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Young children's photographic practice: Representation and world knowledge

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YOUNG CHILDREN'S PHOTOGRAPHIC PRACTICE: REPRESENTATION AND WORLD KNOWLEDGE

by

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Abstract

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REPRESENTATION AND WORLD KNOWLEDGE

by

Iris Sroka

Advisor: Professor Harry Beilin

Representation is at the heart of cognitive and developmental psychology, having received attention from Piaget, Vygotsky, and Bruner, who theorized that underlying the different stages in cognitive development were qualitatively different modes of representation. This study was undertaken to explore the early development of representational functioning, taking the position that examining such functioning in action, or practice, offered opportunities to elucidate the child's knowledge of the world in coordination with the child's ability to act on the basis of representations of the world to create photographic artifacts.

Children from three to eight years of age were presented with a photograph of objects arranged on a table in a room and asked to "make a photograph that looks just like this one." In order to solve the problem posed, the child had to have an understanding of the relatively complex representation-object relationship as embodied in the photographic process, or a theory of photographic practice. The design of the study allowed children to express what they understood about the relationship between photographic representations and the world, and about how photographic

representations are constructed.

Older children demonstrated greater mastery at reconstructing the array, capturing the visual content of the target photograph, were more likely to reflect on several criteria simultaneously when judging sameness, and employed more complex strategies to solve the task than younger children. Older children also demonstrated a deeper grasp of the complex relationship between a photograph and the world it represents than younger children. Both what children said needed to be fixed in their photos to achieve a greater degree of match to the TARGET photo and what they actually did to improve the accuracy of subsequent trial photos were significantly associated with age. Finally, what children actually did to correct errors of "match" was more relevant to Experimenter-judged errors of match, more complex, and more successful than what they said was wrong with their photos. The findings on children's talk and action demonstrate that children were better able to express what they knew about the task through their actions in the effort of making their photos than when they had to translate this knowledge into another symbol system and talk about what they knew about the task.

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This work is dedicated to the past:

to my grandparents

Izak and Rosa Sroka

and

Jakub and Sara Stern

who did not survive The War and yet are with me every step I take,

and to my uncle

Beno Sroka

who did, but just could not wait.

This work is, finally, dedicated to the future:

to my son

Adam Riis Sroka Yavner --

Every step I take, with them, I take for you.

May you be and achieve more than I.

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I. INTRODUCTION: Representation

Representation is at the heart of cognitive and developmental psychology, having received attention from Piaget, Vygotsky, and Werner, who theorize that underlying the different stages in cognitive development are qualitatively different modes of representation. Other investigators have explored developmental changes in representational functioning as well (e.g., DeLoache, 1987, 1989a, 1989b; Kosslyn, 1978a, 1978b, 1978c, 1980, 1981; Kosslyn & Pomerantz, 1977; Pylyshyn, 1973, 1981).

Mandler (1983) points out that the term representation has been used in two different senses: in one, as symbolic representation and in the other, as knowledge (what is known) and the way in which it is organized (the structure of that knowledge): "Thus, we can ask whether some piece of information is represented, and we can also ask how it is represented (p. 420)." Mandler suggests that symbolic representation refers to the use of symbols or symbolic productions that stand in relationship to the external world, and, therefore, serves a communicative purpose:

> ...representation as the use of symbols...refers to...symbolic productions that people use to represent (to stand for, to refer to) some aspect of the world or some aspect of their knowledge of the world. In this usage, representation involves a relationship between a symbol and its referent....Because symbols are involved, representation in this sense has a communicative function,

telling someone (or sometimes oneself) that when x is used it is meant to stand for a piece of shared knowledge. (p. 420-421)

Deregowski (1977) also distinguishes the two principal senses in which representation has been used within the domain of developmental psychology: as the things children make in their efforts to represent, and as their internally organized knowledge:

> Representation...has...at least two distinctive meanings. One of these refers to the artifacts created by the child which are intended to represent the external world, the other to the internal schema or frames of reference which the child uses in his interaction with the external world. Unlike the former, the latter are not directly accessible and have to be elicited by a variety of techniques, including analysis of children's artifacts. (p. 219)

The present study was concerned with the early development of representational functioning, taking the position that examining such functioning in the context of "doing it," or practice, offers opportunities to elucidate representation in both senses: the child's knowledge of the world, in coordination with the child's ability to act on the basis of representations of the world to create photographic artifacts. The latter, I suggest, reflect what I will call the child's theory of photographic practice. First, however, we must consider what we know about the kinds of knowledge or

understanding that the child would have to have to constitute such a theory. To do this we need to examine how pictorial representations work, and how the photograph, in particular, works.

II. PICTORIAL REPRESENTATION AND THE PHOTOGRAPH

Pictorial representation is about the relationship between the world or a part of it and the representation of that world or its part. There have been a number of theories proposed to account for how representations are able to be comprehended as depictions of the real world.

Point-projection theory assumes that each ray projected from the picture surface to the perceiver's eye corresponds to a ray projected from the actual world of objects and events (Gibson, 1971). This theory essentially hypothesizes that a picture represents to the extent that the light rays from the picture surface are projected isomorphically to the pattern of projected light rays from the original objects and events represented. The picture is a successful representation of the object to the degree to which this isomorphism exists. In this point-projection theory no learning or coding processes are required for successful perception of the representation. The child need only have the ability to perceive the object directly. In order to perceive either the real-world or its representation the child need only perceive the light rays because the theory also assumes isomorphism of processing of the light rays from both the real-world original and the pictorial source, and attributes no importance to cognitive processes.

Gibson's (1971, 1979) theory of ecological optics is an alternative to point-projection theory. He asserts that the ability to comprehend the representation as a representation of the thing is based on the degree to which the 2-dimensional

pictorial representation recovers and makes available the specifying information of the optic array of the original. Ecological optics assumes that perception of the specifying information of the optic array from the real world and from the representation is direct and unlearned.

In yet another view, symbol theory replaces light rays with symbols as the elements of significance in representing the real world. According to this theory, a picture is composed of symbols that one learns to "read." Symbols in one such view are loosely equated with words, and this renders pictorial representations comparable to written texts. According to symbol theory the picture represents the real world to the degree to which the perceiver understands the language of pictures. Goodman (1968), for example, suggests that meaning is derived from a representation to the degree that the viewer understands the nominal, conventionally prescribed relationship between the object and the representation that comes to stand for that object. Therefore, in order to successfully perceive the representation, symbol theory requires that the child learn the symbol code of pictorial representation used in the culture, and which may vary from culture to culture. In sum, symbol theory suggests that the significance of a representation is based on a code, much the same way as written language represents spoken language. Ultimately, however, symbol theory fails to account for very young children's ability to perceive representations, because they could not yet have learned the conventions of their culture.

