 toys from the table, she said, “OK, this is the first toy, I am going to hide it here.” If the child hesitated, the experimenter prompted him or her by saying, “I just hid the toy here [pointed to place in the room], so you need to choose a sticker to show Lynn how to set up the hiding game the exact same way tomorrow.”

Some children asked if they must use stickers, wishing to use only markers instead. Because the iconic and abstract symbol conditions would be meaningless without the use of the symbols, children were required to use the stickers in some way. They were told that they must use the stickers to stand for the toys, and if necessary, the experimenter paused after hiding an object and did not hide the next one until the child chose a symbol and placed it on the map.

Throughout the entire map-making task, if the child turned to the experimenter for validation of their choices (e.g., asking, Is that the right place on the map? Is this the correct sticker for that toy? Should I make a key?), the experimenter responded that the child should make the map however would be best to tell Lynn about the hiding game.

After the experimenter finished hiding the 12 objects and the child finished making his or her map, the knowledge probes were administered again (see above). In order to ensure that children could not access their map to make any additional changes after the map-making task was completed, the child placed his or her map into an envelope marked “To: Lynn” and slid it underneath a locked door (ostensibly Lynn’s office door).

Map-Evaluation Task

Children were asked to evaluate others’ maps in order to assess whether they could recognize an effectively communicative map even if they had not made one themselves, and whether they could explain why it was effective. Children were told that they would look at
maps made by two other children who had done the same thing that they had just completed, but
that it had taken place in a different room, using a different map, different toys and different
stickers. Each map had 3 each of 4 types of stickers placed in various locations. One map had a
key; specifically, four identical symbols to those placed within the map were placed in the
margin next to a word (written in child-like handwriting). The words served to “decode” the
referent that each type of symbol represented. The other map did not have a key – the stickers on
the map showed where things had been hidden, but did not delineate which toys had been
selected, or what referent was represented by each sticker. Children who had been in the iconic
condition when creating their own maps evaluated iconic symbol maps; those in the abstract
condition evaluated maps with abstract symbols. Figure 4 presents the maps that children were
asked to evaluate.

Children were asked to help the experimenter choose the map that would be better to help
her set up the next hiding game identically to the map-creator’s hiding game. Children selected a
map and were asked to justify their choice to say why the selected one would help and why the
unselected one would not.

Iconicity Validation.

As explained earlier, the iconicity validation task was designed to corroborate the greater
iconicity of the iconic symbols as compared to the abstract symbols. Given results from adults
already described, it was predicted that the iconic symbols would elicit greater agreement among
children than would the abstract symbols. At the same time, however, it was important to find
that agreement was not perfect, because 100% agreement would imply that the symbols were in
fact completely transparent to a potential symbol-user and thus it would be perfectly reasonable
to omit a map key.
Children were given two sets of 12 index cards (4 by 6 inch). The cards for one set contained photos of each of the toys used in the map-making task (one object per card, that is, the three koosh ball referents were presented on three separate cards), and cards for the other set contained either the abstract or iconic symbols (one sticker per card). Children received the opposite set of symbols that they had received for the map-making and map-evaluation tasks. For example, a child who had used iconic symbols in the map-making and map-evaluation tasks received abstract symbols in the iconicity validation task, and vice versa. The experimenter spread out the symbol cards on the table in a random order of two rows of six cards each. Children were asked to pick a sticker that they thought went best with each object by placing the photo card alongside the symbol selected for that photo. They were told that they could choose as many or as few stickers to match the photos as they wished, and that it was permissible to use the same sticker for multiple photos. For example, if a child wished to use the same sticker for all three of the koosh ball photos, she placed those three photos in a line on the table alongside the selected sticker. After the child completed the sorting, the experimenter recorded the child’s responses.

*Interpretive Theory of Mind Measures*

These tasks test children’s ability to recognize that different people can come to different conclusions even after encountering the same information. Thus, all tasks assess children’s knowledge of interpretation in the context of ambiguous stimuli (Chandler & Helm, 1984; Carpendale & Chandler, 1996; Lalonde & Chandler, 2002; Taylor, 1988).

*Droodles.* The droodle task tests interpretive mind because *two people* are given access to the same reality (i.e. a portion of a drawing showing through the window) but because of the opaque nature of the image, should be expected to interpret the same stimulus differently.
Children are given the opportunity to show their appreciation that two people are equally free to entertain *many different false beliefs* of the same reality. In brief, children saw a drawing in its entirety and were asked to guess what two other people might think if they only saw a small piece of the entire drawing. Figure 5 presents the three droodles used in the task.

Children were first introduced to two people depicted in photographs, both of whom were the same sex as the child, and were told that they would be asked what these people might say if they saw the droodles. Then, children were shown the *full view* of the droodle scene (e.g., a chicken) and were asked to describe it. After establishing the initial interpretation for the full view of the picture, the experimenter presented the *restricted view* by covering the drawing with a frame that left only a section of the picture exposed (e.g., a small part of the chicken’s feathers on his head). Next, children were asked questions about each droodle, which required them to imagine what the two photographed people would say. The first question was, “when [Person 1] sees this [restricted view], what will he/she think it is? The second question was, “when [Person 2] sees this [restricted view], what will he/she think it is?” Thus, children were informed about the *full view* of the drawing, but were asked to imagine what two naïve individuals might think upon seeing only the *restricted view* of the droodle. This procedure was used for 3 droodles – a butterfly, a turtle, and a chicken. Scoring of droodle responses followed that of Lalonde and Chandler (2002), and is described in the Results section.

*Ambiguous figures.* Following the reasoning of Carpendale and Chandler (1996), the ambiguous figures task was chosen as a measure of interpretive theory of mind because the available evidence in the task equally supports both Person 1 and Person 2’s interpretations of the same stimuli. Thus, success at the task should show that children recognize that different people can have grounds for attributing different meanings to the same stimulus. In brief,
children evaluated others’ likely responses for a stimulus that can be justifiably interpreted in several ways. The stimuli used were the classic ambiguous figures *duck / rabbit* and *faces / vase*, which are presented in Figure 6.

In brief, children were first shown the duck/rabbit ambiguous figure and were told that the two people depicted in the photographs disagreed when figuring out what the drawing depicts. Specifically, children were first asked what the figure looked like, and the experimenter pointed out the alternative shape if necessary. Thus, it was established that children saw both interpretations before they were asked the two target questions about each figure. The order of presentation of the stimulus alternatives (duck/rabbit, faces/vase) was counterbalanced, but remains constant in the following explanation for clarity of presentation. The *explanation question*, which required the children to either endorse or refute the divergent answers for the single stimulus, was posed first to the child – “When [Person 1] saw this picture, he/she said it was a duck. But when [Person 2] saw it, he/she said it was a rabbit. Is it OK for one person to say it's a duck and the other to say it's a rabbit?” If the child did not spontaneously offer a justification beyond yes or no, the experimenter prompted for elaboration by saying, “Why is it ok? [or Why isn't it OK?]” The *prediction question*, which asked children to predict how a group of children might react to the stimulus, was asked second – “If we showed this picture to children in another school, would they think it's a duck or a rabbit, or would you not know what they would think?” This procedure was then repeated for the second figure. Scoring of ambiguous figures responses followed that of Carpendale and Chandler (1996), and is described in the Results section.
General Cognitive Functioning

The WISC-vocabulary task was included as a measure of children’s word knowledge and verbal comprehension (Weschler, 2003). The WISC-matrix reasoning task was included as a measure of children’s fluid intelligence, as many investigators have recognized that it is a good estimate of children’s general intellectual ability (see Kaufman, Flanagan, Alfonso & Mascolo, 2006 for a review; also Weschler, 2003). The memory for hidden objects task was included as an assessment of children’s memory after a delay.

**WISC-Vocabulary.** The task administration instructions from the WISC-IV were followed (Weschler, 2003). There are set starting items depending on the age of the child. Children were asked to give the meaning of a series of words, which are ranked in difficulty from easiest to hardest. For instance, item #10 is “what is the alphabet?” and one possible correct answer is that the [English] alphabet is composed of 26 letters that are used to spell words. If the child gave an unclear answer, the experimenter followed up by asking the suggested questions in the WISC-IV administration manual, such as “tell me more about that,” or “what do you mean?” The task continues until children answer “I don’t know” or are incorrect on 5 consecutive items. Scoring is described in the Results section.

**WISC-Matrix reasoning.** The task administration instructions from the WISC-IV were followed (Weschler, 2003). Children were asked to examine a grid of pictures or figures. There was one blank space in the grid, and a list of 5 possible answers to complete the blank. Children were asked to select the item from the response choices that would complete the pattern shown in the grid. For example, one item shows a 2 x 2 grid with 2 yellow light bulbs, 1 green light bulb, and a question mark in the blank space. The correct answer is that a green light bulb in the blank space completes the pattern, and it is one of the 5 answer choices. Children only have to point to
an item to respond, they do not have to explain their reasoning for selecting that item. Again, there are set starting items depending on the age of the child. There are 3 practice items at the start of the task, in which the experimenter can explain the correct answer to the child if she answers incorrectly. The task continues until children answer “I don’t know” or are incorrect on 4 consecutive items, or if they perform at chance level (incorrect on 4 out of 5 items). Scoring is described in the Results section.

Memory for hidden objects. This task was designed to test children’s memory for the objects that the experimenter had hidden in the map-making phase, after a delay of approximately 45 minutes. It also served the practical purpose of lending credibility to the story that another experimenter would be using the child’s map the next day to set up the hiding game for another child, and that all of the referent toys would be back in the box when the other experimenter and child began. Although children had made a map showing what toys had been hidden in each place, they did not use these maps – they relied only on their memory for this task. As previously described, children’s maps remained in an envelope underneath “Lynn’s office door.”

Children were given 12 index cards (4 by 6 inch), each with the name of a hidden object. The cards did not distinguish between multiple exemplars of the same type of object – for instance, there were 3 cards that each had the word “slinky” (any of which could be used to mark the location of any slinky), instead of a card for each of the different types of slinkies. To indicate where the child thought the object would be found, he or she was asked to place each card where they thought the corresponding object could be found, but was asked to wait to look underneath until they had placed all of the cards. This served to keep the 12 trials relatively independent of one another. That is, if children had looked in each place as they went (thus
receiving feedback on the accuracy of their placements mid-task), the later trials would have benefited from the elimination of previous placements from the response possibilities. For younger children and older children who had trouble reading the cards, the experimenter read each card aloud and then handed it to the child for each placement.

The placement of all of the cards in the room served as the dependent variable of the memory task, and the experimenter recorded the number of correct card placements. Then the experimenter and child looked in each place, and the child was guided to correct locations as needed (this was not counted as correct, it was merely done to enhance the child’s enjoyment of the task). Thus, the toys were removed from the hiding places and returned to the big toy box. Scoring is described in the Results section.
Chapter 3
Results

Overview

The first section presents results from each measure examined alone. The second section presents analyses of the relationships among measures. Table 1 presents a hierarchical list of tasks and the variables that were coded from them.

Throughout the results, exact p-values are reported for maximum specificity, but the standard $p < .05$ was the criterion used to assess statistical significance. For maximum specificity and to confirm that any age groupings did not collapse across large differences between groups, age was used with all four levels (ages 6, 7, 8, and 9) in all analyses. Furthermore, although no sex effects were predicted, sex was included in the analyses. These decisions were made because the symbolic medium used was a map and there are often sex differences on map performance (see Liben, 2002), even though the measures used in the present study were symbolic-communicative instead of spatial measures. Thus, when age, map condition and sex were all taken into account, this decision meant that there were small cell sizes of 5 each.

Many of the outcome variables described below are dichotomous, and the analysis approach selected was analysis of variance (ANOVA) rather than nested chi-squares, logistic regression, or ANOVA with arcsin transformed data. Although these alternative analysis approaches can be used for dichotomous dependent variables, ANOVA is robust to violations of its assumptions. Moreover, Lunney (1970) has shown that ANOVA can be an appropriate statistical technique for analyzing dichotomous data provided there are at least 40 degrees of freedom for error. D’Agostino (1971) has also argued that especially when the cell proportions lie between .25 and .75, alternative analysis methods are unlikely to lead to different conclusions.
than ANOVA. Thus, ANOVA was selected because of the greater transparency of the meaning of the data with this approach. Finally, unless mentioned otherwise, all post-hoc tests used the Bonferroni correction for multiple comparisons.

To foreshadow the results, the major findings that emerge from these analyses are as follows. First, older children were generally more knowledgeable than younger children with respect to knowing that the symbol-user would need to know which toys were selected, what symbol stood for each toy, and where the toys were hidden. In addition, older children were more likely than younger children to attempt creating a map key to communicate meaning to the symbol-user. Map key strategies also varied qualitatively with age – older children made more categorical map keys (i.e., they used one type of symbol to represent one type of referent), whereas younger children made more redundant map keys (i.e., they specified the same symbol-referent link repeatedly). With respect to the interpretive mind measures, older children performed better on both droodle and ambiguous figures than did younger children. Finally, measures of general cognitive functioning served as expected – children’s WISC scores improved with age but did not deviate from the standardized expected scores, and there was no effect of age or participant sex for the memory task.

Concerning the relations between measures, even when children were aware of the information the symbol-user needed to know and suggested a possible way to communicate that information, many still failed to attempt a map key. Also, production and comprehension were related across tasks – children who had attempted a map key in their own representations were more likely to recognize when another person had effectively communicated in the map-evaluation task. Furthermore, there was a strong relationship between age and interpretive mind, but global intelligence did not account for this association. Specifically, for iconic symbols (but
not for abstract symbols), children’s interpretive mind was a predictor of symbol communication over and above the contribution of age and general cognitive functioning. The analyses leading to these general conclusions are described below.

Measures Presented Individually

Children’s Map Understanding

Knowledge probes. The knowledge probes were designed to assess children’s understanding of the knowledge that was necessary for the symbol-user to know which toys were selected, what stickers stood for the toys, and where the toys were hidden. The coding collectively considered children’s answers across the five knowledge probes because children’s responses on any individual item were not necessarily reflective of their overall understanding of the symbol-user. For example, children’s responses to any individual question could be incomplete, although the overall response to the set of five questions could be complete and accurate. All reasons were coded dichotomously (present or absent), and a single response could receive more than one reason code. A second coder scored 25% of the data, and agreement was 91%.

The first set of three variables coded indicates the information that the child stated the symbol-user needs to know – which toys were selected among the many possible items in the toy box (e.g., children explicitly mentioned that Lynn will need to know which toys were selected from the toy box), what symbol stood for each referent (e.g., children explicitly identify and say that Lynn needs to know what types of objects are represented by what types of stickers), and where the objects were hidden (e.g., children explicitly mention that Lynn will need to know where objects are hidden). Examples of responses that were scored for each code are presented in Table 2.
Each knowledge probe question was asked twice, first after planning but prior to map-making, and second, after the toys had been hidden and map-making was complete. This procedure permitted assessment of whether the process of map-making prompted children to think more about what the map-user needed to know. The three analyses presented next used the which, what or where variables (after map-planning vs. after map-making) as the dependent variable in a 4 (age) X 2 (sex) X 2 (map condition) repeated measures analysis of variance (ANOVA). For which, no significant effects were found. For what, an age effect was found, $F(3, 64) = 3.56, p = .02$, which was driven by 6-year-olds mentioning it significantly less often (.33) than 9-year-olds (.74). Also, a marginally significant effect of time emerged, $F(1, 64) = 3.46, p = .07$, such that there was a trend toward more children mentioning what during map-planning (.61) than after map-making (.50). The time X sex interaction was also significant, $F(1, 64) = 4.70, p = .03$, such that boys mentioned what more during map-planning (.69) than after map-making (.45), but there was no difference in time for girls.