A semiotician of the French School, Barthes (1977) proposes that there are two levels at which representations function. On one level, representations fulfill a

symbolic or connotative role that is concerned with the "readability" of the representation based on shared conventions, or a code which, if available to the observer, allows him to access the meaning or message of the representation. The code becomes available through social and historical experience. On another level, the pictorial representation fulfills a denotative function. This refers to the non-coded "looks like" relationship of the representation as "analogon" to the real world. The capacity to process the denotative message is given biologically; we are born able to perceive. The capacity to process the connotative message, on the other hand, is based on the acquisition of the appropriate code.

In a somewhat comparable view, Gombrich (1961, 1982) suggests that the relationship between object and representation is constituted by both conventional and "natural" components. Interpretation enters into understanding the relationship between object and representation and constitutes the perceiver's share in the representational function.

Likewise, the processes of perception and of representation of the world are cognitively endowed for Arnheim (1969, 1971, 1974). Arnheim, fundamentally a Gestaltist, holds that understanding a pictorial representation entails having an organized conception of the world to start with. The principles of structuring, restructuring and organizing that govern cognition also govern the understanding of pictorial representation. Arnheim accords cognition primacy in the representational process, which concerns both the production and the comprehension of representations. With the introduction of cognitive elements into the process of

perception, Arnheim is able to press the notion that knowledge of a medium of representation is an essential factor in the representational process, along with one's knowledge of the real world.

Perception and Representation. The picture-making process represents a certain transformation of the optic array originally available to the eye (or the camera lens). As a result, the optic array from the resultant 2-dimensional pictorial surface to the eye is in several very important ways not the same as the one from the real-world original to the eye. The differences center around three major distinctions between the real-world original and its pictorial representation. First, the range of light intensities from a picture does not match the light intensities from the real world. Second, the viewer is more than likely to assume a viewing point other than the (usually) fixed station point from which the picture was created. (The station point specifies the exact position of the "eye" of the representor, that is, the distance from the represented array, height from the ground, and directional orientation from which the representation was made.) Third, no point-to-point correspondence of brightness or color exists, especially in the case of black and white photographs and caricatures, that is, between the representation and the world it represents. Yet, there is no loss of comprehension when we look at these apparently depleted representations. Clearly, point-projection theory is unable to provide an adequate account of this phenomenon, and though Gibson's notion of ecological optics may offer an adequate account of perception of the world and its representations, it does not account for the

ability to comprehend the relationship between the world and at least partially conventional representations.

Symbolic Optics. What remains clear across these varied accounts is the phenomenon itself, namely, that in the face of rather significant transformations and absences of isomorphisms between the world and its representations there is no commensurate loss of comprehension. It appears that two-dimensional, single-perspective visual arrays available from pictorial representations recover the real world through the perceiver-decoder's application of a formal set of relationships, or set of rules, comprising a symbolic code to operate on pictorial representations. That is, in order to perceive and make sense of a pictorial representation, the viewer might well utilize a "symbolic" optics system that assumes the employment of a Gibsonian ecological optics to get the representation to the eye, and then the application of a symbolic system to comprehend the relationship between the object and the representation of the object. I am assuming an ecological optics underlying perception largely because infant perception research (see, for example, Cohen, DeLoache and Strauss, 1979, and Ruff, 1979) strongly suggests that the ability to decode the optic array from the real world is built in and that the perception-decoding process is direct, though with development an increasing sensitivity to critical features of the environment elaborates this underlying ability.

Formulation of a symbolic system is appealing because this is where we might find development beyond the initial expression or unfolding of direct or maturational

processes. Though the research available (see, for example, Gibson, 1971, 1979, and Jones & Hagen, 1980) indicates that in picturing cultures a representation is very rarely taken as the object itself by adults and older children precisely because it is so unlike the object, the phenomenon of picture comprehension is not fully accounted for by any theory of perception. What remains unexplained begs a developmental explanation. In order to make sense of a representation the perceiver must interpret and comprehend it on two levels: as form, that is, as an object *qua* object (as a piece of paper or other surface with markings on one side of it), and as content, that is as a representation of a specific real-world array. The coordination of these two into a meaningful relationship between them seems ripe for a developmental account.

Past Pictorial Research. In addition to the infant perception research there is a body of picture perception research that argues against a developmental symbolic system model. In Deregowski's (1968) research in picture-naive cultures, adults who had no previous experience with photographs were shown photographs of familiar objects and persons. At first these adults displayed no apparent comprehension of a relationship between the markings on the surface and the object or person represented. The photographs were interacted with only as objects themselves that had markings on the surface, and these markings were seemingly without meaning. However, this initial reaction quickly gave way, usually with only the slightest directive suggestion from the experimenter, to recognition of the person or object in the photograph. In a classic study, Hochberg and Brooks (1962) raised their own newborn baby in a

picture-free environment for 18 months. At that time they showed the child pictures of familiar objects and persons which the baby recognized with little or no hesitation.

DeLoache (1987) and Marzolf and DeLoache (1994), on the other hand, found a very rapid change between two-and-a-half and three years of age in children's knowledge of representation, which they attribute to the differentiation of symbolic knowledge from knowledge of object attributes. Beilin and Pearlman (1991), in a study of children's knowledge of the dual nature of the photograph found that young children confuse the properties of the medium and the properties of the objects depicted in that medium.

The assumption of the research reported here is that ultimately, all forms of representation, in order to work as such, require the "beholder" to grasp the symbolic nature of the relationship between the representation and the thing of which it is a representation. While photographs have often been used in psychology as substitute stimuli for "real" objects, only relatively recently have a few psychologists (e.g., Arnheim, 1974) chosen the photograph itself as the object of psychological analysis.

Photographic Representation. Two things make the photograph a particularly interesting and rich form to examine. First, the photograph is unique among representations in terms of how it "gets done." A photograph, traditionally defined, usually *requires* the real world in an immediate and intimate way: unlike other forms of representation, "it" (the thing or event being represented) must have "been there" for the photograph to have captured it, *and* the maker of the photograph must have

"been there," too. By virtue of its being causally related to the object or event being depicted, it can capture reality in a way other forms of representation cannot. This leads to the second point, which is that people *believe* the photograph can capture reality with particular fidelity (Beilin, 1991). It may be that because the viewer knows the photograph is the product of particular optical, mechanical, and chemical processes the viewer believes it to be objectively realistic, even though the viewer was not present when the photograph was taken.

According to Gibson (1971, 1980), pictures have a dual nature: the surface of the picture offers information about the thing being represented, and it offers information about itself as a representation. It is because the picture specifies information along these two lines that the viewer does not typically take the picture for the thing it is a picture of. In his last statement on picture perception, Gibson says that the specifying information about surfaces, substances, layouts and events are perceived "in the course of development of the young animal by maturation and learning taken together, by *encountering* the surfaces in the habitat, without schooling (1980, xiii)." However, he asserts the process of comprehending the meaning of the marks on the surface that make up the picture is different, and that the process differs from one form of representation to another, suggesting that this relationship of meaning must be learned.

Addressing a different duality in the nature of photography as representation, Arnheim (1974) notes that a viewer perceives the shapes of his world as a direct result of the reflection of light from the objects in that world. He goes on to suggest

that in the case of the photograph some more complex process must go on if the information in the photograph is to be understood:

> ...the shapes are selected, partially transformed, and treated by the picture taker and his optical and chemical equipment. Thus in order to make sense of photographs one must look at them as encounters between physical reality and the creative mind of man - not simply as reflections of that reality in the mind but as a middle ground on which the two formative powers, man and world, meet as equal antagonists and partners, each contributing its particular resources. (p. 159)

Similarly, for Kracauer (in Arnheim, 1974), "the photographic image is a kind of compromise product between physical reality as it impresses its own optical image on the film and the picture maker's ability to select, shape, and organize the raw material" (p. 157). Further, Bazin (in Arnheim, 1974) suggested that "the essential factor of photography "is not to be found in the result achieved but in the way of achieving it" (p. 157).

The question that remains unanswered and that concerns us here, is how a perceiver, equipped with a camera, becomes this "formative power" and the nature of the particular resources brought to the photographic moment by the developing picture-maker. The purpose of the present research was to examine young children's grasp of the relationship between a symbolic representation and what it represents, in the context of photographic practice. The investigation was designed to explore the

child's understanding of symbolization as well as the child's knowledge about the world in the context in which a photograph is made, and how the child coordinates these two cognitive functions.

Children were presented with a photograph of objects arranged in a room and asked to "make a photograph that looks just like this one." This task requires numerous coordinations of symbolic and world knowledge. That is, in order to solve the problem posed, the child has to have an understanding of the relatively complex representation-object relationship as embodied in the photographic process. In short, a correct solution requires some theory, that is, knowledge or awareness, of photographic practice. The photograph's properties, the way in which the photograph is made, and people's beliefs about photographs, make photographs well suited for a developmental investigation of symbolic reasoning.

Specifically, in order to solve the problem of making a photograph that looks just like another photograph, the child has to understand that:

(1) the photograph is a representation/symbol of a real world (i.e., that it stands in symbolic relation to the real world);

(2) the photograph represents the real world in such a way that information specifying the real world may be extracted from it;

(3) the real world represented can be reconstructed from this information;

(4) the real world represented has to be reconstructed in order to be photographed again (unless one photographs the photograph);

(5) the photograph also provides information that specifies itself as an object constructed under particular conditions (for the purposes of this study, primarily station point).

In addition, the child needs to:

(6) reconstruct the real world from the information in the photograph;

(7) assume the specified station point and take the photograph;

(8) assess the accuracy of the photograph taken in terms of the degree to which it re-presents the information that the original photograph presents (about itself and about the world that with which it is in symbolic relationship);

(9) if necessary, make modifications in the real world and/or the photographic conditions, based on the assessment.

Success at this task would indicate that the child has coordinated his knowledge of the symbolic relationship with his knowledge of the world into a theory of photographic practice. Data from the study were analyzed from a developmental point of view in order to gain insight into the understanding of media-specific properties and their relation to the internal (or psychological) system of representation.

III. METHOD

Design

Children participated in three tasks. First was a pre-pre-task designed to provide an introduction to, instructions on the use of, and practice with, the camera (the camera and stimulus materials are described in detail below). The pre-pre-task interview helped establish previous experience with cameras and photographs.

Next, each child participated in a pre-task designed to provide a baseline measure of the child's ability to construct a photo, in which each child was shown a photograph of a single, familiar object and asked to take a photograph "that looks just like this one." Children were asked to reflect on the degree of match between the TARGET photo and their MATCH photo.

Finally, the children participated in the experimental task. In this task, each child was asked to make a photograph "that looks just like" the task photograph presented. The TARGET photo showed objects arranged in a room. The experimental setting was the same room in which the TARGET photo was taken.

The task requires that the child have some understanding that in order to make a photograph that matches an "original" photograph (without photographing the photograph) one must reconstruct the real world of the original. To do so, the child has to determine the relative placement of the objects in the room as specified in the TARGET photo by first either mentally representing or physically assuming the specified station point of the TARGET photo. The child then has to physically arrange the objects, assume a station point with the camera, and take a photograph of

the arranged objects.

After taking a photo, the children were asked to compare their photograph to the TARGET photograph to assess the degree of "match" between them. If not satisfied, the child was encouraged to "try again" (presumably to make modifications and adjustments, e.g., re-arrange the objects or assume another station point) and retake the MATCH photo.

The children were interviewed about all their MATCH photos, how they were like and not like the TARGET photo, and how photos and drawings are different, at the end of the photo-taking session. An observational record of the photo-taking session was also kept.

Subjects

A total of 47 children (28 boys and 19 girls) from the greater New York metropolitan area participated in this study. The children were recruited by a professional recruiter who contacted public pre- and elementary schools in the five boroughs of New York City. With the permission of the administrations, the recruiter distributed announcements about the study. Interested parents contacted the recruiter and were screened to ensure the children represented a range of ethnic and socio-economic backgrounds and family structures, and were between three and eight years old. Five children, three girls and two boys, were 3.0 to 3.11 years old; eleven children, three girls and eight boys, were between 4.0 and 4.11 years old; six children, two girls and four boys, were 5.0 to 5.11 years old; eight children, three