Finally, for where, a marginally significant effect of time was found, $F(3, 64) = 3.58, p = .06$, such that children mentioned it less during map-planning (59%) than after map-making (71%). An age X sex interaction was also found, $F(3, 64) = 3.51, p = .02$, such that 6-year-old boys mentioned where significantly more than did girls (.78 vs. .41), whereas 7-year-old boys mentioned it less than girls (.38 vs. .71).

The second set of variables considers the child’s verbally stated strategy for communicating information about which, what and where. Because there were no effects of time using repeated measures ANOVAs for this set of variables, results are presented collapsing across the first and second administrations of the knowledge probes. That is, if a child received credit either time (during map-planning or after map-making) for a given strategy, then they
receive credit in the overall score, but do not receive double credit on the overall score if they received credit both times. Table 3 presents the coding definitions and examples for each strategy.

After preliminary analyses showed no sex effects, all of the following analyses were done using age and map condition as the independent variables. Means and standard deviations for global, picture, and word are presented in Table 4. Younger children were significantly more likely to use global strategies than were older children, $F(3, 72) = 8.31, p = .001$. Specifically, 6- and 7-year-olds’ performance did not differ significantly, but 6-year-olds used global strategies significantly more often than all other age groups (whereas 7-year-olds did not). For the picture and word strategies, there were no significant effects of age or map condition or their interaction.

The following analyses for the resemblance and key strategies were also done by age and map condition, but are presented separately from Table 4 because the means and standard deviations must be broken down by both map condition and age. For the resemblance strategy, means and standard deviations are presented by age and map condition in Table 5. There was a significant increase with age in children’s comments that the resemblance between the symbols and referents would communicate meaning to the map-user, $F(3, 72) = 4.11, p = .01$. Specifically, 6-year-olds offered resemblance significantly less often than 8-year-olds. There was also a significant age by map condition interaction $F(3, 72) = 4.37, p = .007$. To examine the nature of this effect, t-tests were conducted separately for each age. There was no difference in referencing resemblance for the 6-, 7-, or 8-year-old children, but the oldest 9-year-old children used resemblance to convey meaning was significantly more in the iconic condition, $t(19) = 3.92, p = .001$. 
For the key strategy, there was a significant increase with age, $F(3, 72) = 5.87, p = .001$, such that 6-year-olds mentioned a key strategy significantly less often than did 9-year-olds, and there was a marginally significant ($p = .06$) difference between 6- and 8-year-olds, but no other age groups were from one another. Although there was no effect of map condition ($p = .18$) or the interaction ($p = .38$), means and standard deviations are presented in Table 6 because a difference between map conditions in key-making was predicted.

For an overall view of children’s verbally stated strategies for communicating information to the map-user, Figure 7 presents the means reported above in a graphic format.

It is worth highlighting that these strategies are only children’s verbally stated strategies, which did not always correspond with what they did. That is, children could mention making a key, pictures or words but not attempt any one of these strategies, and likewise, they could attempt a key, pictures or words without ever mentioning this strategy in the knowledge probes. Children’s verbally stated strategies are revealing of the things that they were aware could communicate meaning. Whether they actually enacted these strategies is a question addressed best by the next section on children’s map keys.

It is also noteworthy that the figure and these tables present strategies that are not mutually exclusive. That is, most of the 9-year-olds in the iconic condition mentioned and commented on the resemblance between symbol and referent, but the data presented thus far do not show whether they also attempted a notation strategy (either a key, picture or word) in conjunction with resemblance. To do so would supplement their comments about resemblance with a notation, suggesting that they were aware that resemblance was not enough to communicate symbol meaning to the symbol-user. To examine the possible connection between attempting a notation strategy and commenting on resemblance, the frequencies with which
children mentioned resemblance in conjunction with attempting versus not attempting a map key were examined. (More detailed discussion of data on children’s map keys is included in the next section below.) Frequencies are presented in Table 7, split by age and map condition. Data are presented collapsed by age because of the low frequencies of numbers in this table. Few children relied exclusively on resemblance, but the frequencies by age are so low that they are difficult to interpret.

*Map keys.* Children’s map keys were examined as a second way to assess whether they attempted to convey symbol meaning to the symbol-user, and if so, what strategy they chose to achieve this goal. For all of the coding presented in this section, a second coder scored 25% of the data, and agreement with the main coder was 96%.

Children’s maps were first scored by whether or not they used symbols to represent a category of similar objects (i.e., all slinkies represented by blue dots). Just over two-thirds of children (N = 55, or 69%) planned or began using symbols categorically in this way. Table 8 presents the means and standard deviations, by age in years and map condition, for children’s use of map symbols in categories. A 4 (age) X 2 (map condition) ANOVA revealed a significant age effect in using symbols categorically, $F(3, 72) = 3.31, p = .03$, such that 9-year-olds categorized significantly more than did 6- and 7-year-olds. A significant age by map condition interaction was also revealed, $F(3, 72) = 4.89, p = .004$. Follow-up t-tests showed that in the abstract condition, 6-year-olds were significantly more likely to categorize symbols, $t(18) = -2.47, p = .02$, whereas 8-year-olds were more likely to categorize iconic symbols, $t(19) = 2.41, p = .03$. Ten children (13%) received credit for using symbols categorically, but experienced a problem implementing symbol categorization. They erred in the assignment of symbols to referent toys during map-making even though it was evident from their comments in the planning stage that
they had intended the symbols to represent categories of objects rather than for individual objects.

Children were scored as having attempted a key if there was any type of notation on the map (e.g., word, picture, letter) that appeared to have been created to communicate meaning, or if the child had explicitly stated that a notation was created to communicate meaning, even if the notation was not complete or effective. Two-thirds (N = 52, or 66%) of children attempted a key. The dichotomous variable of attempting versus not attempting a key served as the dependent variable in a three-way ANOVA in which age in years, participant sex, and map condition (iconic or abstract) were between-subjects factors. Table 9 presents the means and standard deviations for this analysis by age in years and map condition. As expected, there was a significant effect of age, $F(3, 64) = 3.45, p = .02$, such that 9-year-olds were significantly more likely to attempt a map key than were 6-year-olds. There was no significant effect of sex (means were .68 and .64 for girls and boys, respectively), map condition, or the interactions.

Children’s map keys were also classified as effective or ineffective. Keys were scored as effective if they provided a map user the necessary information to determine which toys were selected, and what symbols stood for each referent. Of the 52 children who attempted a map key, 45 were judged to be effective. The predominant strategy was scored as one of four types: categorical (an exemplar symbol was placed by exemplar referents), redundant (the same symbol-referent link was specified multiple times), modification (the symbols were changed by drawing or writing on them), or global (a notation of symbol meaning that instructs a global concept but not specifics, such as “the stickers mean toys”). Of the 45 children who created effective keys, 27 used categorical strategies, 12 used redundant strategies, and 6 used modification strategies. Of the 7 children who created ineffective keys, 2 used categorical
strategies, 3 used modification strategies, and 2 used global strategies. Figure 8 presents the key strategies by age of the children who created effective keys, and Figures 9 – 13 present examples of each type of strategy.

The last item of interest with respect to map keys concerns the unexpected finding that while making their map, some children failed to remember what symbols they had used for each referent toy. That is, although they were in the privileged position of being the symbol-creator and had access to their own symbolic intentions, their symbols were not transparent in meaning for them. For example, S#48 (age 6;5, iconic condition, girl) had to repeatedly remind herself what type of sticker she had already used for a previous exemplar of a referent, and asked the experimenter several times to show her what toys were hidden in specific places so she could remember the symbol-referent pairing she had already begun to use. This variable was called trouble reading own symbols and means and standard deviations for an age by map condition ANOVA are presented in Table 10. There was no trend with age but it occurred marginally significantly more often in the abstract map symbol condition, $F(1, 72) = 3.28, p = .07$.

Examining this effect by frequency (number of children who showed the effect), 4 of 39 children in the iconic condition versus 11 of 41 children in the abstract condition had trouble reading their own symbols.

**Map-evaluation task.** Children’s responses were scored for overall accuracy by coding whether they selected the correct map (the map with a key) and justified it correctly (coding for children’s justifications is described in detail below). For all of the coding presented in this section, a second coder scored 20% of the data, and agreement with the main coder was 96%.

This dichotomous dependent variable of overall accuracy was analyzed in a three-way ANOVA in which age in years, participant sex, and map condition (iconic or abstract) served as
between-subjects factors. Table 11 presents the means and standard deviations by age and map condition. As expected, there was a significant main effect of age, $F(3, 64) = 6.01, p = .001$, such that 6-year-olds performed significantly worse than the 7-, 8-, and 9-year-olds, and these three older age groups did not differ. There was no significant main effect of sex (means were .77 and .78 for girls and boys, respectively), map condition or the interactions.

Also coded were the specific reasons children mentioned when justifying their map choice. A single response could receive more than one reason code (i.e., the reason “here you don’t know what stuff is where” received both the what and where codes), and each reason code was scored dichotomously. Table 12 presents the coding definitions and examples for each strategy, and Table 13 presents the proportions of these reasons given by age.

The frequencies of the key, what, and knowledge reasons were significantly different across ages and occasionally varied with map condition. For the key reason, $F(3, 72) = 4.29, p = .008$, 6-year-olds used this reason significantly less often than 7-, 8-, and 9-year-olds but none of the older age groups differed from one another. Children’s references to the key also occurred more often in the abstract condition than in the iconic condition, $F(1, 72) = 5.57, p = .02$. For the what reason, $F(3, 72) = 8.64, p = .001$, 6-year-olds used this reason significantly less often than 7-, 8-, and 9-year-olds but none of the older age groups differed from one another. For the knowledge reason, 6-year-olds invoked it significantly less often than did 9-year-olds, $F(3, 72) = 2.67, p = .05$. Finally, the multiple reason showed a marginally significant increase with age, $F(3, 72) = 2.21, p = .09$, but none of the age groups were significantly different from one another.

 Iconicity validation. For the iconic symbols, there was a strong but not universally agreed upon symbol choice among children for each set of objects. Collapsing across the three exemplars of each type of object, the koosh balls elicited 61-78% agreement for Iconic Symbol
G (see Figure 1 for the list of symbols and Figure 2 for the photos of the referents), the tubes elicited 46-54% agreement for Iconic Symbol H, the toothbrushes elicited 61-63% agreement for Iconic Symbol V, and the slinkies elicited 44-49% agreement for Iconic Symbol W. The slinkies also elicited a second agreed upon symbol at 20-27% agreement for Iconic Symbol H (the predicted and agreed upon iconic symbol for tubes).

As predicted, and consistent with the data from the adult sample, the abstract symbols showed fewer instances of agreement across participants for the “best symbol.” Collapsing across the three exemplars of each type of object, the koosh balls elicited 6 possible best symbols, with agreement ranging from 13-26%. The tubes elicited 7 possible best symbols, with agreement ranging from 13-21%. The toothbrushes elicited 5 possible best symbols, with agreement ranging from 13-23%. Finally, the slinkies elicited 2 possible best symbols but with a clear preferred symbol, Abstract Symbol W at 36-44% and Abstract Symbols T and E at 13% and 15%, respectively. The Abstract Symbol W sticker resembles a bulls-eye, which many of the children said also resembled a slinky if they looked through it from one end to the other. This similarity to the iconic symbols was unexpected and not intended by design, but taken together with the other iconicity validation results, was a minor issue.

**Interpretive Theory of Mind Measures**

**Droodles.** Children’s responses to the droodle task were coded using criteria from Lalonde and Chandler (2002). There were two responses per droodle (one for Person 1, one for Person 2) to the target question, “what would [Person 1 or Person 2] think this is?” Each individual response was scored as one of the following: (a) reality error, (b) contamination error, (c) I don’t know, or (d) false belief. A reality error was defined as a response with an obvious reference to the underlying picture (i.e., Person 1 will think the butterfly droodle is a butterfly).
A contamination error was defined as a response that contained no explicit reference to the underlying picture, but one that could be seen to have a direct connection to the larger scene (i.e., Person 1 will think that the butterfly droodle is a cocoon or a caterpillar). An “I don’t know” response was defined as one in which the child repeatedly said “I don’t know,” despite multiple queries from the experimenter. A false belief response was defined as a response that had no obvious connection to the underlying picture.

The pair of responses (to each of the two people) was also coded. The response pair was scored as interpretive if responses for the first and second person were each scored as false belief and were different false beliefs. The response pair was scored as non-interpretive if the two responses were identical false beliefs, or if one of the responses had been coded as a reality error, contamination or an “I don’t know.” A second coder scored 25% of the data, and agreement with the main coder was 94%.

The number of interpretive response pairs for each of the three droodles was summed, yielding a single droodle measure ranging from 0 to 3. This served as the dependent variable in a two-way ANOVA in which age in years and participant sex were between-subjects factors. Means and standard deviations are presented in Table 14. As expected, there was a significant main effect of age, $F(3, 72) = 8.75, p = .001$. Post-hoc tests showed that 6-, 7-, and 8-year-olds’ scores did not significantly differ from one another, but all were significantly lower than 9-year-olds’ scores. There was no significant effect of participant sex or the interaction.

In order to validate that the restricted views of each of the droodles could indeed be interpreted as many different things (an essential condition to ensure the external validity of the task), children’s responses for each of the two people were examined. The restricted view butterfly droodle elicited 67 different categories of responses, the most common of which was
flower or petal (n = 23), but also foot (3), teeth (5), bird (5), fly (3), curtains (2) and many guesses that occurred only once, including (among others), seashell, fingers, skeleton, jump ropes, dog's ear, spiderweb, sharky things, and raindrop. The restricted view of the turtle droodle elicited 87 different categories, the most common of which was shell (8) or face (8), but also rock (3), sun (5), pond/lake (3), bear (2), sleeping person (2), and many idiosyncratic answers including alien, grumpy fish, the letter E, arm, frisbee, road, and lightbulb. Finally, the restricted view of the chicken droodle elicited 56 different categories, the most common of which was hand (12), but also rabbit's ear (4), hair (5), person with mohawk (5), foot (3), and unique responses including tissue, marble, maze, cactus growing, weeds sticking up from grass, guy wearing a crazy hat, and dinosaur.

Ambiguous figures. The ambiguous figures task was coded using criteria from Carpendale and Chandler (1996). For ease of presentation, the examples that follow use the duck-rabbit stimulus as an example, but identical criteria were used to score the faces-vase stimulus as well. A second coder scored 35% of the data, and agreement with the main coder was 95%.

The explanation question was, “When [1st person] saw this picture, he/she said it was a duck. But when [2nd person] saw it, he/she said it was a rabbit. Is it OK for one person to say it's a duck and the other to say it's a rabbit? Why is it ok? [or, Why isn't it OK?]” Responses were scored as passing if the child judged both interpretations to be legitimate and explained that this difference was due to the ambiguous nature of the object. For example, one girl exactly 7 years of age (S# 16) said, “Because both of them are on there. Because if you look at one, like, one [person] might see one thing and the other [person] might see the other thing. And it's, there's both of those things on there [the paper] so it's right about both things.” Responses were scored
as failing if any one of the following was the case: (a) the child erroneously stated that it is not possible or reasonable for the two people to answer differently, that one of them was wrong; (b) if the child considered both interpretations to be “okay” but could not justify this judgment despite queries from the experimenter; (c) if the child justified the divergent interpretations without noting the ambiguous nature of the stimulus (e.g., S#51, age 6;2, boy, “Yeah, that’s ok. Because they think what they want.”); or (d) if the child provided a circular answer (e.g., S#35, age 6;1, girl, “Yes. Because I just think that because I just think it and it’s fine.”).