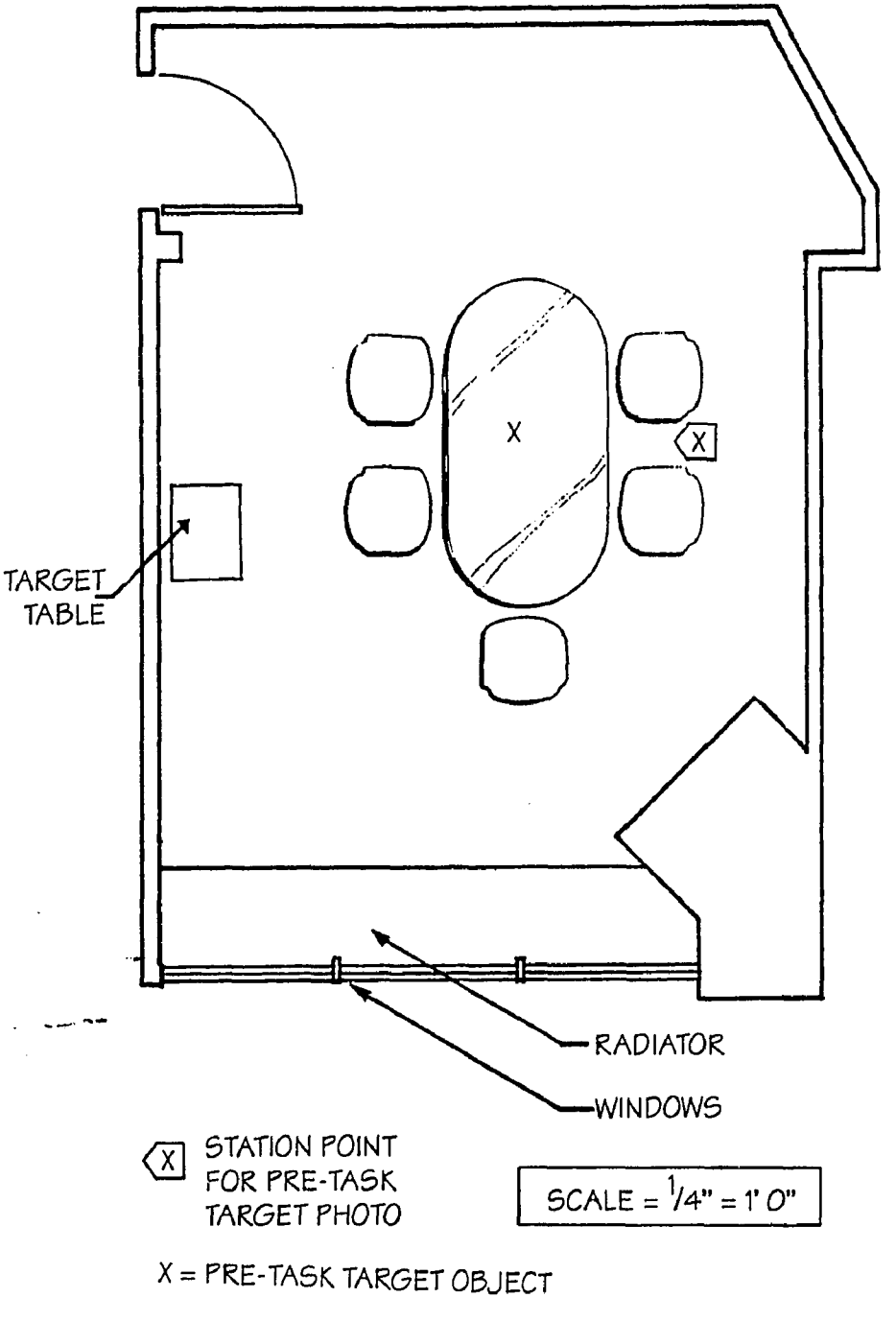
girls and five boys, were 6.0 to 6.11 years old; twelve children, six girls and six boys, were between 7.0 and 7.11 years old; and five children, two girls and three boys, were between 8.0 and 8.11 years old.

Materials

The pre-task and task TARGET photos and all experimental sessions with subjects were conducted in the same conference room at the offices of Children's Television Workshop in Manhattan, New York. The room was 14 ft (4.27 m) by 20 ft (6.1 m). It had a single, standard door entrance and was painted light blue on three walls. The window, under which was a radiator unit, constituted the fourth wall. A 42 in. (106.68 cm) by 84 in. (213.36 cm) blond wood table with five blue fabric-covered chairs (two on either side of the table, one at the window end) occupied the center of the room. There was also a smaller table, 24 in. (60.96 cm) by 18 in. (45.72 cm) positioned at the midpoint of the wall between the door and the window. Figure 1 represents the layout of the experimental room at the beginning of the experimental session and for the pre-task TARGET photo.

Figure 1

Layout of the Experimental Room as it Appears in Pre-Task TARGET Photo and at Beginning of the Experimental Session



The pre-task TARGET photo, taken with a Polaroid 600 Cool Cam using Polaroid 600 Sun color film, pictured an orange and pink plastic Slinky in its arched position on the blond wood table with the tops of two medium-blue chairs visible on the far side of the table, and a light-blue featureless wall in the background. The Slinky was photographed head-on from a station point 3.5 ft (1.07 m) away and 3.5 ft (1.07 m) high. Figure 2 is the pre-task TARGET photo.

Figure 2
Pre-Task TARGET Photo

The task TARGET photo, taken with the same Polaroid 600 Cool Cam pictured an array of six objects constructed for the study:

- a dark blue wooden block, 12 in. (30.48 cm) by 12 in. (30.48 cm) by 3 in. (7.62 cm) and scored every 3 in. (7.62 cm) in orange to mark off a 4 x 4 pattern;
- a smaller dark blue wooden block, 6 in. (15.24 cm) by 6 in. (15.24 cm) and scored in orange every 3 in. (7.62 cm) to mark off a 2 x 2 pattern;
- a medium green oval disk, 12 in. (30.48 cm) long by 8 in. (20.32 cm) wide and supported on a wedge so that it stood on an angle;
- a yellow-orange four-sided tower, 9 in. (22.86 cm) high, 3 in. (7.62 cm) wide at one end and 5 in. (12.7 cm) wide at the other, with different bright red markings on three sides (on one, the shape of a thunderbolt) and one side free of markings;
- an 8 in. (20.32 cm) high pyramid, each side a different color with one side also bearing contrasting .5 in. (1.27 cm) dots; and,
- an "X" constructed of two 14 in. (35.56 cm) by 3 in. (7.62 cm) by 3 in. (7.62 cm) heavy cardboard boxes with multicolored flecks and distinctive but different lines on each side against a yellow background.

For the task TARGET photo, the smaller table was rotated 45 degrees and positioned in the corner of the experimental room by the window with the TARGET objects arranged on it. The light blue wall to the right of the corner line was featureless and the left was a large, three-paned window with white vertical blinds partially opened. The long side of the TARGET table backed against the windowed

wall. The TARGET array was photographed from a station point 4 ft (1.22 m) off the left corner of the table and 4 ft (1.22 m) high. Figure 3 represents the layout of the room for the task TARGET photo.

Figure 3

Layout of Experimental Room as it Appears in Task TARGET Photo

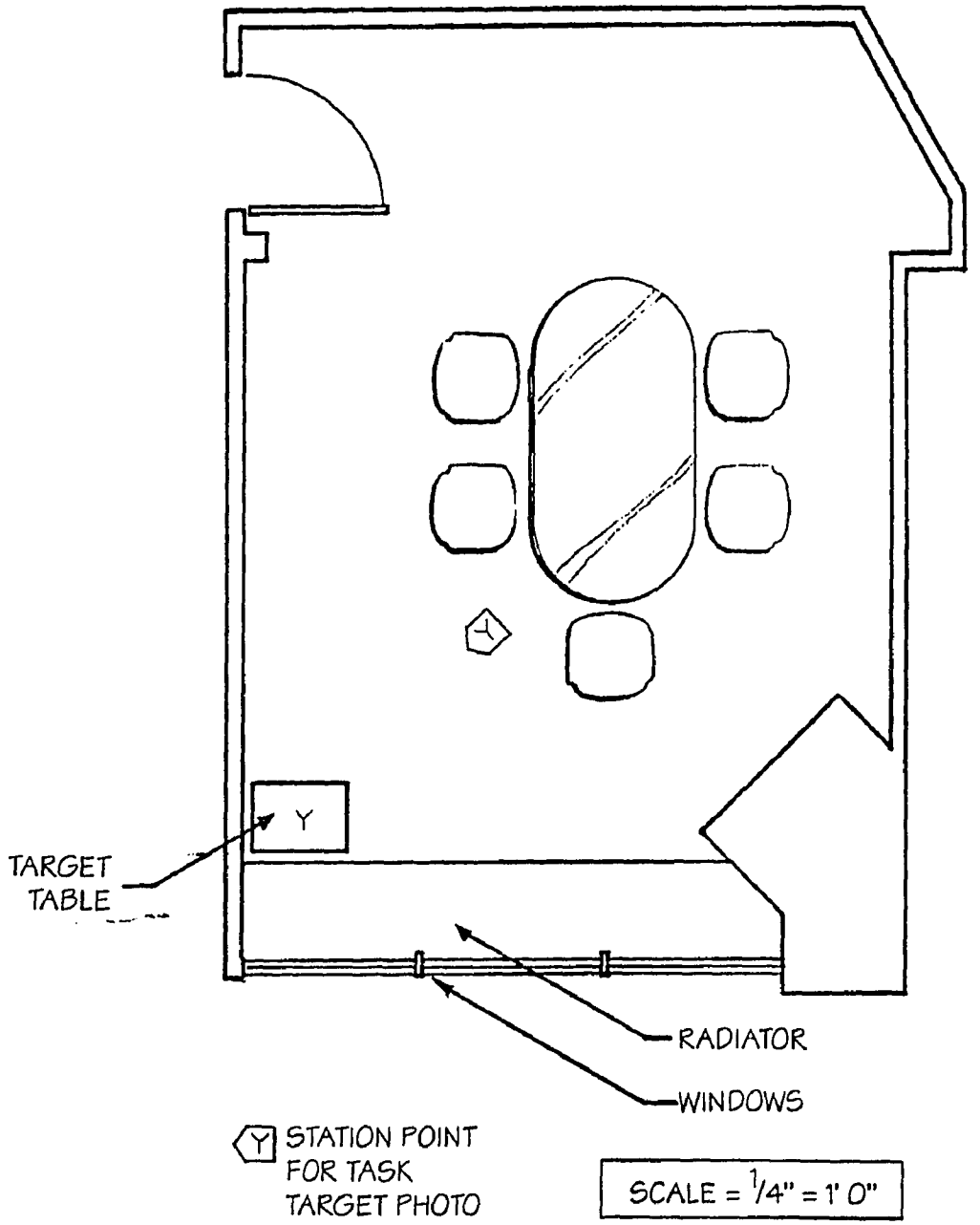
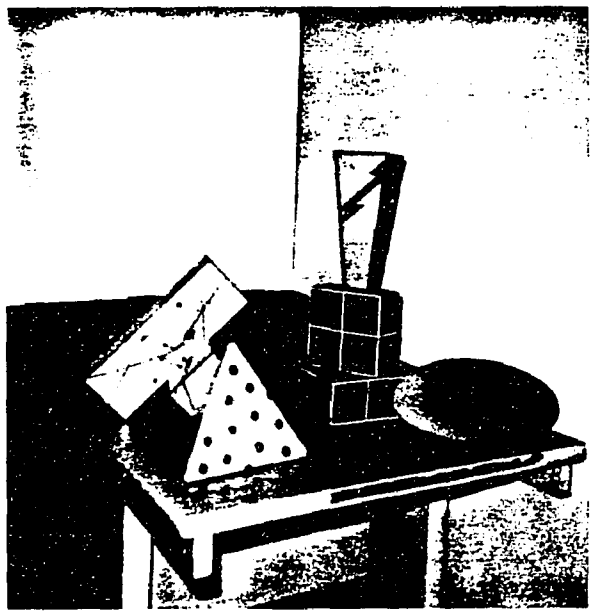


Figure 4 is the TARGET photo.

Figure 4

Task TARGET Photo



The large blue block appeared lying flat in the far right corner, the smaller blue block standing upright and kaddie-cornered on top of it. The tower with its thunderbolt side facing out stood inverted on top of the smaller blue block. The green oval was in front of, and partially occluded, the large blue block. The "X" appeared on the left rear corner of the table and the pyramid, with its blue and dotted sides visible, was in front and to the right of the "X", which it partially occluded.

In addition to the target objects featured in the pre-task and task TARGET photos, seven additional "distractor" objects were constructed. These objects were sometimes similar to TARGET objects in terms of color or general shape and included:

- a 15 in. (38.1 cm) high slanted blue cone with a flat, blue oval base 10 in. (25.4 cm) by 6 in. (15.24 cm) dotted with multi-colored half inch (1.27 cm) dots;
- a 4 in. (10.16 cm) blue wooden cube;
- a 12 in. (30.48 cm) by 12 in. (30.48 cm) by 4 in. (10.16 cm) dark blue wooden base block with 4 in. (10.16 cm) square "leg" blocks attached to and supporting each corner;
- a red-orange 6 in. (15.24 cm) by 4 in. (10.16 cm) by 4 in. (10.16 cm) block;
- a trapezoidal block 5 in. (12.7 cm) by 8 in. (20.32 cm) at the base, 4 in. (10.16 cm) by 7 in. (17.78 cm) at the top;
- a "T" shape constructed of two blocks of the same proportions and coloration as the TARGET "X" object; and,
- a shape constructed of two blocks of the same proportions and coloration as the "X" and "T" object but with the blocks attached to each other in a parallel fashion, the ends offset by 4 in. (10.16 cm).

The lighting conditions for the pre-task and task TARGET photos were held constant in the experimental setting so that lighting was not a variable in this study. The camera was loaded at the beginning of each experimental session with the same

Polaroid 600 Sun color film that was used to take the target photos. The children used the same Polaroid 600 Cool Cam used to take the TARGET photos.

Procedure

The pre-pre-task interview, the pre-task, and task photo sessions, and the follow-up interview were conducted in a single, continuous session with individual children. In most cases two Experimenters were present, one conducting the session and one taking back-up notes and observational records. At the beginning of each experimental session, the child was led into the experimental room which contained the objects in the pre-task and task TARGET photos plus the distractor objects, in random placement at the end of the blond wood table (the end nearest to the door). As noted above, the smaller table ran lengthwise against the midpoint of the wall between the door and the window.

To begin the session, the children were brought into the experimental room, introduced to the Experimenters, interviewed about their knowledge of and experience with cameras and photographs, and instructed on the use of the camera. The children were then encouraged to take a practice photograph and were asked what they took a photograph of immediately after it developed (see Appendix A for Pre-Pre-Task Introduction and Instructions).