The prediction question was, “If we showed this picture to children in another school, would they think it's a duck or a rabbit, or would you not know what they would think?” Responses were scored as passing if the child refused to make a prediction and explained why it would be difficult to do so. For example, one girl (S# 7, age 9;9) responded, “I have no clue what they could think. Because they could have many different opinions of what it could be. Some kid might look at it and see something completely different than me.” Responses could also be correct if they indicated that some people might support one interpretation while others would favor the other. For example, one girl (S# 12, age 9;10) responded, “They could think both, I think. Because some people might think of this part [pointed to picture] as the back of the head and some people might think of this part as the mouth.” Responses were scored as failing if the child made a clear and specific prediction. For example, one girl (S# 11; age 8;0) said, “They'd think it's a duck. Because here is his beak, head, eyes, and it would be quacking.” Responses were also scored as failing if children did not make a prediction but could not explain why, despite queries from the experimenter.

The number of correct responses to the explanation and prediction questions were summed across both ambiguous figures stimuli, yielding a single ambiguous figures measure
ranging from 0 to 4. This served as the dependent variable in a two-way ANOVA in which age in years and participant sex were between-subjects factors. Means and standard deviations are presented in Table 15. As expected, there was a significant main effect of age, $F (3, 72) = 6.31$, $p = .001$, such that 6-year-olds performed significantly poorer than 8- and 9-year-olds. There was no significant effect of participant sex or the interaction.

**General Cognitive Functioning**

*WISC-Vocabulary.* The WISC-vocabulary measure was scored according to the WISC version IV criteria (Weschler, 2003). Each response received a score of 0, 1 or 2, according to the WISC-IV administration manual, which gives examples of responses for each item that should receive each score. In general, a response that was incorrect or very vague received a 0, a response that was partially correct but omitted critical information received a 1, and a response that was complete and correct received a 2. The raw score indicated the sum of the scores on all items that the child had completed.

The raw vocabulary scores served as the dependent variable in a two-way ANOVA in which age in years and participant sex were between-subjects factors. Means and standard deviations for this analysis are presented in Table 16. As expected, the main effect of age was significant, $F (3, 72) = 16.21$, $p = .001$, such that the raw vocabulary scores of all age groups were significantly different from one another except for 7- and 8-year-olds. There was no main effect for participant sex or the interaction.

Next, the vocabulary scores were examined using the version IV standard score, which is scaled to control for age. The standard score indicated how typical a particular raw score was for a child of a particular age. For instance, a raw score of 20 achieved by a child age 6 years; 3 months received a higher standard score than a the same raw score achieved by a child aged 9
years; 0 months. A standard score of 10 is the expected 50% percentile rank. As expected, neither main effect for age or participant sex, nor their interaction, were significant. As shown in Table 17, results showed that both sexes and all age groups were at or slightly above the expected median standard score of 10.

**WISC-Matrix reasoning.** The WISC-matrix reasoning measure was scored according to the version IV criteria (Weschler, 2003). Children received one point for every puzzle they answered correctly, and the sum of these scores made up the raw score. The raw matrix reasoning scores served as the dependent variable in a two-way ANOVA in which age in years and participant sex were between-subjects factors. Means and standard deviations are presented in Table 18. The main effect of age was significant, $F(3, 72) = 12.57, p = .001$, such that 6-year-olds’ scores were significantly lower than 7-, 8-, and 9-year-olds’ scores, but none of the older age groups were significantly different from one another.

Next, the matrix reasoning scores were examined using the version IV standard score. Means and standard deviations are presented in Table 19. Despite the fact that it is scaled to control for age, there was a significant main effect of age, $F(3, 72) = 3.93, p = .01$. Post-hoc tests showed that this effect was driven by the significant difference between 7- and 9-year-olds’ scores, such that 7-year-olds outperformed the expected median standard score of 10, whereas 9-year-olds did not. No other age groups’ scores were significantly different from one another.

There was no significant effect of participant sex or an interaction between age and participant sex.

**Memory for hidden objects.** Responses on the memory task were examined with respect to the number of times (out of 12) that the child placed an object name card onto the correct place where an exemplar object had been hidden in the map-making task. For instance, children
were given 1 point if they placed a “slinky” card on top of the couch pillow where a slinky was hidden underneath. If the incorrect item (i.e., a toothbrush) had actually been hidden in this location, children were not given credit for the placement. Thus, the task required children to remember the location of each type of referent toy, not merely the locations themselves. However, children were not required to distinguish between different exemplars of the same type of object (i.e., the big slinky and the small slinky). The number of correct placements served as the dependent variable in a two-way ANOVA in which age in years and participant sex were between-subjects factors. Neither main effect nor their interaction was significant, however, Table 20 presents the means and standard deviations.

Creating Overall Scores

Before moving on to the analyses examining the impact of interpretive mind, age, and general cognitive functioning on children’s overall symbol-communication performance, details are presented on the calculation of two aggregate scores – one for symbol communication, and another for interpretive mind.

Symbol Communication Score

An overall symbol communication score was created by summing 17 items that indicated children’s sensitivity to the symbol-user. From the knowledge probes, items used were: which, what, and where and one point if the child suggested any sort of notation (word, picture or key, but not multiple points if the child had mentioned all of these). Because some effects of time had been found in the repeated measures ANOVAs of the knowledge probes, scores for both administrations of the knowledge probes (one set of responses after map-planning and another after map-making) were summed. Thus, there were 4 possible points from each set, or 8 total possible points from all of the knowledge probes. From the map key making, items used were:
key attempt and key effectiveness. Finally, from the map-evaluation task, items used were:

overall correctness, and the justifications name, key, what, where, multiple, and knowledge.

Next a reliability analysis was conducted to ensure that these 17 items together created a reliable scale. Cronbach’s alpha was .84, and the overall alpha did not change to be considerably higher or lower if any individual item had been deleted. Scores ranged from 0 to 16, with a mean of 8.4, standard deviation of 3.9, and a median of 9.00.

Interpretive Theory of Mind Score.

To create a single interpretive theory of mind (iToM) score, the scores on the droodle task (i.e., 3 items on which children were scored as interpretive or not) were summed with the ambiguous figures task accuracy (i.e., explanation and prediction questions for the duck-rabbit and faces-vase figures, totaling 4 ambiguous figures items).

Next a reliability analysis was conducted to ensure that the seven items together created a reliable scale. Cronbach’s alpha was relatively low (.52), however, the total alpha was higher than if any of the individual items had been dropped. Scores ranged from 0 to 7, with a mean of 3.16, a standard deviation of 1.73, and a median of 3.00. (As an aside, reliability was slightly higher but not considerably better if conducted within item type instead of summing across the two tasks. The Cronbach’s alpha for the 3 droodle items was .59, and for the 4 ambiguous figures items it was .54.)

Relations Between Measures

Overview

The goal of the following section is to examine relationships between the various individual measures presented thus far. Correlational analyses are presented first, which examine the consistency of children’s performance across the various map-symbol measures.
instance, does children’s awareness of the things the map-user needs to know necessarily lead to their making a notation (key, picture or word) to communicate that information? Second, inter-relationships between age, iToM and general cognitive functioning are presented. Third, regression and residuals analyses are presented, which assessed whether children’s iToM scores were predictive of their symbol communication scores over and above the effects of age, intelligence, and memory.

How Related is Children’s Performance Within the Map Tasks?

Is awareness of map-user associated with attempting notations of symbol meaning? The frequencies of children’s responses to the knowledge probes (i.e., that the symbol-user needs to know which toys were selected, what symbols stand for each toy, and where the toys are hidden) were examined in relation to whether they suggested a notation (key, picture, or word), and whether they enacted that strategy by attempting a key. Table 21 presents the proportions and frequencies of these factors by age in years and map condition. The striking finding is that even when children are aware of the things that the map-user needs to know (which, what, and where) and suggest a possible way to communicate these things (a key, picture, or word), they still may fail to attempt a key or make an effective key.

Does own map key attempt relate to selection of correct other person’s map? A chi-square analysis was performed examining whether children attempted a map key in the map-making task with their overall accuracy in selecting and justifying the correct map in the map-evaluation task. Table 22 presents the frequencies (in number of children) of this analysis. Results showed that children who attempted a key on their own map were more likely to select the correct other person’s map, $\chi^2 (1, N = 80) = 20.14, p = .001$. The effect also held if key effectiveness was examined instead of key attempt, $\chi^2 (1, N = 80) = 10.93, p = .001$. 
Inter-relationships Between Age, Interpretive Mind, and General Cognitive Functioning

Next, the inter-relationships among age, interpretive mind, and general cognitive functioning (WISC-vocabulary, matrix reasoning, and memory) were examined. Table 23 presents the correlation matrix for these variables. The strong positive correlation between age and iToM is particularly notable, as it was stronger than the relationship between age and either of the WISC measures. Also, the WISC subtasks related strongly to one another, and interpretive theory of mind showed moderate positive correlations with the WISC subtasks. Finally, the memory measure did not relate significantly to age, iToM or the WISC subtasks.

Intelligence and interpretive mind. Can the positive correlation between age and iToM simply be explained by children’s global intelligence? To address this question, two partial correlation analyses were conducted between age and interpretive theory of mind, one that controlled for WISC-vocabulary scores and another that controlled for WISC-matrix reasoning scores. Raw scores were used in these analyses because standard scores were scaled for age, and of interest was whether an effect remained between age and iToM beyond the contribution of intelligence.

After controlling for WISC-vocabulary, a strong positive correlation remained between age in months and interpretive theory of mind ($r = .57, p = .001$). The same pattern was found controlling for WISC-matrix reasoning instead of vocabulary ($r = .60, p = .001$).

Does iToM Predict Symbol Communication Score?

As described earlier, one of the main goals of this study was to examine whether interpretive theory of mind might serve as a mechanism of symbol understanding. It was predicted that a more sophisticated interpretive mind would result in better performance on the symbol-communicative map tasks. To answer this question initially, two simple regressions were
conducted to evaluate whether children’s interpretive theory of mind scores predicted their symbol communication scores. These analyses were conducted separately for each map condition because it was predicted that iToM would be particularly important to success in the iconic condition.

**Iconic symbols.** In the iconic condition, iToM was a significant predictor of children’s symbol communication scores with an $R^2 = .27, F(1, 37) = 13.67, p = .001$.

**Abstract symbols.** In the abstract condition, iToM was not a significant predictor of children’s symbol communication scores with an $R^2 = .05, F(1, 39) = 2.03, p = .16$.

**Does iToM Uniquely Contribute to Symbol Communication Score Over Age, Global Intelligence and Memory?**

The strongest test of the prediction that iToM serves as a mechanism of symbol understanding is whether it predicts children’s symbol-communication scores uniquely, over and above the contribution of chronological age and general cognitive functioning. To test this question, a stepwise regression was performed for the iconic condition to examine whether the relationship between iToM and symbol communication scores held after accounting for age, intelligence, and memory. Given that iToM was not a significant predictor of symbol communication in the abstract condition, the parallel analysis for the abstract condition tested whether age, intelligence, and memory were better predictors than iToM. In both of these analyses, symbol-communication scores was the outcome variable. Age in months, WISC-vocabulary, WISC-matrix reasoning, and memory were entered on the first level, and iToM was entered on the second level.

**Iconic symbols.** Results for this analysis are presented in Table 24. At the first level of the model, age, WISC-vocabulary, WISC-matrix reasoning and memory as a whole were significant
predictors of children’s symbol-communication scores, $R^2 = .40$, $F (4, 34) = 5.58$, $p = .001$. Within this multiple regression were the significant predictors age in months (standardized $\beta = .53$, $p = .009$) and memory (standardized $\beta = .29$, $p = .036$), but WISC-vocabulary and matrix reasoning contributed negligibly. When iToM was added on Step 2, the R-square increased ($R^2 = .46$) marginally significantly, $p$-change = .056. At the second level, the beta value for age in months dropped below significance ($p = .221$), but memory remained significant (standardized $\beta = .34$, $p = .015$). Interpretive mind was also a significant predictor of children’s symbol-communication scores. The standardized beta value for iToM was $\beta = .35$, $p = .056$.

Abstract symbols. An analogous stepwise regression was conducted for the abstract condition. Results for this analysis are presented in Table 25. At the first level of the model, age, WISC-vocabulary, WISC-matrix reasoning and memory as a whole were significant predictors of symbol communication scores, $R^2 = .34$, $F (4, 36) = 4.69$, $p = .004$. However, none of these individual components at Step 1 contributed significantly. When iToM was added on Step 2, it did not contribute significantly to the prediction, $p$-change = .602, and again, none of the betas for the components contributed significantly to children’s symbol-communication scores.

Do Intelligence and Memory Contribute Uniquely to Symbol Communication Beyond Age?

The previous analyses showed that when used together, age, intelligence and memory predicted children’s symbol communication scores. The next analysis addressed whether the influence of intelligence and memory could be explained by age alone (leaving out iToM entirely for the moment).

Thus, another stepwise regression was performed with age on Step 1, WISC-vocabulary, matrix reasoning, and memory on Step 2, and symbol-communication scores as the outcome variable. This analysis was not split by iconic and abstract symbols because there were no
hypotheses about the differential importance of any of these factors depending on map condition. At the first level with only age in the equation, it significantly predicted children’s symbol communication scores, $R^2 = .23$, $F (1, 78) = 22.60, p = .001$. When the WISC subtasks and memory were added on Step 2, the R-square slightly increased ($R^2$ change = .06) but this increase was not significant, $p$-change = .08. However, the overall model remained significantly predictive, $F (4, 75) = 7.70, p = .001$.

Consequently, the last analysis will focus on controlling for age only, as it proved to be the most robust predictive factor across measures.

*An Alternate Approach to Controlling for Age*

To the extent that age was not a perfect predictor of interpretive mind, how might the error in that prediction itself be predictive of children’s symbol communication scores?

*Calculating a predicted versus actual iToM score.* A predicted iToM score was created for each child using the regression equation with age predicting iToM. That equation was interpretive theory of mind = - 4.41 + (.08 * age in months). The residual scores were then calculated between actual and predicted iToM (actual iToM score minus predicted iToM score). This yielded a set of scores (the unstandardized residuals, hereafter called iToM difference scores) ranging from -3.27 to +2.97. A score of 0 indicated that a child’s actual iToM score was equal to that predicted by the overall relationship between age and iToM, a positive score indicated that a child had a more sophisticated iToM score than predicted by their age, and a negative score indicated that a child had a less sophisticated iToM score than predicted by their age.

*Relationship between symbol communication and iToM difference score.* Children’s iToM difference scores were divided into three groups by examining the frequency of scores: the
lowest, under-performing third (-3.27 to -.54), the middle, average-performing third (-.47 to +.30) and the uppermost, high-performing third (+.31 to +2.97). Next, two t-tests were conducted, which compared the symbol-communication scores of the under-performing iToM group to those of the high-performing iToM group. One t-test was conducted for the iconic condition, and another was conducted for the abstract condition. Means and standard deviations for these analyses are presented in Table 26. For the iconic condition, children in the under-performing iToM group had significantly lower symbol-communication scores than did the children in the high-performing iToM group (means 6.3 versus 9.3, respectively), \(t(26) = -2.03, p = .05\). For the abstract condition, there was not a significant difference in children’s symbol-communication scores between under-performing and high-performing iToM groups (means 9.1 vs. 8.6, respectively).

Examination of the means in Table 26 shows that the under-performing iToM children (n = 11) scored at particularly low levels for symbol-communication relative to the scores in the five other cells. Examining this effect by the characteristics of individual children who fell within the under-performing iToM group, there was a range of ages (two 6-year-olds, three 7-year-olds, two 8-year-olds, four 9-year-olds) and sex (6 girls, 5 boys). In the knowledge probes, 8 children suggested that they could make a notation (key, word or picture) to communicate to Lynn, but only 5 attempted a key. Four of the children who attempted a key did so after hiding was complete, and only one child created a key during the hiding process. In contrast, 4 children relied exclusively on resemblance as a strategy to communicate meaning. Only one child within this group commented on resemblance as well as suggested and attempted a key. Finally, as a group, these 11 children’s WISC-vocabulary and matrix reasoning scaled scores were higher (11.6 and 11.5, respectively) than the expected scaled score 10.
Chapter 4
Discussion

Overview

The discussion of results will follow this general structure of the three sets of hypotheses set forth in the research questions, concerning (1) children’s symbol-communicative performance using a map, (2) the relation of performance on the symbol-communicative tasks to interpretive theory of mind, especially for iconic symbols, and (3) whether any effects found in (1) and (2) could be attributed to more general cognitive functioning, namely global intelligence and memory.

Children’s Symbol-Communicative Performance Using a Map

It was predicted that younger children would rely more on symbol resemblance (especially in the iconic condition) and less on notation strategies to communicate meaning to the symbol-user. It was also predicted that older children would show greater awareness of the information that needed to be communicated to the symbol-user, and that they would be more successful in formulating and enacting a strategy to do so (using words, pictures, or a key).

The curse of iconicity? The most surprising finding in children’s performance on the map tasks was that relatively few children explicitly and exclusively used symbol resemblance to communicate to the symbol-user. Of the 16 children in the iconic condition and 11 children in the abstract condition who explicitly commented on the resemblance between symbol and referent, only 6 and 3 (respectively) used resemblance exclusively (instead of written notations) as a way to communicate meaning to the symbol-user. This is surprising in light of children’s beliefs in iconicity and insistence on iconic symbols in the early elementary school years (Beilin & Pearlman, 1991; Lehrer & Schaulbe, 2002; Liben & Downs, 1989; Myers & Liben, in press).
Although the relative iconicity of the symbol conditions was validated in both adult and child testing, it was also surprising that children “saw” iconicity in the abstract symbols at all. Anecdotally, some children selected a blue abstract symbol to represent the purple toothbrush (reasoning that purple and blue were related colors) or used an abstract symbol with dots to represent the koosh ball (reasoning that the ends of the hairs might resemble the dots if seen from far away). Thus, although the study was designed to discourage iconic resemblance in the abstract condition, children were adept at justifying their symbol choice based on a complex narrative of symbol-referent relatedness.

Notably, the base room map provided to children was, itself, iconic. Consequently, this iconic map of the room could have set up children’s expectations about symbol “transparency” from the start of the task. However, given children’s infrequent exclusive use of symbol resemblance to convey the assignment of meaning, this effect seems unlikely. The iconic map was used in order to facilitate children’s ability to see the correspondence between the symbols on the map and the actual furniture and layout of the room. Although (as discussed in the literature review) iconicity does not always help children, in actuality color iconicity is routinely used in maps, and particularly in maps created for children. The map of the room was therefore similar to other maps children had likely been exposed to already. Furthermore (and unlike the referents used in the map-making task), the size and color of each piece of furniture in the room were unique. For example, the black couch was the only rectangular black object in the room, so that the color, shape, and placement of the furniture symbols (which had no alternative referents to which these features might be likely to refer) created a situation in which children could readily recognize the referents of the symbols by their color, shape and relative position in the room. Notably, this was not the case for the referent toys used in map-making – the iconic
symbols conveyed some information about the referent (i.e., Iconic Symbol G conveyed roundness and spikiness) but not everything (i.e., to which round and spiky toy does it refer?).

Moreover, the context of the map-making task was particularly important in this study, namely that moderate symbol-referent iconicity was designed to be insufficient to communicate symbol meaning. In another context in which the koosh ball was the only round and spiky referent, resemblance alone may have been sufficient, insofar as everyone – map-maker and map-user alike – may reasonably be assumed to universally select and interpret a specific toy as the referent of a particular symbol. Thus, particularly important to the task was the interaction between the specific study context (i.e., the target and distracter referents) and children’s need to communicate symbol meaning. Given the low proportions of children who received credit for recognizing that Lynn would need to know which toys were selected, it is possible that children did not sufficiently attend to the distracter referents.

It is worth mentioning that in some contexts, iconic resemblance may indeed be adequate for a symbol-user to identify the referent of a symbol. Of course, resemblance is not sufficient to establish the representational link (the intentional assignment of meaning by a creator is critical), but in some contexts, resemblance may be sufficient for a symbol-user to identify the representational link that is intended by a creator. That is, in a context in which there are no alternative iconic interpretations available for a particular symbol, resemblance between a referent and potential symbol can be one of many cues indicating to a symbol-user that the symbol was intended to stand for the referent it resembles. However, in some contexts (as in the present study), iconicity alone does not provide adequate information. Part of the developmental process for children is to recognize and distinguish between contexts in which iconicity may be sufficient for a particular purpose, and contexts in which additional information needs to be
transmitted. The results from the present study suggest that 6- to 9-year-olds have made some strides toward unpacking this complex issue. Future research should further elucidate whether these results are specific to this experimental context or whether they reflect a more general pattern of symbol understanding that is typical of children in this age range.

Another possible reason for these surprising findings regarding symbol iconicity is that the map-making task began with a planning phase in which children were explicitly asked to pick out symbols (stickers) from an array of choices. Such a context may have accentuated to children the “universe” of possible symbol-referent choices (within the context of this task), thus making them more attuned to the selective, intentional nature of their symbol choice. That is, given the method, there was no opportunity for the child to remain oblivious to the intentional symbol-selection process, because the very act of having to choose among many possibilities may have served to alert the child to the availability of the multiple representational possibilities for a single symbol. Because they had to consciously pick symbols (stickers) and perhaps had to struggle with that selection, they may have been primed to be aware of the issues of selectivity and intentionality. If this was the case, perhaps children were especially aware that their symbol choice would not be clear to a symbol-user on the basis of resemblance alone. Given this possibility, then the present study provides a conservative test of the hypotheses concerning interpretive mind and symbol communication, and the effects found are likely to be more robust in a context in which the selective, intentional nature of symbols is not highlighted.

Whether or not children attempted a map key was another measure of children’s beliefs in symbol transparency to a symbol-user. This measure was less explicit in that it did not rely on children’s verbal responses to the knowledge probe questions, but rather examined the strategies that they enacted to communicate to the symbol-user. Older children were more likely than
younger children to attempt a map key, but there was no difference between conditions (.64 iconic, .68 abstract). One possibility is that the substantial proportion of children who did not attempt a key (.33 of children) relied on symbol resemblance but did not explicitly state it in response to the knowledge probe questions. Another possibility is that younger children indiscriminately accept any degree of symbol-referent resemblance (for 6-year-olds, .10 in the iconic condition and .20 in the abstract condition commented on resemblance) whereas older children have firmly established beliefs about what “counts” as iconicity (for 9-year-olds, .80 in the iconic condition commented on resemblance whereas only .11 in the abstract condition did so).

Knowledge of map-user and communication of symbol meaning. Other facets of children’s performance followed the predicted pattern. In response to the knowledge probes, older children were more likely to explicitly state that the map-user would need to know what symbols stood for each toy, to suggest a key as a way to communicate that information, and to enact that suggestion by attempting a map key. In contrast, younger children were more likely to convey less specific, more global things about the map and representation – for example, that stickers stand for toys in general, but lacking the specification of precisely which stickers stood for which toys. In fact, several of these children even wrote the statement “stickers stand for toys” on their maps as a form of global key (see Figure 10). Younger children were also more likely to have trouble reading their own symbols, as exhibited by their forgetfulness mid-task about which symbols they had chosen to stand for particular toys. This occurred more often in the abstract condition, but did not lead to increased map key attempts for younger children as a group.
These results support the conclusion that symbol understanding develops gradually and unevenly across components of success. Even though children may be aware that some concepts or instructions need to be conveyed to a map-user, they may not succeed at transmitting all of the necessary information. For example, a child could know that symbols show *where* things are hidden but fail to recognize that the symbols also conveyed *which* toys were selected. Or, a child could succeed at responding that the symbol-user needs to know *which* toys were selected, *what* symbols stand for each object, and *where* they were hidden, but not attempt a key to communicate these concepts. Furthermore, it is interesting that fundamental ideas about representation (i.e., that the map stands for the room, that stickers stand for objects) are not yet taken for granted by younger children, but seem so intuitive for older children that it does not occur to them to communicate these ideas to a map-user.

Consistent with previous research (Myers & Liben, in press), children’s map keys showed a qualitative shift with age, such that older children made more categorical keys (i.e., using one type of symbol to represent one class of referents) whereas younger children made more redundant keys (i.e., specifying the same symbol-referent link multiple times). This shows that with age, children become more sensitive to the notion that symbols can represent *ideas* (i.e., multiple objects can be categorized and represented by a single symbol) rather than *individual objects* (i.e., each object needs a unique symbol). This is a step in the direction of mature symbol understanding, as our ability to use symbols flexibly would be compromised if we were only capable of conceiving of symbol-referent links as one-to-one. Moreover, perhaps the increased use of categorical keys with age is part of the more general tendency to categorize the world more systematically and flexibly (Piaget, 1970).
Unique to this study was the link between children’s own map-making and their evaluation of maps created by other people. Children who attempted a map key themselves were more likely to recognize and correctly explain when another person had done the same, and older children were practically at ceiling for selecting and explaining the correct other person’s map. Furthermore, the quality of children’s reasons improved with age. Younger children could succeed on the task by characterizing a key as a “name or label” (thus de-emphasizing the representational nature of a key), whereas older children provided more higher-level reasons: more references to the fact that a map with a key tells you what symbols mean, more references to the knowledge state of the symbol-user or creator, and more references to the idea that multiple symbols could stand for a particular referent.

**Does Interpretive Mind Matter to Symbol Development?**

Consistent with previous work (Carpendale & Chandler, 1996; Lalonde & Chandler, 2002), children’s performance on the droodle and ambiguous figures tasks improved with age. Of primary interest to the present study was whether interpretive theory of mind (iToM) functioned as a mechanism of symbol understanding. It was predicted that iToM should be particularly relevant to success in the iconic symbol condition. Children with a more sophisticated interpretive theory of mind should be especially sensitive to the fact that although iconic symbols conveyed some information about the referent, resemblance alone was not sufficient for the map-user. Two sets of analyses bear on this question – the regressions and the residuals analysis.

First, the regression analyses provided the strongest evidence for the importance of interpretive theory of mind to symbol development. In the iconic condition, iToM uniquely contributed to children’s overall symbol-communication scores beyond the contribution of age,
intelligence, and memory. Together, the predictors accounted for 46% of the variance in children’s symbol-communication scores. This finding is particularly remarkable given the strength of the relationship between symbol communication and the control variables, which had already accounted for 40% of the variance before iToM was added to the model. However, this was only the case in the iconic condition. In the abstract condition, iToM was not a significant predictor of symbol-communication, and furthermore, age, intelligence and memory were less strong predictors.

Second, the residual analyses examined whether the error in the prediction of age to interpretive mind would itself be predictive of children’s symbol communication score. The high-performing iToM children were those who had more sophisticated iToM than predicted by their age, whereas the under-performing iToM children were those who had less sophisticated iToM than predicted by their age. When examined separately for the iconic and abstract conditions, the low-performing iToM group performed significantly worse on symbol-communication in the iconic condition than did the high-performing iToM group. There was no difference between iToM groups in the abstract condition.

Age and interpretive mind were highly correlated (.66), so given this large overlap, it is unclear what drives what developmentally. Is interpretive mind responsible for some portion of the age effect? Or is chronological age responsible for the iToM effect? This question can be speculated on from the current data, but is best addressed longitudinally. Nevertheless, given that chronological age itself is not a process that explains performance (but is only a marker of developmental change), it seems reasonable to propose that children’s developing interpretive theory of mind is one process partially responsible for driving the many age effects found in the present study.
Are Smarter Children Just Smarter?

It was predicted that intelligence and memory may account for some, but not all, effects otherwise attributed to age and interpretive theory of mind. The regression analyses which were already discussed shed some light on this question. In neither the iconic or abstract condition did either WISC scale (vocabulary or matrix reasoning) contribute significantly to the model.

Partial correlation analyses were also conducted to examine whether holding intelligence constant would eliminate the correlation between age and interpretive theory of mind. The pattern of results discussed below is identical whether WISC-matrix reasoning or vocabulary scores are the controlling factor. The most striking result within this set of analyses is that even after intelligence is controlled for, the relationship between age and iToM remains. The magnitude of the correlation is somewhat smaller (.66 uncontrolled versus .57 or .60, depending on which WISC scale is the controlling factor), but the relationship between age and iToM remains strong and significant. This suggests that iToM is a separate developing process from children’s general intelligence, an exciting idea that contributes to the literature showing a link between theory of mind and other cognitive processes, such as executive functioning and language ability (Flavell, 2004).

Study Limitations

Limitations of interpretive mind measures. Although the expected age effects on the droodle and ambiguous figures tasks were found, and although iToM functioned in many ways as predicted, there are limitations of the measures used to assess interpretive mind. As a scale, the droodle and ambiguous figures items had a poor Cronbach’s alpha, although the seven items functioned better together than if any one of them had been dropped. Also, the alpha was not
better even if scores were examined within tasks instead of summing across the droodle and ambiguous figures tasks.

Furthermore, the interpretive mind tasks are limited in their utility because they ask children to speculate on others’ responses to stimuli with little to no information about those people. One could argue that the most interpretive response in these tasks is to say “I don’t know what they would say, I’m not them,” and indeed, some children in the present study provided this response. In fact, one possible cause of the low reliability could be that the current coding system collapses across potentially different kinds of responses. It is clear that an incorrect answer in the ambiguous figures task is to state that it is not possible or reasonable for two people to answer differently. However, it is less clear whether a response that justifies the divergent interpretations without noting the ambiguous nature of the stimulus is qualitatively the same kind of incorrect response (e.g., S# 51, age 6;2, boy, “Yeah that’s ok. Because they think what they want.”). The current conservative scoring for interpretive responses certainly does not overestimate a child’s interpretive capacities and perhaps this is the best course of action given that it is consistent with the current interpretive mind literature. However, this coding system conceivably fails to account for responses that might be better categorized as “transitional” or “ambiguous” (with regard to their interpretiveness), rather than unequivocally wrong. Perhaps there are improved, or at least different ways to score children’s responses to these tasks, which might lead to better internal reliability and perhaps even stronger results.

Nevertheless, the conceptual rationale motivating the measurement of interpretive mind is generally valid: to use one’s knowledge of the mind and the available stimuli to anticipate what a naïve person might think, and to recognize that ambiguous stimuli is likely to result in several different false beliefs about that stimuli. We do this all the time in everyday life, such as
when we give a presentation or write a paper, when we discuss interpersonal conflicts, and generally when we try to communicate with other people. However, the droodle and ambiguous figures tasks are not without their flaws, and the field would do well to assess interpretive theory of mind in several ways rather than to restrict the phenomenon to a few limited measures.

Direction of causality. Although this study has many strengths, it cannot definitively answer whether interpretive theory of mind develops first and is then applied to symbol understanding, whether the sequence occurs in the reverse order, or whether there is a bi-directional influence between the two processes. A longitudinal design would be best suited to examining whether interpretive theory of mind comes online first and is then recruited for symbol understanding, whether symbol understanding informs interpretive theory of mind, or whether they are co-constituting processes. However, it is clear from the present study that the processes are associated, and future research should elucidate the process by which this relationship unfolds.

Future Directions

Audience assessment as a function of symbol-user’s knowledge. In the present study, the children were given almost no information about the map-user. They knew only that she was another experimenter for the study, who would be perceived to be knowledgeable about the study and generally proficient at understanding symbols. Anecdotally, some children asked for more information about Lynn, asking anything from basic information (i.e., Does she know how to get from the sidewalk to this room?) to more complex information (i.e., Is she an adult or a child? Does she know how to read? Has she done this before, has she read kids’ maps before? What does she call these [pointing to koosh ball referents]?). Occasionally children would also
ask for additional information about the two people depicted for the droodles and ambiguous figures (i.e., Have they seen these pictures before?)