Then, for the pre-task, the children were shown the photograph of the arched Slinky and asked to take a photograph just like the one shown (See Appendix B for Pre-Task Protocol).

For the experimental task, the children were presented with the task TARGET photo and asked to take a photograph to match the TARGET photo. Each child was asked an ordered set of probes after each MATCH photo developed regarding the child's perception of the degree of match between the MATCH and the TARGET photographs. Each child was encouraged to make any adjustments and re-take the MATCH photo up to four times, or until the child explicitly indicated satisfaction with the match or refusal to take another.

Hypotheses

The requirements (items 1-9, pages 13-14) for successful solution of the task fall into three categories which offer opportunities to hypothesize and assess developmental change. Each requirement may fit more than one category:

A. Child As Viewer: Perception and analysis of the TARGET photo requires looking and noticing (items 1-5, 8-9). This category operates on gross (overall, large scale determinations) and fine (detailed determinations) levels, and was measured by the occurrence of "random" photographs and the inclusion of objects (both TARGET and extraneous objects) in the reconstruction of the real-world display. The occurrence of randomly taken photographs was expected to decrease with age, reflecting increasingly sophisticated understanding of the problem. Children's photographic specificity (i.e., including appropriate objects and excluding extraneous ones), was expected to increase with age, also reflecting increasingly sophisticated grasp of the task.

B. Child As Doer: Transformation and re-creation of the environment requires conceptual understanding of the symbolic relationship between the TARGET photo and the real world, and of the information the TARGET photo offers about both the real world and itself (items 1-5). This category operates on gross and fine levels. The gross level was measured by the occurrence of random photographs and the inclusion of target objects. The fine level was measured by both inter-object orientation and proximity, and intra-object specificity (details within objects themselves, such as the uniquely specified side of an object facing out). Older children were expected to be increasingly sensitive to and accurate about the inclusion/exclusion of objects, and the details of arrangement, reflecting an increasing understanding of the relationships between and within objects specified by the TARGET photo.

C. Child As Photographer: Conceptualization of perspective would be reflected in children's picture-taking behavior (items 4-9) which was measured by the occurrence of random MATCH photographs and the accuracy of the station point (centeredness, height, distance) assumed by the child in order to take the MATCH photo. With increasing age children were expected to achieve increasing accuracy in their assumption of the specifically correct station point and in their horizontal/vertical orientation of the photographic frame, reflecting increasing grasp of the rules that govern the appearance of photographed objects in array.

The ability to understand the symbolic relationship between the TARGET photo and the real world, as expressed by children's systematic transformations and

re-creations of the environment, were expected to develop earlier than their abilities as photographers. That is to say, younger children would be able to successfully reconstruct the environment but be less successful at assuming the particular perspective specified by the TARGET photo. Piagetian theory on perspective-taking would support this hypothesis on the basis that the ability to assume the correct station point is dependent on the child's ability to decenter, an achievement of development, and that the ability to understand symbolic relationships is not tied to a self-referencing viewpoint.

Finally, based on the notion that development moves one toward greater differentiation and hierarchical integration (Harris, 1963; Werner & Kaplan, 1984) older children were expected to take more MATCH photos because they would be less easily satisfied with the degree of match between their MATCH photograph and the TARGET photograph and able to integrate increasingly complex than younger children.

Data and Analyses

The data consisted of the actual MATCH photos each child took, the interviews conducted with the children, and observational records of the sessions. Coding schemes for the qualitative measures were based on content analyses. All the data were reviewed by two raters and scored by consensus. Inter-rater reliability was assessed on several measures (intentionality of the MATCH photo, horizontal and vertical centeredness, and experimenter-judged error of the MATCH photo). For this

test, a third rater's scoring of the data was compared to the consensus-derived scoring of the two primary raters. Analyses consisted mainly of crosstabulations and correlations where appropriate.

MATCH Photos. MATCH photos were analyzed for degree of match with the TARGET photo. Specifically, the following were noted:

- occurrence and number of random photographs;
- inclusion of objects;
- arrangement of objects;
- intra-object details;
- station point (centeredness, height, distance);
- number of photos taken to achieve satisfaction of match.

Analyses of these data allow inferences to be made as to the roles played by symbolic and world knowledge functions: from the inclusion and arrangement of the objects inferences were made about the child's notions of symbolization, and from the station point assumed inferences were made about the child's world and photographic knowledge.

From the occurrence of random photographs without an attempt to include and arrange objects it was inferred that children do not understand that there is a symbolic relationship between the TARGET (or any) photo and what is pictured nor that there is information available in the photograph to act upon. This would imply that children are taking photographs for the kinesthetic-haptic pleasure of the action, much

the same way they scribble on paper with crayons.

From the occurrence of random photographs that are accompanied by an unsystematic attempt to include and arrange objects it was inferred that children have some concept of a relationship between the TARGET photo and the real world, but that this concept is a global, undifferentiated one.

From the occurrence of MATCH photos that reflect inaccurate station points (and to the degree of inaccuracy) but appropriate and accurate inclusion and arrangement of objects it was inferred that children understand the symbolic relationship between the TARGET photo and the world. It was also inferred that children are able to extract and act upon the information available about the real world from the photo, but are unable to extract and act upon the information available in the photo about the photograph itself as a constructed object.

Interviews. Interview questions explored what children identified as the degree of match between their photos and the TARGET, and nature of any mismatch. Interviews were analyzed for the level of understanding expressed about the nature of the task. From such analyses inferences were made about what the child's conceptualization is of the task and its solution.

Observational Records. Observational records were recorded for each session and noted actions taken as well as any spontaneous speech. Analysis of observational records served to clarify and confirm coding on the other categories of analyses.

IV. RESULTS

Introduction. Given the discrete nature of the individual items measured for both the pretask and task MATCH photos, a cross-classified table format (crosstab) was decided on as the optimal way to describe relationships with age. The age categories are presented as the column entries of the table (from left to right) while the scores making up each item are presented as the row entries. The specific cell entries are the number of children in the age category achieving a particular score for the measure. Statistics were calculated by six-month age breaks but are presented by year of age for ease of reading the tables. The Total column presents the row frequency totals and percentages.

Since both age and item scores constitute ordered variables (i.e., they are at least ordinal in nature), it is possible to use the Goodman-Kruskal Gamma coefficient to measure the degree of association between age and performance on each item. The Gamma coefficient ranges between -1 and +1 with a value near 0 indicating no linear association between the rows and columns of the table; a value of Gamma greater than 0 would indicate a positive relationship and a negative value would indicate an inverse relationship. Each table is accompanied by the value of Gamma for that table and its significance test (T-value).