It would be interesting to assess whether children adapt their notations to match the cognitive capacities of the intended symbol recipient. Would characteristics of the symbol-user impact children’s notations to communicate to that person? If participants were told that Lynn was a young child instead of an adult, would their map notations have been different? Perhaps children’s notations might have been less complex, or used redundancy purposefully to ensure that she understood the symbol-referent link. If they were told that Lynn was a child who cannot yet read, would participants show sensitivity to her illiteracy, perhaps by using pictures instead of words? More interestingly, it would be revealing about children’s understanding of the mind if children did not make these adaptations. If children persisted in using words to communicate to a symbol-user who cannot read, this would suggest an inability to take the perspective of that person.

_Ineffective symbol communication_. The complimentary roles of being both symbol-creator and symbol-user have been hypothesized as important contributors to symbolic development (Liben, 1999). The more experience a child has in _creating_ a symbol, the more effective that child should be when _using_ symbols and vice versa. Thus, it would be interesting to assess how an inability to _understand_ someone else’s symbol impacts children’s performance when _creating_ their own symbols. Consider the outcome if the present study had begun with the map-evaluation task, which clearly contrasts an effective communicative symbol with an ineffective one. Having been unable to read the no-key map, left to merely guess what the symbol-user meant to convey, would children have been more likely to include a key in their own map? Would they call upon their own experiences as the symbol-user of an ineffective
representation to inform the effectiveness of their own representations? Of course, a study assessing this question would need to cross domains (i.e., drawings versus maps) – if children both evaluated and created representations within the domain of maps, they could include a key just because the other person’s map had, without considering \textit{why} the key was useful, or \textit{how} it helped them.

\textit{Symbol communication in a different context}. Indeed, although the advantage for this research of using the symbolic medium of a map key is that there is a conventional way (i.e., the map key) to communicate meaning, this could also be a limitation. That is, sometimes it may be unclear whether children really understand \textit{what} a map key does, \textit{why} it is important, and \textit{how} it serves to communicate meaning. At some point do children just know that maps should have keys and abide by this unthinkingly? There were some older children in the present study who immediately began to make a map key during the map planning process, before the experimenter had completed the instructions. This raises the question, were they doing so automatically because they had merely learned that “maps have keys, but I don’t know why,” or were they doing it as a result of thinking about what the symbol-user would need to know? In that sense, more interesting are the younger children who likely have no formal schooling about maps yet, but who essentially invented their own strategy to communicate meaning (i.e., writing within the map instead of in the margin) after thinking about what the symbol-user needed to know. Thus, future research would do well to compare a novel symbol-communicative context with a map context to examine whether children understand what a map key functions to do, and whether they can invent a strategy to communicate meaning outside of that familiar context.
Conclusion

In summary, this study shows that although children understand some things about symbols relatively early (i.e., duality in toddlerhood), they master concepts about assignment of meaning and communication with symbols much later. Moreover, this study underscores that development is gradual in nature and uneven across components of success. Even though children may be aware that some concepts or instructions need to be conveyed to a symbol-user, they may not succeed at transmitting all of the necessary information. Finally, this study provides evidence that one contributing factor to sophisticated symbol understanding is the capacity to understand that someone else’s interpretation of the same symbol may be different from one’s own, even though the child as the symbol-creator may see this link as obvious and transparent. This constructive understanding of the mind is a mechanism of symbol understanding over and above the contributions of age, intelligence and memory.

“Symbols are not proxy for their objects, but are vehicles for the conception of objects…In talking about things we have conceptions of them, not the things themselves; and it is the conceptions, not the things, that symbols directly ‘mean.’ ” (Langer, 1957, p. 61). Just as Langer emphasized many years ago, this study shows that elementary school-aged children gradually come to understand that graphic symbols do not have inherent, fixed meaning, but rather reflect the intentions and decisions of the people who create them.
REFERENCES


APPENDIX A: Tables and Figures

Table 1: Hierarchical list of tasks and variables coded from them

**Map-Making Task**

**Map Planning & Pre-Knowledge Probes**
Information the symbol-user needs to know
- Which
- What
- Where
Verbally stated strategy to communicate which-what-where
- Global
- Picture
- Word
- Resemblance
- Key

**Map-Making**
Map keys
- Categorical use of symbols
- Key attempt
- Key effectiveness
- Key strategy (categorical, redundant, modification, global)
- Trouble reading own symbols

**Post Map-Making Knowledge Probes**
Information the symbol-user needs to know
- Which
- What
- Where
Verbally strategy stated to communicate which-what-where
- Global
- Picture
- Word
- Resemblance
- Key

**Iconicity Validation Task**
Agreement for iconic symbols
Agreement for abstract symbols

**Map-Evaluation Task**
Correct map selected and justified referencing key
- Overall accuracy
Reasons when justifying map choice
- I did that
- Name or label
- Key
- What
- Where
Multiple Knowledge

Interpretive Theory of Mind Measures

Summary score
Droodles, for each of the 3 items (butterfly, turtle, chicken):
Response pair: interpretive or non-interpretive
Person 1: reality, contamination, don’t know, or false belief
Person 2: reality, contamination, don’t know, or false belief
Ambiguous Figures, for each of the 2 items (duck/rabbit, faces/vase):
Prediction
Explanation

Validation of ambiguousness of droodle restricted views

General Cognitive Functioning

WISC-Matrix Reasoning
Raw score
Standard score
WISC-Vocabulary
Raw score
Standard score
Memory for Hidden Objects
Number correct
<table>
<thead>
<tr>
<th>Question Asked Prior to Response</th>
<th>Illustrative Sample Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Which</strong></td>
<td></td>
</tr>
<tr>
<td>Will Lynn know which toys were hidden? (question #2, before hiding)</td>
<td>Yes because these [the stickers child chose] will tell her which toys we hid. (S# 55 – 6;2 / A /M)</td>
</tr>
<tr>
<td>Will Lynn know what the stickers mean? (question #4, after hiding)</td>
<td>Ummm most of them. She might not be sure about the blue [sticker] cause it does look like this [picks another blue toy out of the toy box] (S# 73 – 8;5 / 1 / F)</td>
</tr>
<tr>
<td><strong>What</strong></td>
<td></td>
</tr>
<tr>
<td>What will Lynn need to know to set up the finding game the exact same way as we have? (question #3, before hiding)</td>
<td>These are the toothbrush [iconic symbol M] cause they look like them and these are the balls [iconic symbol G] and these [points to slinkies] are these [iconic symbol E] and these three [points to tubes] are these [iconic symbol D]. (S#15 – 9;9 / 1 / M)</td>
</tr>
<tr>
<td>Will Lynn know which toys were hidden? (question #2, after hiding)</td>
<td>Because I made a map and like under it just in case she doesn't know what it is, it says what it is… [then in response to #5, child said the following] After I put all of the stickers on it I put what it means, what like the sticker means. (S#65 – 8;0 / A / F)</td>
</tr>
<tr>
<td><strong>Where</strong></td>
<td></td>
</tr>
<tr>
<td>Will she know what the stickers mean? (question #4, before hiding)</td>
<td>Umm (pause) yeah. (E: ok tell me more about that) She'll know where the toys are because the sticker will be where it was. (S# 74 –8;2 / A / F)</td>
</tr>
<tr>
<td>What will Lynn need to know to set up the hiding game the same way as we have? (question #3, after hiding)</td>
<td>Well she'll look at it and then she'll say, &quot;okay, this is a map, so I'll look at the angles of the stuff and I'll see.&quot; Like you know how we hid a hairball behind this pillow, well she'll look at the angle of it, and she'll say, &quot;okay here's the pillow so it must be under there.&quot; And probably if they [the stickers] overlap, they will be right next to each other [in the room], like they look right next to each other, but it's [the map] a bird's eye view. (S# 95 – 7;1 / A / M)</td>
</tr>
</tbody>
</table>

**Notes:** Ages given in number of Years; Months. I = iconic condition, A = abstract condition; M = male, F = female
### Table 3: Coding examples of knowledge probe responses – verbally stated strategies for communicating information to the symbol-user (*global*, *picture*, *word*, *resemblance*, and *key*)

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Definition</th>
<th>Illustrative Sample Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global</strong></td>
<td>Mentioning or describing the need to communicate the most fundamental information to the map user with no further specifics.</td>
<td>Just look at the map. (S# 9 – 9;9 / A M) E: How will Lynn know which toys were hidden? C: I'm gonna put the stickers on the map. (S# 42 – 6;7 / I / M)</td>
</tr>
<tr>
<td><strong>Picture</strong></td>
<td>Mentioning or describing drawing pictures or using markers to color in order to convey meaning</td>
<td>Umm, draw what the ones, the ones that the stickers mean on the paper near the stickers. (S# 16 – 7;0 / I / F)</td>
</tr>
<tr>
<td><strong>Word</strong></td>
<td>Mentioning or describing the need to label with words or letters</td>
<td>Well I think once I put the sticker on I'm gonna stop and write under it. (S# 65 – 8;0 / A / F)</td>
</tr>
<tr>
<td><strong>Resemblance</strong></td>
<td>Mentioning or describing that the resemblance between the symbol and referent will convey meaning to the map user. Coded only if the child was referring to symbols as they were originally presented (i.e., the stickers given to all children in the same map condition but not modified by the child in any way). If the child mentioned coloring, marking on, or changing the stickers in any way this was scored in the other strategies.</td>
<td>Because they [the stickers] look like the items...because like the hairball is the circle with lines and the slinky is a coil (S# 67 – 9;11 / I / M) [She’ll know what the stickers mean] because they look like what they are. (S# 97 –8;0 / I / F)</td>
</tr>
<tr>
<td><strong>Key</strong></td>
<td>Mentioning or describing making a key, or described a key even if she didn’t use the term key.</td>
<td>I could grab an extra sticker of each and it put it down on a piece of paper and write down slinky, ball or whatever (S#90 –8;8 / A / M) A key is basically is like telling someone what is what on paper instead of in your voice. (S# 70 –9;11 / A / F)</td>
</tr>
</tbody>
</table>

*Notes: Ages given in number of Years; Months. I = iconic condition, A = abstract condition. M = male, F = female.*
Table 4: Means and standard deviations for proportions of *global*, *picture* and *word* strategies in response to knowledge probes, by age in years

<table>
<thead>
<tr>
<th>Age</th>
<th>Global</th>
<th>Picture</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>.55 (.51)</td>
<td>.20 (.41)</td>
<td>.60 (.52)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>.25 (.44)</td>
<td>.40 (.50)</td>
<td>.65 (.49)</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>.00 (.00)</td>
<td>.33 (.48)</td>
<td>.76 (.44)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>.11 (.32)</td>
<td>.32 (.48)</td>
<td>.58 (.51)</td>
</tr>
<tr>
<td>Combined</td>
<td>.23 (.42)</td>
<td>.31 (.47)</td>
<td>.65 (.48)</td>
</tr>
</tbody>
</table>
Table 5: Means and standard deviations for proportions of *resemblance* strategy in response to knowledge probes, by age in years and map condition

<table>
<thead>
<tr>
<th>Map Condition</th>
<th>Iconic</th>
<th>Abstract</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>.10 (.32)</td>
<td>.20 (.42)</td>
<td>.15 (.37)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>.10 (.32)</td>
<td>.30 (.48)</td>
<td>.20 (.41)</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>.67 (.50)</td>
<td>.42 (.52)</td>
<td>.52 (.52)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>.80 (.42)</td>
<td>.11 (.33)</td>
<td>.47 (.52)</td>
</tr>
<tr>
<td>Combined</td>
<td>.41 (.50)</td>
<td>.27 (.45)</td>
<td>.34 (.48)</td>
</tr>
</tbody>
</table>
Table 6: Means and standard deviations for proportions of key strategy in response to knowledge probes, by age in years and map condition

<table>
<thead>
<tr>
<th>Map Condition</th>
<th>Iconic</th>
<th>Abstract</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>.00 (.00)</td>
<td>.20 (.42)</td>
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<td>7-year-olds</td>
<td>.40 (.52)</td>
<td>.30 (.48)</td>
<td>.35 (.49)</td>
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<td>8-year-olds</td>
<td>.44 (.53)</td>
<td>.50 (.52)</td>
<td>.48 (.51)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>.50 (.53)</td>
<td>.89 (.33)</td>
<td>.68 (.48)</td>
</tr>
<tr>
<td>Combined</td>
<td>.33 (.48)</td>
<td>.46 (.51)</td>
<td>.40 (.49)</td>
</tr>
</tbody>
</table>
Table 7: Frequencies of children’s reliance on *resemblance* only or in conjunction with *map key attempt*

<table>
<thead>
<tr>
<th></th>
<th>Resemblance Only</th>
<th>Resemblance with Key Attempted</th>
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<tbody>
<tr>
<td><strong>Iconic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 &amp; 7-year-olds</td>
<td>2</td>
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<td>8 &amp; 9-year-olds</td>
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<td>10</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 &amp; 7-year-olds</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8 &amp; 9-year-olds</td>
<td>1</td>
<td>5</td>
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</table>
Table 8: Means and standard deviations for *categorical use of map symbols*, by age in years and map condition

<table>
<thead>
<tr>
<th>Map Condition</th>
<th>Iconic</th>
<th>Abstract</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>0.30 (.48)</td>
<td>0.80 (.42)</td>
<td>0.55 (.51)</td>
</tr>
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<td>7-year-olds</td>
<td>0.70 (.48)</td>
<td>0.40 (.52)</td>
<td>0.55 (.51)</td>
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<td>8-year-olds</td>
<td>1.0 (0)</td>
<td>0.58 (.52)</td>
<td>0.76 (.44)</td>
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<tr>
<td>9-year-olds</td>
<td>1.0 (0)</td>
<td>0.78 (.44)</td>
<td>0.89 (.32)</td>
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<tr>
<td>Combined</td>
<td>0.74 (.44)</td>
<td>0.63 (.49)</td>
<td>0.69 (.47)</td>
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</table>
Table 9: Means and standard deviations for map key attempt, by age in years and map condition

<table>
<thead>
<tr>
<th>Map Condition</th>
<th>Iconic</th>
<th>Abstract</th>
<th>Combined</th>
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<tbody>
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<td>6-year-olds</td>
<td>.40 (.52)</td>
<td>.40 (.52)</td>
<td>.40 (.52)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>.67 (.50)</td>
<td>.70 (.48)</td>
<td>.68 (.48)</td>
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<tr>
<td>8-year-olds</td>
<td>.67 (.50)</td>
<td>.75 (.45)</td>
<td>.71 (.46)</td>
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<tr>
<td>9-year-olds</td>
<td>.80 (.42)</td>
<td>.89 (.33)</td>
<td>.84 (.38)</td>
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<td>Combined</td>
<td>.64 (.48)</td>
<td>.68 (.47)</td>
<td>.66 (.48)</td>
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</table>
Table 10: Means and standard deviations for trouble reading own symbols, by age in years and map condition

<table>
<thead>
<tr>
<th>Map Condition</th>
<th>Iconic</th>
<th>Abstract</th>
<th>Combined</th>
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<tbody>
<tr>
<td>6-year-olds</td>
<td>.20 (.42)</td>
<td>.30 (.48)</td>
<td>.25 (.44)</td>
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<td>7-year-olds</td>
<td>.10 (.32)</td>
<td>.20 (.42)</td>
<td>.15 (.37)</td>
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<tr>
<td>8-year-olds</td>
<td>.11 (.33)</td>
<td>.33 (.49)</td>
<td>.24 (.44)</td>
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<td>9-year-olds</td>
<td>.00 (.00)</td>
<td>.22 (.44)</td>
<td>.11 (.32)</td>
</tr>
<tr>
<td>Combined</td>
<td>.10 (.31)</td>
<td>.27 (.45)</td>
<td>.19 (.39)</td>
</tr>
</tbody>
</table>
Table 11: Means and standard deviations for proportions for *map-evaluation task overall accuracy*, by age in years and map condition