The Gamma coefficient in large samples is approximately normal in distribution and so a Z-score test can be calculated to determine whether or not the degree of association is significant. The Z-score is often referred to as a T-value (not to be confused with the Student t-test). A T-value of 2.0 is usually taken as the cutoff

score. A T-value of 2.0 with a two-tailed probability of 0.046 is approximately equivalent to a Z-score of 1.96 with a two-tailed probability of .05, the cut-off for a Z-test. The use of 2.0 is a concession to the fact that the Gamma coefficient is only approximately normal in distribution.

All coding was done by consensus by the two Experimenters who collected the data. In addition, reliability checks were conducted on five measures: intentionality of attempt (coded and scored as: random, photo of the TARGET photo, intentional without actual reconstruction, or intentional with reconstruction), horizontal centeredness (coded and scored as: random, left, right, or correct), vertical centeredness/height of station point (high low, or correct), distance from array (too close, too far, or correct), and Experimenter-judged error of the MATCH photos (coded and scored as: no judgeable photo, array and station point errors, array errors only, station point errors only, or no errors). A third adult independently coded these measures for the first and second MATCH photos produced by the total sample. A Cohen's Kappa was calculated comparing the original scoring with the second, independent scoring. In general, agreement was quite high. Table 1 presents the Kappa achieved for each reliability check.

Table 1

Reliability Checks on Coding for Five Measures on First and Second MATCH Photos

Measure	Kappa
Intentionality of Attempt	
MATCH Photo 1	.96
MATCH Photo 2	1.00
Horizontal Centeredness	
MATCH Photo 1	.95
MATCH Photo 2	.92
Vertical Centeredness (Height of Station Point)	
MATCH Photo 1	.79
MATCH Photo 2	.86
Distance from Array	
MATCH Photo 1	.85
MATCH Photo 2	.87
Experimenter-Judged Error	
MATCH Photo 1	.68
MATCH Photo 2	1.00

1. Results of Pre-pretask Interview

The pre-pretask interview was designed to collect baseline information about the children's experience with cameras and photographs and instruct them on the use of the Polaroid 660 Sun camera. Over 95% of the children recognized the camera as a camera, and once identified for the two who did not, all said one could take pictures with it. All the children recognized a sample photo (of a stuffed toy) as a "picture" of the toy. Seventy percent of the children had used a camera themselves prior to the session (younger children tended not to have used one previously). With the

exception of two children, all families owned at least one camera. Over 93% of the children reported that numerous people in their families took pictures, including parents, siblings, themselves, and other members.

2. Analyses of Pretask and Task MATCH Photos: Introduction

The skills that go into making a photograph "that looks just like" a target photograph have been described and operationalized earlier. Three scales were developed to reflect the three underlying categories of information that have to be processed in order to solve the task and that reflect the basic questions the task poses:

1) "What is this a picture of?" The child's answer is embodied in the "world" or array as the child reconstructs it and is reflected in measures referred to as comprising the MATCH photo's "world score." These include: the number of target objects, extraneous objects, interobject relationships, and intraobject relationships as organized in *the child's array*. This measure is based on observational records of the pretask session.

2) "How do the things look in the picture?" The photograph-specific characteristics such as relevant and extraneous features, and interobject and intraobject relationships *as they appear on the child's MATCH photo* comprise the "sub-photo score." Included are: the number of target objects, extraneous objects, and inter- and intraobject relationships actually visible in the MATCH photo.

3) "Where do I put myself to take my photo?" The position of photographer uniquely specified by the TARGET photo is reflected in the "photographer score."

This includes measures of: centeredness of the primary object or objects, height of the station point, distance from the primary object, and appropriate and accurate occlusions *as they appear on the child's MATCH photo*. This aspect of the task plays an important role in determining the overall accuracy of the MATCH photo.

3. Analyses of Pretask Items

The pretask was designed to determine whether all children understood the nature of the task, and to provide an opportunity for each child to practice with the camera. Overall, all World and Sub-photo sub-scale measures increased significantly with age while results on the Photographer sub-scale were mixed. All tables for pretask measures (including Tables 2 - 12) are presented in Appendix D.

Forty out of the total sample of 47 children produced scorable pre-task photos. Completely random photos and photos with no clear features were not scored. MATCH photos of the pre-task TARGET photo itself were not scored. The younger children comprise the majority of those who produced unscorable pre-task MATCH photos: of the 16 children between 3.0 and 4.11 only 12 produced scorable pre-task photos; of the 14 children between 5.0 and 6.11 only 12 produced scorable pre-task photos; and of the 17 who were between 7.0 and 8.11 months only 15 produced scorable pre-task photos.

"World" sub-scale measures were calculated in the task PHOTO analyses that consider what the child actually puts in his or her reconstruction of the actual array. All four individual measures that comprise this sub-scale score were significantly

related to age in the pretask. Tables 2 - 5 in Appendix D present these findings. The number of primary, or foreground objects and secondary, or background objects children included in their reconstructed array increased with age (Table 2). The number of extraneous objects included in the array decreased with age (Table 3). Children's inclusion of appropriate interobject relationships in the reconstructed array increased with age (Table 4). Finally, older children included more of the appropriate intraobject relationships defined in the pretask TARGET photo than did younger ones. This relationship with age was also significant (Table 5).

The results of the individual measures that will comprise the "sub-photo" sub-scale in the task PHOTO analyses, which examine the visible content of the MATCH photo are shown in Tables 6 - 9 in Appendix D. Three of the four measures are significantly related to age. The total number of target objects (out of 4) the child captured in the pretask MATCH photo is significantly related to age. Older children captured more of the secondary or background objects visible in the pretask TARGET photo in their own pretask MATCH photos (Gamma=.68, $p<.05$, Table 6). The data on the number of extraneous objects (expressed as a negative) the child captured in the pretask MATCH photo does not show a clear pattern of association between this item and age in the pretask (Table 7). As will be seen, this measure is marginally significant in the task condition.

The degree to which the child's pretask MATCH photo reflects the appropriate interobject relationships (out of 6) shows that older children captured in their own MATCH photos more of the specified interobject relationships of the pretask

TARGET photo (Gamma=.61, $p<.05$, Table 8). The relationship between children's ability to capture the specified intraobject relationships of the pretask TARGET photo (out of 3) in their own pretask MATCH photo and age (Table 9) shows that this ability increases with age (Gamma=.70, $p<.05$).

The findings of the individual measures that will comprise the "photographer" sub-scale in the task PHOTO analyses, which examine the ability of the child to assume the specifically correct station point from which to take the MATCH photo, are presented in Tables 10 - 12, Appendix D. These measures were coded from information specified in the child's MATCH photos. Two of the three measures show no significant relationship with age. These findings support the hypothesis that being able to extract from and act upon the information in the TARGET photo that specifies the position of the photographer is different from understanding the information the TARGET photo specifies about the real world it represents. This ability does not develop until later in childhood. As will be seen, a similar pattern of results was found in the task condition.