<table>
<thead>
<tr>
<th>Age</th>
<th>Iconic</th>
<th>Abstract</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>.40 (.52)</td>
<td>.50 (.53)</td>
<td>.45 (.51)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>.90 (.32)</td>
<td>.80 (.42)</td>
<td>.85 (.37)</td>
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<td>8-year-olds</td>
<td>.92 (.29)</td>
<td>.78 (.44)</td>
<td>.86 (.36)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>1.00 (0)</td>
<td>.90 (.32)</td>
<td>.95 (.23)</td>
</tr>
<tr>
<td>Combined</td>
<td>.80 (.40)</td>
<td>.74 (.44)</td>
<td>.78 (.42)</td>
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<tr>
<td>Strategy</td>
<td>Definition</td>
<td>Illustrative Sample Response</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><em>I did that</em></td>
<td>Referenced the child’s own previous map-making</td>
<td>Because it has stuff, like it has what I did kind of. (S# 20; 8;1 / I / F)</td>
<td></td>
</tr>
<tr>
<td><em>Name or label</em></td>
<td>Referred to the key but characterized it as a name, answer, label, writing, or list</td>
<td>Because that one doesn’t have answers [map without key] and this one does [map with key]. (S# 30 – 7;7 / I / M)</td>
<td></td>
</tr>
<tr>
<td><em>Key</em></td>
<td>Referred to the key explicitly by pointing to it or naming the word “key”</td>
<td>It’s because there’s this little map that says all of the words. (S# 3 – 7;4 / I / M)</td>
<td></td>
</tr>
<tr>
<td><em>What</em></td>
<td>Acknowledged that the map with the key tells what the stickers mean</td>
<td>It has all the signs on it, but this one doesn’t tell what the signs, you don’t know what it stands for. (S# 30 – 7;7 / I / M)</td>
<td></td>
</tr>
<tr>
<td><em>Where</em></td>
<td>Recognized that the map tells where things are</td>
<td>Here you don’t know what stuff is where. (S# 8 – 9;11 / A / F)</td>
<td></td>
</tr>
<tr>
<td><em>Knowledge</em></td>
<td>Referred to the knowledge of oneself, the symbol-creator, or the symbol-user</td>
<td>If you used this one [map with key], you might think this one [points to symbol] was a candy cane or something, and you would put it in the wrong spot. You could probably guess but maybe that’s not what they wanted. (S# 12 – 9;10 / I / F)</td>
<td></td>
</tr>
<tr>
<td><em>Multiple</em></td>
<td>Explained that there are many possible meanings of symbols or many possible symbols for a single referent</td>
<td>Lots of stickers could mean a yo-yo, you would have no clue what the stickers mean. (S# 22 – 9;11 / A / F)</td>
<td></td>
</tr>
</tbody>
</table>

*Notes:* Ages given in number of Years; Months. I = iconic condition, A = abstract condition. M = male, F = female.
Table 13: Proportions for justifications in the map-evaluation task, by age in years

<table>
<thead>
<tr>
<th>Age Group</th>
<th>I did that</th>
<th>Name or label</th>
<th>Key</th>
<th>What</th>
<th>Where</th>
<th>Knowledge</th>
<th>Multiple</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>0</td>
<td>.30</td>
<td>.30</td>
<td>.30</td>
<td>.15</td>
<td>.15</td>
<td>0</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>.05</td>
<td>.25</td>
<td>.70</td>
<td>.80</td>
<td>.15</td>
<td>.45</td>
<td>0</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>.10</td>
<td>.43</td>
<td>.76</td>
<td>.81</td>
<td>.19</td>
<td>.38</td>
<td>.05</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>0</td>
<td>.37</td>
<td>.68</td>
<td>.90</td>
<td>.26</td>
<td>.58</td>
<td>.16</td>
</tr>
<tr>
<td>Combined</td>
<td>.04</td>
<td>.34</td>
<td>.61</td>
<td>.70</td>
<td>.19</td>
<td>.39</td>
<td>.05</td>
</tr>
</tbody>
</table>
Table 14: Means and standard deviations for the droodle task, by age in years and participant sex

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Female</th>
<th>Male</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>0.73 (0.65)</td>
<td>0.56 (0.73)</td>
<td>0.65 (0.67)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>1.08 (1.17)</td>
<td>1.38 (1.19)</td>
<td>1.20 (1.15)</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>1.17 (1.19)</td>
<td>1.22 (0.83)</td>
<td>1.19 (1.03)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>2.22 (0.97)</td>
<td>2.20 (0.79)</td>
<td>2.21 (0.86)</td>
</tr>
<tr>
<td>Combined</td>
<td>1.25 (1.12)</td>
<td>1.36 (1.05)</td>
<td>1.30 (1.08)</td>
</tr>
</tbody>
</table>
Table 15: Means and standard deviations for the ambiguous figures task, by age in years and participant sex

<table>
<thead>
<tr>
<th>Sex</th>
<th>Female</th>
<th>Male</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>1.0 (0.9)</td>
<td>1.0 (1.0)</td>
<td>1.0 (0.9)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>1.8 (1.4)</td>
<td>1.6 (1.6)</td>
<td>1.8 (1.5)</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>2.0 (1.3)</td>
<td>2.3 (0.9)</td>
<td>2.1 (1.1)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>2.7 (1.1)</td>
<td>2.5 (1.2)</td>
<td>2.6 (1.1)</td>
</tr>
<tr>
<td>Combined</td>
<td>1.8 (1.3)</td>
<td>1.9 (1.3)</td>
<td>1.8 (1.3)</td>
</tr>
</tbody>
</table>
Table 16: Means and standard deviations for the WISC-vocabulary raw scores, by age in years and participant sex

<table>
<thead>
<tr>
<th>Age</th>
<th>Female</th>
<th>Male</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>18.2 (5.0)</td>
<td>20.3 (2.9)</td>
<td>19.2 (4.2)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>26.0 (4.1)</td>
<td>24.5 (7.8)</td>
<td>25.4 (5.7)</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>25.6 (4.8)</td>
<td>33.6 (6.6)</td>
<td>29.0 (6.8)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>31.4 (8.9)</td>
<td>33.0 (8.4)</td>
<td>32.3 (8.4)</td>
</tr>
<tr>
<td>Combined</td>
<td>25.1 (7.2)</td>
<td>28.1 (8.7)</td>
<td>26.4 (8.0)</td>
</tr>
</tbody>
</table>
Table 17: Means and standard deviations for the WISC-vocabulary standard scores, by age in years and participant sex

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>10.1 (2.7)</td>
<td>11.2 (1.6)</td>
<td>10.6 (2.3)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>12.8 (2.8)</td>
<td>11.3 (3.5)</td>
<td>12.2 (3.1)</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>10.7 (3.1)</td>
<td>12.9 (2.9)</td>
<td>11.6 (3.2)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>10.7 (3.4)</td>
<td>11.9 (4.0)</td>
<td>11.3 (3.7)</td>
</tr>
<tr>
<td>Combined</td>
<td>11.1 (3.1)</td>
<td>11.8 (3.1)</td>
<td>11.4 (3.1)</td>
</tr>
</tbody>
</table>
Table 18: Means and standard deviations for the WISC-matrix reasoning raw scores, by age in years and participant sex

<table>
<thead>
<tr>
<th>Sex</th>
<th>Female</th>
<th>Male</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>11.6 (3.6)</td>
<td>12.2 (3.2)</td>
<td>11.9 (3.4)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>17.4 (2.3)</td>
<td>19.1 (5.8)</td>
<td>18.1 (3.8)</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>17.7 (4.7)</td>
<td>21.7 (4.6)</td>
<td>19.4 (5.0)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>18.9 (7.5)</td>
<td>19.8 (4.4)</td>
<td>19.4 (5.9)</td>
</tr>
<tr>
<td>Combined</td>
<td>16.3 (5.3)</td>
<td>18.2 (5.6)</td>
<td>17.2 (5.5)</td>
</tr>
</tbody>
</table>
Table 19: Means and standard deviations for the WISC-matrix reasoning standard scores, by age in years and participant sex

<table>
<thead>
<tr>
<th>Age</th>
<th>Female</th>
<th>Male</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>10.6 (2.3)</td>
<td>11.1 (2.2)</td>
<td>10.9 (2.2)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>12.7 (1.7)</td>
<td>13.4 (3.3)</td>
<td>13.0 (2.4)</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>11.2 (2.9)</td>
<td>12.9 (3.2)</td>
<td>11.9 (3.1)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>10.4 (4.7)</td>
<td>9.4 (3.1)</td>
<td>9.9 (3.9)</td>
</tr>
<tr>
<td>Combined</td>
<td>11.3 (3.0)</td>
<td>11.6 (3.3)</td>
<td>11.4 (3.1)</td>
</tr>
</tbody>
</table>
Table 20: Means and standard deviations for the memory task, by age in years and participant sex

<table>
<thead>
<tr>
<th>Age</th>
<th>Female</th>
<th>Male</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-year-olds</td>
<td>4.9 (2.5)</td>
<td>4.9 (2.0)</td>
<td>4.9 (2.3)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>5.3 (2.6)</td>
<td>7.4 (1.9)</td>
<td>6.2 (2.5)</td>
</tr>
<tr>
<td>8-year-olds</td>
<td>7.6 (2.0)</td>
<td>6.0 (1.6)</td>
<td>6.9 (2.0)</td>
</tr>
<tr>
<td>9-year-olds</td>
<td>6.6 (2.8)</td>
<td>5.4 (2.1)</td>
<td>6.0 (2.4)</td>
</tr>
<tr>
<td>Combined</td>
<td>6.1 (2.6)</td>
<td>5.9 (2.1)</td>
<td>6.0 (2.4)</td>
</tr>
</tbody>
</table>
Table 21: Proportions and frequencies for children’s awareness of map user’s knowledge (\textit{which, what, where}), verbally stated strategies to communicate to map-user (\textit{key, picture, word}), and map keys (\textit{attempted, effective})

<table>
<thead>
<tr>
<th></th>
<th>Total N per cell</th>
<th>Which</th>
<th>What</th>
<th>Where</th>
<th>Suggest Key, Picture or Word</th>
<th>Key Attempted</th>
<th>Key Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>6-year-olds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iconic</td>
<td>10</td>
<td>.15</td>
<td>.45</td>
<td>.75</td>
<td>.65</td>
<td>.40</td>
<td>.20</td>
</tr>
<tr>
<td>Abstract</td>
<td>10</td>
<td>n = 2</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n = 1</td>
<td>5</td>
<td>9</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td><strong>7-year-olds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iconic</td>
<td>10</td>
<td>.20</td>
<td>.65</td>
<td>.65</td>
<td>.85</td>
<td>.65</td>
<td>.60</td>
</tr>
<tr>
<td>Abstract</td>
<td>10</td>
<td>n = 3</td>
<td>7</td>
<td>6</td>
<td>9</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n = 1</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>8-year-olds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iconic</td>
<td>9</td>
<td>.14</td>
<td>.81</td>
<td>.95</td>
<td>.86</td>
<td>.71</td>
<td>.67</td>
</tr>
<tr>
<td>Abstract</td>
<td>12</td>
<td>n = 1</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n = 2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td><strong>9-year-olds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iconic</td>
<td>10</td>
<td>.26</td>
<td>.95</td>
<td>.84</td>
<td>1.0</td>
<td>.84</td>
<td>.79</td>
</tr>
<tr>
<td>Abstract</td>
<td>9</td>
<td>n = 2</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n = 3</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>
Table 22: Frequencies (in number of children) of key attempt by map-evaluation task

<table>
<thead>
<tr>
<th>Key attempt</th>
<th>Not Attempted</th>
<th>Attempted</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map-evaluation task</td>
<td>Incorrect</td>
<td>Correct</td>
<td></td>
</tr>
<tr>
<td>Incorrect</td>
<td>14</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>Correct</td>
<td>4</td>
<td>49</td>
<td>53</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>62</td>
<td></td>
</tr>
</tbody>
</table>


Table 23: Correlation matrix between age, iToM, WISC-vocabulary, WISC-matrix reasoning, and memory

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>iToM</th>
<th>WISC-vocab</th>
<th>WISC-matrix</th>
<th>Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1</td>
<td>.66*</td>
<td>.59*</td>
<td>.48*</td>
<td>.18</td>
</tr>
<tr>
<td>iToM</td>
<td>1</td>
<td>.41*</td>
<td>.35*</td>
<td>.08</td>
<td></td>
</tr>
<tr>
<td>WISC-vocab</td>
<td>1</td>
<td>.56*</td>
<td>.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WISC-matrix</td>
<td>1</td>
<td></td>
<td>.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memory</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *p < .05
Table 24: Stepwise regression predicting symbol communication score for iconic symbols

<table>
<thead>
<tr>
<th>Step, Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>age in months</td>
<td>.14</td>
<td>.05</td>
<td>.53**</td>
</tr>
<tr>
<td>WISC-vocabulary</td>
<td>.03</td>
<td>.09</td>
<td>.07</td>
</tr>
<tr>
<td>WISC-matrix reasoning</td>
<td>-.09</td>
<td>.11</td>
<td>-.13</td>
</tr>
<tr>
<td>memory</td>
<td>.43</td>
<td>.20</td>
<td>.29*</td>
</tr>
<tr>
<td>R² = .40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F (4, 34) = 5.58, p = .001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>age in months</td>
<td>.07</td>
<td>.06</td>
<td>.28, ns</td>
</tr>
<tr>
<td>WISC-vocabulary</td>
<td>.04</td>
<td>.08</td>
<td>.09</td>
</tr>
<tr>
<td>WISC-matrix reasoning</td>
<td>-.11</td>
<td>.10</td>
<td>-.15</td>
</tr>
<tr>
<td>memory</td>
<td>.49</td>
<td>.19</td>
<td>.34**</td>
</tr>
<tr>
<td>interpretive theory of mind</td>
<td>.74</td>
<td>.38</td>
<td>.35*</td>
</tr>
<tr>
<td>ΔR² = .06, p-change = .056</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R² = .46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F (5, 33) = 5.63, p = .001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Final model</strong></td>
<td>R² = .46</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *p < .05  **p < .025
Table 25: Stepwise regression predicting symbol communication score for abstract symbols

<table>
<thead>
<tr>
<th>Step, Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>age in months</td>
<td>.05</td>
<td>.05</td>
<td>.18</td>
</tr>
<tr>
<td>WISC-vocabulary</td>
<td>.14</td>
<td>.10</td>
<td>.29</td>
</tr>
<tr>
<td>WISC-matrix reasoning memory</td>
<td>.16</td>
<td>.14</td>
<td>.23</td>
</tr>
<tr>
<td>memory</td>
<td>-.18</td>
<td>.27</td>
<td>-.10</td>
</tr>
<tr>
<td>R² = .34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F (4, 36) = 4.69, p = .004</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>age in months</td>
<td>.07</td>
<td>.06</td>
<td>.23</td>
</tr>
<tr>
<td>WISC-vocabulary</td>
<td>.15</td>
<td>.10</td>
<td>.30</td>
</tr>
<tr>
<td>WISC-matrix reasoning memory</td>
<td>.16</td>
<td>.14</td>
<td>.23</td>
</tr>
<tr>
<td>memory</td>
<td>-.16</td>
<td>.27</td>
<td>-.09</td>
</tr>
<tr>
<td>interpretive theory of mind</td>
<td>-.23</td>
<td>.43</td>
<td>-.09</td>
</tr>
<tr>
<td>ΔR² = .01, p-change = .602</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R² = .35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F (5, 35) = 3.74, p = .008</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Final model: R² = .35</td>
<td></td>
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</tbody>
</table>

Note: *p < .05  **p < .025
<table>
<thead>
<tr>
<th>iToM Difference</th>
<th>Map Condition</th>
<th>Iconic</th>
<th>Abstract</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underperforming</td>
<td></td>
<td>6.3 (3.4)</td>
<td>9.1 (4.0)</td>
<td>7.8 (4.0)</td>
</tr>
<tr>
<td>Average</td>
<td>Iconic</td>
<td>8.2 (3.5)</td>
<td>8.5 (4.0)</td>
<td>8.4 (3.6)</td>
</tr>
<tr>
<td>Performance</td>
<td>Abstract</td>
<td>9.3 (4.1)</td>
<td>8.6 (4.2)</td>
<td>9.0 (4.1)</td>
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<tr>
<td>High Performing</td>
<td>Combined</td>
<td>8.1 (3.9)</td>
<td>8.7 (4.0)</td>
<td>8.4 (3.9)</td>
</tr>
</tbody>
</table>
**Figure 1: Iconic and abstract symbol sets**

<table>
<thead>
<tr>
<th>Iconic Symbols Available to Children</th>
<th>v.</th>
<th>o.</th>
<th>m.</th>
<th>g.</th>
<th>u.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image" alt="predicted symbol for toothbrush" /></td>
<td><img src="image" alt="predicted symbol for koosh ball" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>k.</td>
<td>w.</td>
<td>e.</td>
<td>i.</td>
<td>h.</td>
<td>a.</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="predicted symbol for slinky" /></td>
<td></td>
<td></td>
<td></td>
<td><img src="image" alt="predicted symbol for tube" /></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abstract Symbols Available to Children</th>
<th>k.</th>
<th>c.</th>
<th>h.</th>
<th>u.</th>
<th>e.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image" alt="predicted symbol" /></td>
<td><img src="image" alt="predicted symbol" /></td>
<td><img src="image" alt="predicted symbol" /></td>
<td><img src="image" alt="predicted symbol" /></td>
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</table>

<table>
<thead>
<tr>
<th>b.</th>
<th>r.</th>
<th>w.</th>
<th>t.</th>
<th>v.</th>
<th>n.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="predicted symbol" /></td>
<td><img src="image" alt="predicted symbol" /></td>
<td><img src="image" alt="predicted symbol" /></td>
<td><img src="image" alt="predicted symbol" /></td>
<td><img src="image" alt="predicted symbol" /></td>
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</tbody>
</table>
Figure 2: Target and distracter referent toys

<table>
<thead>
<tr>
<th>Target Referents</th>
<th>Distracter Referents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koosh Balls</td>
<td>Centipede Bugs</td>
</tr>
<tr>
<td>Slinkies</td>
<td>Coiled Bracelets</td>
</tr>
<tr>
<td>Tubes</td>
<td>Hollow Containers</td>
</tr>
<tr>
<td>Toothbrushes</td>
<td>Combs</td>
</tr>
</tbody>
</table>
Figure 3: Entire toy box as presented to children

Contents of Entire Toy Box
Figure 4: Map-evaluation task stimuli

<table>
<thead>
<tr>
<th></th>
<th>With Key</th>
<th>Without Key</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td><strong>Iconic</strong></td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
</tbody>
</table>
Figure 5: Droodle task stimuli

<table>
<thead>
<tr>
<th>#1: butterfly</th>
<th>Restricted View</th>
<th>Full View</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1" alt="Restricted View" /></td>
<td><img src="image2" alt="Full View" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>#2: turtle</th>
<th>Restricted View</th>
<th>Full View</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image3" alt="Restricted View" /></td>
<td><img src="image4" alt="Full View" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>#3: chicken</th>
<th>Restricted View</th>
<th>Full View</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image5" alt="Restricted View" /></td>
<td><img src="image6" alt="Full View" /></td>
</tr>
</tbody>
</table>
Figure 6: Ambiguous figures task stimuli

Duck / Rabbit

Faces / Vase
Figure 7: Children’s verbally stated strategies for communicating to map-user during knowledge probe questions.
Figure 8: Children’s map key strategies by age
Figure 9: No map keys (Top: S#16 – 7;0 / I / F, Bottom: S#41 – 6;11 / A / F)

Notes: Ages given in number of Years; Months. I = iconic condition, A = abstract condition. M = male, F = female.
Figure 10: Global map keys (S#66 – 6;2 / I / M, Bottom: S#25 – 6;10 / I / F). The yellow writing on the bottom map reads, “The stickers are for where the toys hide”

Notes: Ages given in number of Years; Months. I = iconic condition, A = abstract condition. M = male, F = female.
Figure 11: Categorical map keys (Top: S#7 – 9;9 / I / F,  Bottom: S#79 – 8;1 / A / M)

Notes: Ages given in number of Years; Months. I = iconic condition, A = abstract condition. M = male, F = female.
Figure 12: Redundant map keys (Top: S#55 – 6;2 /A / M, Bottom: S#13 / I / F)

Notes: Ages given in number of Years; Months. I = iconic condition, A = abstract condition. M = male, F = female.
Figure 13: Modification map keys (Top: S#67 – 9;11 / I / M, Bottom: S#11 – 8;0 / A / F)

Notes: Ages given in number of Years; Months. I = iconic condition, A = abstract condition. M = male, F = female.
APPENDIX B: Experiment Script

Parent Consent, Family Information Form and Child Assent

Take parent & child to room 507. Ask parent to sign consent form and **be sure they initial on the back where it asks about consent to archive records and show video in professional contexts.** We keep one copy of the consent, and they get a second copy. Also ask them to fill out yellow family information form.

While parent is doing consent and info form, verbally administer child assent:

Hi, ____ (child’s name) ___, my name is ____ (research assistant’s name) ___. I have a few games today that your ____ (parent/guardian) ____ said it is ok for you to play with me, and I want to tell you about them too. First I am going to hide a bunch of toys around this room, and you will watch and make a map showing someone else how to set up the hiding game the same way. We will also play a puzzle game where you pick the piece that completes the puzzle. Last, we will look at some funny looking drawings and talk about what people think about them. Then at the end, I will have some stickers that you can choose to take home, a Penn State Scientist certificate, and a toy from the toy bag. Also, just to let you know, this camera is going to be recording what we’re doing so I can remember what we did (because I can’t write it all down). Does that sound like something you want to do with me?

*If child seems antsy, tired or not eager to do study, say:*

Anytime you want a walking or stretching break, a water break or a bathroom break, just let me know.

*If child is really combative, disobedient, etc during the study, say:*

Do you want to finish doing the games I have today? If so, then you have to listen to the rules and cooperate, but if not, we can stop. What do you want to do – continue and cooperate or stop?

Introduction to map task

First we are going to be playing a hiding game. It is kind of like hide-and-seek, but we are going to be hiding objects, instead of ourselves.

*Have child sit at table facing away from mirror on side closest to computer (camera has been pre-focused to center on this location). E1 sits across from child at table.*

I have a big box of toys here, see? *(show kid box of toys with brief glance into box so that they can see there are lots of different objects in it)* There are all sorts of toys in here. Look at all these toys! I’m going to pick a few of them for us to use in the hiding game today. I am going to hide 12 of these toys in different places in this room.

*Pull out 12 toys – 4 different categories, and 3 identical items of each, i.e., 3 slinkies, 3 koosh balls, 3 toothbrushes, and 3 tubes – but do not remove them from the box in
categories (e.g., take out 1 slinky, then a tube, then a koosh ball then maybe another slinky and so on) and put them on the table in a random order. Do not cluster the items into categories – for example, don’t put all of the slinkies together. If the child later wants to cluster them into categories, that is fine, but they should be brought out and put on the table randomly. **IMPORTANT – LEAVE THE BOX ON THE TABLE FOR THE ENTIRE MAP-MAKING PROCESS** (so child can see there are other possible referents, and what we’ve selected is only a subset of those).

After that, we’ll do some other things for a little while. Then later on, you get to play the finding game! You will get to find the stuff that we hid and put the toys back in the toy box.

But tomorrow another grownup, Lynn, will want to play the hiding game with another kid. So when Lynn comes in tomorrow, all the toys will be back in the box, because we will have found them and put them back into the toy box. She will want to hide them again just like we did. She will need to know what toys she needs to put in each place. She’ll just need to know what kinds of things are in each place – so for example, it won’t matter which tube she uses, she’ll just need to put any of these tubes we’ve used in a place where any of the tubes were. But it will matter if she puts a slinky where a tube was. So she’ll want to put the same kind of thing in the same place. Do you understand?

So what I want you to do is to make a map that will show her how to set things up in the same way I set them up today.

**Tape map on table in front of child (just taping 2 corners is fine) – make sure it is aligned with the room.**

This is a map of the room we’re in, and I’ve taped it on the table so that it lines up with the room. The map shows the room on paper. Here’s where you are [point], and here’s [point] where I am. The door to the room is there [point].

**Can you point to where the windows over there [point to windows above the air conditioner] are on the map?** [If child needs another example, use the door to 507A (the small room off of 507) as another orientation example so that child gets correspondence between room and map.] Do you have any questions before we move on?

While I hide this stuff, your job is to sit at the table and watch really closely and make the map (point to map in front of child) to show these hidden things, so that Lynn can figure out what kinds of things were hidden and set up the hiding game in the same way.

So, to make the map for Lynn, you get to put stickers on the map in front of you. Here are some stickers that you can use to make your map. [AT THIS POINT, PUT BOX OF EITHER ICONIC OR ABSTRACT STICKERS IN FRONT OF CHILD - DEPENDING ON WHICH CONDITION THEY ARE IN]

**Allow child to take a moment and look at the stickers. Make sure to note if child makes any spontaneous connections or associations about the stickers and the toys.**
There are also some markers you can use if you need them too. Before we start, can you write your name in the corner of your paper with one of the markers?

Remember, your job is to use these [gesture toward stickers and markers] to make a map that will tell Lynn how to set up the hiding game tomorrow the same way we are setting up the hiding game today. Remember, she won’t really need to know the difference between the purple toothbrush and the green one, or between the pink tube and the yellow one – she’ll just need to put a toothbrush or a tube in the same place where we’ve put a similar one. Make sure the map tells her what she needs to know. My job is to hide the toys around the room. Your job is to make the map.

### Map Planning: Choosing Symbol-Referent Match

Before I start to hide things, why don’t you pick the stickers that you want to use on the map to stand for the toys. Here are the toys that I’m going to hide (gesture to toys laid out on table) and here are the stickers you can choose from (gesture to stickers laid out on table). You can move stuff [gesturing to toys and stickers casually] if you want to.

Let me know when you are finished picking the stickers that you want to use for the toys, OK? I’m just going to do being a bit of paper work while you do that.

*Have clip board...with something around that you could be “working” on so you aren’t really breathing down the child’s neck while s/he works, but can record comments and actions easily.*

*Give child time to choose sticker-toy matches. DO NOT answer any questions (i.e., is this supposed to go with this?) or validate their choices (i.e., oh that’s a good sticker for that one).*

*Remember that IF child asks whether it is important to distinguish between the pink koosh ball and the orange one (for example), you can answer that it is NOT important – that Lynn just wants to put a koosh ball where a koosh ball was (it doesn’t matter what color), a toothbrush where a toothbrush was (it doesn’t matter which one), etc.*

*To give praise, you can praise their effort (i.e., you are being so thoughtful when you choose your stickers!) but AVOID giving them feedback about the “goodness” of their choices. This can be tough to resist – be very mindful of what you say here.*

*Make sure to note on E1 sheet any spontaneous reasons child gives for pairing stickers with particular items – but do not probe for these reasons.*

**Child MUST use stickers in some way, or else abstract/iconic condition is meaningless! If child doesn’t want to use stickers, get them to do so by saying:**

“Remember to use a sticker!.....You can use any of the stickers that you want.....Lynn is going to be looking for those stickers, and remember, we want to help her......**Use the stickers to stand for the toys**......(if they just want to use markers:) You can use markers too, but you need to use stickers......
After child is done, ask the following probes:

**Probe 1a**—are you done with planning for your map?

**Probe 2a** – will Lynn know which toys were hidden?

**Probe 3a** – what will she need to know to set up the finding game the exact same way as we have?

**Probe 4a** – will she know what the stickers mean?

**Probe 5a** – in case she has trouble knowing what they mean, is there anything you can do on your map to tell her what the stickers mean? [or past tense if key already made: is there anything you’ve done to tell her what the stickers mean?]

*If child suggests a strategy and looks at you for validation, say, “You should make your map however you think will be best to communicate to Lynn. Do you need to do that, or is it ok as it is?”*

### Making Map

Are you ready to make your map? Make sure to put the stickers in the exact same place as I put the toy in the room. Remember, we want to help Lynn set it up the next hiding game in the same way as we have. This is the first toy; I am going to hide it here.

**BE PRECISE - place toys in exact place shown by experimenter map and by silver star sticker at each hiding place in the room.**

*If child hesitates to put sticker on map, a probe may be offered; for example:*

- Okay, I just hid the toy here so now you need to choose a sticker to show Lynn how to set up the finding game the exact same way tomorrow.
- Remember to use a sticker to show where I just hid the toy!
- I’ll hide the next one after you put your sticker on the map.

This is the second toy; I’m going to hide it here… *continue the above instructions until all items are hidden.*

<table>
<thead>
<tr>
<th>Number</th>
<th>Item</th>
<th>Hiding location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>orange koosh ball (3a)</td>
<td>L side of black couch, under multicolored cushion</td>
</tr>
<tr>
<td>2</td>
<td>big slinky (5a)</td>
<td>Put slinky SIDEWAYS, inside second shelf of the stacks of paper below one-way mirror. Prop up envelope to it so that you can’t see it when looking paper stacker.</td>
</tr>
<tr>
<td>3</td>
<td>blue tube (17a)</td>
<td>Inside the lower shelf of the stacks of paper below the scanner</td>
</tr>
<tr>
<td>4</td>
<td>purple toothbrush (18a)</td>
<td>on bookshelf, inside camera bag (make sure the end isn’t peeking out)</td>
</tr>
<tr>
<td></td>
<td>yellow koosh ball (3b)</td>
<td>behind printer (in the middle, not to one side or the other)</td>
</tr>
<tr>
<td>---</td>
<td>------------------------</td>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td>6</td>
<td>small slinky (5b)</td>
<td>L side of blue couch, under yellow cushion (in the middle underneath the cushion)</td>
</tr>
<tr>
<td>7</td>
<td>yellow tube (17b)</td>
<td>R side of blue couch, under couch cushion (in the middle underneath the cushion)</td>
</tr>
<tr>
<td>8</td>
<td>green toothbrush (18b)</td>
<td>R corner of blue chair, under green pillow (placed flat on the cushion, diagonally in the corner)</td>
</tr>
<tr>
<td>9</td>
<td>pink koosh ball (3c)</td>
<td>middle of blue chair, under cushion (in the middle underneath the cushion)</td>
</tr>
<tr>
<td>10</td>
<td>polka dot slinky (5c)</td>
<td>inside microwave (in the middle)</td>
</tr>
<tr>
<td>11</td>
<td>pink tube (17c)</td>
<td>inside red toy chest</td>
</tr>
<tr>
<td>12</td>
<td>blue toothbrush (18c)</td>
<td>on top of bookshelf (the one beside the toy chest), on L side</td>
</tr>
</tbody>
</table>

After all items hidden, ask probes again:

**Probe 1b**— are you done making your map?

**Probe 2b** – will Lynn know which toys were hidden?

**Probe 3b** – what will she need to know to set up the finding game the exact same way as we have?

**Probe 4b** – will she know what the stickers mean?

**Probe 5b** – in case she has trouble knowing what they mean, is there anything you can do on your map to tell her what the stickers mean? *[or past tense if key is already made: is there anything you’ve done to tell her what the stickers mean?]*

After all 12 objects are hidden, ask child to place map in the manilla envelope marked TO: LYNN and close the metal clasps.

OK, now that you’re all done with your map, why don’t you put it in this envelope to Lynn and we will slide it under her office door.

Then slide the envelope under the door of 508 (be sure to retrieve this after child goes home). This is to prevent the child from wanting to make changes to their map later, i.e., if they didn’t make a key but realize this after the next step of evaluating others’ maps that one is necessary. If they express a desire to change their map later, you can say:

Well it is already in the envelope for Lynn and slid under the door. I don’t have a key to that room.

---

**Evaluating Others’ Map**
Get out 2 pre-made maps – one good with key, one bad without a key. Should match the condition child is in – 2 abstract symbol maps for child in abstract symbol condition, and 2 iconic symbol maps for child in iconic symbol condition.

OK, now that you’re all done making your map, you get to look at other kids’ maps! These are maps of two other kids who did the same thing that you just did, but they were in a different room and had different toys to hide.

You made your map for Lynn, but they made these maps to show me how to set up another game just like what they played. So, they picked stickers to go with the toys, they put their stickers on the map, and they tried to show me which toys were hidden so that I can set up the next hiding game exactly like they did it. This is [map with key = Steve / Sarah]’s map and this is [map without key = Andrew / Jenny]’s map.

Which map do you think I should use? Remember, I have to figure out what kinds of things were hidden so that I can set up the finding game in the exact same way. Which one do you think will help me do that?

Child answers: chooses a map

Why did this one help and the other one wouldn’t? Why would this one help me know how to set up the finding game and the other map wouldn’t?

Child answers: tells why

**BREAK**
For younger children (6, 7 years), say “OK now it is time to take a break!” For older children (8, 9 years), offer a break, but don’t force it if they are doing OK. Walk around the hall, do jumping jacks, run in place, get water, offer bathroom break, etc for a couple of minutes.

**Droodles**

Next we are going to be looking at some pictures called droodles, and I’m going to ask you some questions about them. I am going to show you three different droodles and you are going to answer five questions about each one. There aren’t any right or wrong answers – I just want to know what you think. Do you have any questions before we start?

Show child the example droodle – full picture (with cardstock up).

This is an example of a droodle, it looks just like any other picture right? Well, what is special about this picture is that I am going to cover it up, like this [cover up droodle] so you see it through this window. Then I will ask you some questions about it. Do you understand everything so far?

We are also going to be using some other people to help us. Unfortunately, they could not make it here today so I just have pictures of them.
Introduce child to pictures of experimenters, make sure they are the same sex as child, i.e. Liz and Jen if child is female; Adam and Mike for male.

I’m going to ask you some questions about what you think Liz and Jen [or if child is male: Adam and Mike] would think if they looked at these droodies.

OK, let’s begin. This is our first droodie, it is a picture of a butterfly (DROODLE#1). Now we are going to cover it up, like this.

(1) false belief question: Without looking underneath the top sheet, when Jen / Liz / Adam / Mike sees this picture through the window [POINT] for the first time, what will he/she think it is?

(2) When Jen / Liz / Adam / Mike (second person) sees this picture through the window, what will he/she think it is?

(3a) If child gave same answer for 1 & 2: Why did they think the same thing?

(3b) If child gave different answer for 1 & 2: Why didn’t they think the same thing?

(4a) If child gave same answer for 1 & 2: One child said that (the two people) would think different things, is that OK?

(4b) If child gave different answer for 1 & 2: One child said that (the two people) would think the same thing, is that OK?

(5) Would Jen & Liz / Adam & Mike know it was a (description of full view) from seeing this? [POINT to the restricted view droodie]

Then follow the same process, asking these 5 questions for all 4 droodies.

DROODLE #2: turtle    DROODLE #3: chicken

Ambiguous Figures

The next things we’re going to look at are these other types of pictures. (duck / rabbit and faces / vase).

Just like we did with the droodies, I’m going to ask you questions about what Adam / Mike (Jen / Liz) would think about these.

(ITEM 1: duck-rabbit) What does this first one look like?

Child answers

Yes, I see a [duck or rabbit] too. Do you see something else? (if child does not see other interpretation, prompt with): I see a [other interpretation]. Do you see that too?

Explanation question – When [Adam / Liz] saw this picture, he/she said it was a duck. But when [Mike / Jen] saw it, he/she said it was a rabbit. Is it OK for one person to say it’s a duck and the other to say it’s a rabbit? Why is it ok? [or – Why isn’t it OK?]
**Prediction question** – If we showed this picture to children in another school, would they think it’s a duck or a rabbit, or would you not know what they would think?

**Deviant interpretation question** – What if a 3rd person said it was an elephant? Does that make sense for another person to say that, or does it not make sense? Why / why not?

(ITEM 2: face-vase) What does this second one look like?

*Child answers*

Yes, I see [ 2 faces OR a vase ] too. Do you see something else? *(if child does not see other interpretation, prompt with): I see a [other interpretation]. Do you see that too?*

**Explanation question** – When [Adam / Liz] saw this picture, he/she said it was 2 faces. But when [Mike / Jen] saw it, he/she said it was a vase. Is it OK for one person to say it’s 2 faces and the other to say it’s a vase? Why is it ok? *[or – Why isn’t it OK?]*

**Prediction question** – If we showed this picture to children in another school, would they think it’s 2 faces or a vase, or would you not know what they would think?

**Deviant interpretation question** – What if a 3rd person said it was a couch? Does that make sense for another person to say that, or does it not make sense? Why / why not?

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**Vocabulary and Matrix Reasoning**

Next, I’ll be asking you to do a few more things, like answering questions and completing puzzles. Some of the things may be really easy for you, but others may be really hard. Most people do not answer every question correctly, or finish every item, but please try your best on all the items. Do you have any questions?

*Hold data sheet in your lap or below the table, so that child can’t see whether they are getting items correct or not.*

*If child is getting antsy and you need to save time, skip writing down answers, write SEE VIDEO (or SV) on data sheet, and you can go back through video to get answers.*

*Avoid praise, but demonstrate enthusiasm and interest in the child’s effort by saying..*

You’re working hard…Way to work!…That was a hard one, but this next one may be easier *(if they ask for help)* I want to see how well you can do it for yourself.

*(if they ask if it is a test)* Yes, it is a new and different kind, not like school tests.

***See separate instructions & data sheet kept in binders for each subtest.***
**BREAK**
For younger children (6, 7 years), say “**OK now it is time to take a break!**” For older children (8, 9 years), offer a break, but don’t force it if they are doing OK. Walk around the hall, do jumping jacks, run in place, get water, offer bathroom break, etc for a couple of minutes.

**Finding**

***If time is an issue and/or kid is getting tired/cranky even with breaks, it’s ok to drop this (ASK: “Do you want to find the toys we hid, or do you want to finish? It would be fun to find them, but if you’re tired and want to stop just let me know.”). But, be sure to find toys yourself after they leave (and put them back in the box for the next participant) if you drop the finding portion.***

OK now it’s time to find the stuff that we hid. Do you remember where all 12 things are? We just want to know what kinds of hiding places are easier or harder for kids your age to remember, so don’t worry if you can’t remember all of them, ok? Just do your best.

We’re going to play it a little different than a regular hiding game and I want you to use these card markers to show where all 12 things are hidden first. So you will just put the card on top of the place where you think a tube, slinky, koosh ball or toothbrush is, but you won’t look underneath yet. So for example, if you thought a _________ [PICK A CARD AND SAY THE NAME] was under the table, then you would put the card on top of the table, but you wouldn’t look underneath yet. Then after you’ve marked all of the places, we will look under those places to see if there’s something there!

*After child marks all 12 hiding places, go to each one saying,*

OK you thought there would be a _________ here, is there?”

*Reward child even if they didn’t predict the hiding place correctly, for example:*

Excellent, you remembered the place! (even if they didn’t predict the right toy in it) … That was a hard one to remember, let’s try another one … You found another one, great job!

*To record number correct predictions, hold the cards that child has correctly marked and put the incorrectly marked cards on the table as you “discover” what is hidden where. At the end, the number of cards you’re holding is the number correctly found.*

**Iconicity Validation**
(test abstract symbols if child got iconic ones in map task and vice versa)

The last thing we’re going to do is look at the stuff we hid and a different set of stickers than you used before. This is another set of stickers that some other kids use when they make their maps, and I just want to know how you think they go with the toys, ok?
I have pictures of the things we hid to make this part go faster.

 Give child the photos of the referents. Then lay out the symbols in 2 rows of 6 cards each on the table.

Just like you did before, I want you to choose a sticker that you think goes best with each object. The stickers are up here on the table, and your job is to put the photos under the sticker that you think goes best with it. You can use as many or as few stickers as you like. If you want to use the same sticker for more than one photo, you can just stack them together by putting the 2nd photo on the table below the 1st photo, ok? Do you have any questions?

 After child matches up photos to stickers, you can stack up the piles KEEPING THE ORDER AND PAIRING so that you can write down the child’s answers on the data sheet after the child leaves. Eventually, you will write the letter for each symbol next to the item number for each referent toy (i.e., on the back of the photo for each referent, there should be a number written; and on the back of each symbol card there should be a letter written).

### Conclusion

Wow! You did such a great job today, thank you so much for helping me. Since you were such a great helper today, I am going to give you a Penn State Young Scientist certificate and some stickers to say thanks.

 Write child’s name on certificate, then sign with your name and the date.

You can choose 3-4 stickers to go with your certificate. Thank you for helping me with my project!

It is about time for your mom/dad/caregiver to be here, so let’s go down and wait for him/her.
APPENDIX C: Informed Consent Form

Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: The Mind on Paper: Children's Understanding of the Mind and Graphic Symbols

Principal Investigator: Lynn Liben, Ph.D.
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450 Moore Building
University Park, PA 16802
Phone: 814-863-1718; E-mail: liben@psu.edu

Other Investigator(s): Lauren J. Myers, M.S.
Penn State Department of Psychology
507 Moore Bldg
University Park, PA 16802
Phone: 814-404-6957; E-mail: ljmyers@psu.edu

1. Purpose of the Study: The purpose of this research is to help us learn more about children’s understanding of graphic symbols on maps. We are interested in how children come to understand symbols, such as drawings, photos and map symbols. This study examines how children’s understanding of other people’s minds contributes to their understanding of symbols (for example, drawings and maps).

2. Procedures to be followed: If you agree to allow your child to participate in the research, he or she will first play a hiding game. Your child will be asked to make a map showing the location of hidden objects in the room, with the goal of communicating to another person to tell them how to set up the hiding game in the exact same way. Later in the session, your child will play a finding game, in which he or she will get to look for the objects that we previously hid. Next, your child will look at small, ambiguous portions of larger drawings (through a “window” cut out of cardstock) and will be asked some questions about what other people might think about those images. Then, your child will be asked evaluate other people’s maps, and to choose the one that he or she thinks would communicate information most effectively. Last, we will ask your child about the meaning of some standard vocabulary words and play a pattern-matching game in which your child chooses the missing piece that will complete a picture. The session will be video taped for later coding, transcribing and scoring by research assistants. Data from this study will show how children’s awareness of individuals’ understanding of other people’s minds influences the development of symbol understanding in the elementary school years.

3. Discomforts and Risks: This study involves minimal risk; that is, there are no risks of any kind involved in this study beyond those encountered in everyday life.

4. Benefits: The benefits to your child include participating in a fun and engaging task. Children generally display great enjoyment in this task.

Together with answers of other participants, your child’s answers will be used to draw conclusions about whether children consider another person’s knowledge and intentions when reasoning about maps and drawings. The benefits to society include informing researchers, educators, and parents...
about how children come to understand the nature of cognitive and social processes in normally developing children (including the understanding of symbols, maps, and other people’s beliefs and thoughts).

5. **Duration/Time:** The time to complete the research activities is approximately 1 to 1.5 hours.

6. **Statement of Confidentiality:** Your participation in this research is confidential. Only participant numbers and demographics will be used to refer to your child. Only Dr. Liben, Ms. Myers and their research assistants will have access to your data, recordings and identity. The data will be stored and secured at the Moore Building in a locked and password protected file. The data will be destroyed by seven years after the completion of this project (i.e., December 31, 2014). The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Social Science Institutional Review Board and the PSU Office for Research Protections. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

7. **Right to Ask Questions:** Contact Lynn Liben at 814-863-1718 or Lauren Myers at 814-404-6957 with questions, complaints or concerns about the research. You can also call this number if you feel this study has harmed you. You can also call this number if you have complaints or concerns about this research. If you have questions about your rights as a research participant, or you have concerns or general questions about the research, contact Penn State University’s Office for Research Protections at (814) 865-1775. You may also call this number if you cannot reach the research team or wish to talk to someone else.

8. **Voluntary Participation:** Your decision and your child’s decision to be in this research is voluntary. You and your child can stop at any time. You and your child do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you and your child would receive otherwise.

9. **(a) Maintenance of Recordings:** As explained above in #2, we will be video-recording the session. Your consent to participate in this study thus means that you agree to be videotaped. Please place your initials in front of the statement below if you also consent to have us keep the videotapes for future research.

   I give permission for the recordings of us to be archived for future research projects related to children's cognitive development using maps and other graphic images. *(If you do not initial to show your consent, the tapes will be used only for this research and will be destroyed no later than December 31, 2014.)*

   **(b) Use of Recordings in Professional Settings:** The videotapes collected in this research will be coded by research assistants working on this project so we can study children's symbol- and map-related behaviors responses. Your consent to participate in this study thus means that you agree to have the videotapes coded for this research. Please place your initials in front of the statement below if you also consent to have pieces of the videotapes shown for professional presentations (for example, showing other researchers in the field of child development an example of the study protocol).

   I give permission for my (our) recordings to be shown in professional settings knowing that even though our names will not be mentioned, our faces may be recognized. *(If you do not initial to show your consent, the tapes will be used only for coding purposes, but not shown in professional settings. The tapes will be destroyed no later than December 31, 2014.)*
As a token of our appreciation, your child will receive a few stickers and a Penn State Young Scientist participation certificate at the completion of the study.

You must be 18 years of age or older to provide permission for your child to take part in this research study.

If you agree to allow your child to take part in this research study and the information outlined above, please print your child’s name, sign your name, and indicate the date below.

I give permission for my child, ________________________________, to participate in this research project.

You will be given a copy of this signed and dated consent form for your records.

_________________________________________________________________________  __________________________
Parent/Guardian Signature                                            Date

_________________________________________________________________________  __________________________
Person Obtaining Consent                                            Date
Lauren J. Myers  
Curriculum Vitae

EDUCATION
The Pennsylvania State University, Ph.D., Psychology, 2008  
The Pennsylvania State University, M.S., Psychology, 2005  
Furman University, B.A., Psychology and Music, 2002

HONORS AND AWARDS
Don A. Trumbo Psychology Department Student Research Award, 2007  
College of Liberal Arts Research Office Travel Award, 2006  
Bruce V. Moore Graduate Fellowship in Psychology, 2004 – 2006

PUBLICATIONS


ACADEMIC POSITIONS
2008, spring – 2009  Lecturer, Department of Psychology  
Bryn Mawr College

2002 – 2007  Graduate Research Assistant, Lynn S. Liben  
The Pennsylvania State University

2006  Graduate Research Assistant, Rick O. Gilmore  
The Pennsylvania State University

2005, summer  Graduate Lecturer - Introduction to Child Development  
The Pennsylvania State University, Department of Psychology

2005, spring  Teaching Assistant & Lab Instructor - Research Methods in Psychology  
The Pennsylvania State University, Department of Psychology

2004, fall  Lead Teaching Assistant & Lab Instructor - Intro to Child Development  
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