While 75% of the children, representing all age groups, were unable to accurately center on the horizontal axis the principal objects in the frame of the photograph, those who were able to tended to be the older ones (Table 10). The fact that 75% of the children were not able to center the "slinky" in the photographic frame further suggests that this aspect of "self as photographer" develops later. It may be that centering requires more advanced motor abilities or younger children attend to centeredness as a feature of composition only at a gross level.

Accuracy of the height of the station point, or vertical centeredness, and distance from the array are not associated with age (Tables 11 and 12). More than 82% of the children took their pretask MATCH photo from the wrong height (either too high or too low) and over 97% from the wrong distance (either too far or too close). Distance from the primary object to the camera is expressed in the size of the object on the photographic frame. It may be the case that the ability to determine and match distance from the photographed object as expressed by the size of the object on the frame develops later than 9 years of age or that sensitivity to this feature does.

In sum, then, the data from the pretask show that older children more accurately reconstructed the actual pretask array and more closely matched the visible content of the TARGET photo in their MATCH photos than younger children. However, extracting from and acting upon the information that specifies the uniquely correct station point from which to take the MATCH photo poses some problems, even for older children. Children may remain less sensitive to this information or it may be more difficult to process than the other information about the world available in photographs.

4. Analyses of the Task MATCH Photos: Dealing with Attrition

Each child could take up to four MATCH photos in their effort to match the task TARGET photo. In other words, each MATCH photo may be considered a trial.

It is important to recall that in the pre-task condition 40 children of the total sample of 47 produced scorable photos. The pre-task TARGET photo had a single

object as its primary focus. The task TARGET photo presented a group of seven objects as its primary focus. The increased number of target objects involved a similar increase in the number of interobject relationships, intraobject relationships, and occlusions specified. Clearly, the task condition presented a TARGET of greater complexity than the pre-task. In fact, out of the total sample of 47 children only 32 produced scorable first MATCH photos in the task condition. Thirteen of the 15 children who produced random photos, photos of the TARGET itself, or intentional photos that lack any effort to reconstruct the original array are between 3 and 5 years of age: again, it is the younger children who accounted for the unscorable photos. However, five children were able to "recover" (2 in the youngest age group, 2 in the middle age group, and 1 in the oldest age group) so that 37 produced scorable second MATCH photos in the task condition. This suggests, and observational and interview data support the notion that the first MATCH effort may have served as a practice trial for the task condition.

There was also a definite attrition of the population across the four MATCH photo opportunities of the task. Of the 37 children who produced scorable second MATCH photos, only 28 go on to take the third photo, and only 18 take a fourth photo. This raises problems that result from smaller sample sizes (e.g., decreased ability to detect differences or trends). There is a concern when such attrition occurs across trials that the participants who remain across trials are not a representative sample of those who were present at trial one (i.e., the attrition is not due to some random factor that applies equally to all children). This would mean that we could not consider looking

at age trends across all four photos since any possible trends of learning or practice might be confounded with other factors (e.g., cognitive maturity, stamina, incidental and environmental factors).

Preliminary analyses were carried out to see if there was some bias in terms of which children persevered in taking all four photos. Correlations were calculated between the number of photos each child took and age, sex, and the scores the child received on the first photo.

There were significant correlations between the number of photos taken by a child and the child's age and the intentionality of photo score: older children and/or those who took intentional photos (intended to meet the challenge of the task rather than random) took more photos. The correlations were .56 for age ($p < .001$) and .70 for intentionality ($p < .001$). The fact that the age of the child, which represents a rough measure of the child's level of maturity (both cognitive and emotional) and the measure of the child's intentionality on the first photo both correlate significantly with the number of photos suggests that those children who took more photos also tended either to be older or at least more mature in their attitude toward the task.

An attempt to establish learning or practice effects across the four photos with the entire sample therefore does not appear reasonable. However, it may be possible to see learning or practice effects among those children who take three or four photos. However, any claims with regard to such trends would have to be made cautiously since, again, those children who did go on to take either three or four photos were not necessarily representative of the original set of children.

The analyses presented below concentrate on measures of the first and second photos for the purpose of establishing inter-individual developmental trends based on age (as opposed to intra-individual trends across photos). Findings based on the sub-samples of children who took three and who took four MATCH photos are presented in Section 11.

5. Age and Total and Sub-scale Scores

It is possible to calculate a global or total score for each MATCH photo that quantifies the degree to which the MATCH photo matches the TARGET photo, reflecting the ability of the child to solve the problem. This is a composite of the sub-scales measuring the three underlying categories of information that have to be processed to the solve the task: the reconstruction of the array represented by the TARGET photo, or "what is this a picture of?" ("world" sub-scale), photograph-specific characteristics such as interobject and intraobject relationships, or "how do the things look?" ("sub-photo" sub-scale), and characteristics that specify the photographer such as station point and occlusions, or "where do I put myself" ("photographer" sub-scale). World, sub-photo, and photographer consist of the elemental measures noted earlier:

A) world: the number of target objects minus the number of extraneous objects plus the number of interobject relationships plus the number of intraobject relationships included in the array;

B) sub-photo: the number of target objects minus the number of extraneous objects plus the number of interobject relationships plus the number of intraobject relationships visible in the MATCH photo;

C) photographer: centered (no=0/yes=1) plus height of station point (incorrect=0/correct=1) plus distance (incorrect=0/correct=1) plus the number of appropriate occlusions plus the number of accurate occlusions.

We start by considering whether the total score and the underlying sub-scales show differences as a function of age, which would be indicative of developmental changes. However, it must again be noted that total scores, requiring a score on all sub-scales, for first MATCH photos (trial 1) were calculated only for the 32 of the 47 children in the study who produced scorable first MATCH photos. Again, none of the very youngest children aged 3 to 4 years produced scorable first MATCH photos. As noted above, five more children were able to produce scorable MATCH photos on the second trial so that complete sub-scales were available to calculate total scores for 37 second MATCH photos. Table 13 presents the correlations between sub-scale (world, sub-photo, photographer) and total scores and child's age for the first MATCH photo and the second.

Table 13

Correlation of Sub-Scale and Total Scores for MATCH Photos 1 and 2 by Age

WORLD SCORE PHOTO 1	SUB-PHOTO SCORE PHOTO 1	PHOTOGRAPHER SCORE PHOTO 1	TOTAL SCORE PHOTO 1
.7243	.7010	.5931	.7386
(n=32)	(n=32)	(n=32)	(n=32)
p<.001	p<.001	p<.001	p<.001

WORLD SCORE PHOTO 2	SUB-PHOTO SCORE PHOTO 2	PHOTOGRAPHER SCORE PHOTO 2	TOTAL SCORE PHOTO 2
.7821	.7738	.5719	.7917
(n=37)	(n=37)	(n=37)	(n=37)
p<.001	p<.001	p<.001	p<.001

All these measures show significant correlations with age, indicating that higher scores are associated with greater age (and concomitant mental maturity). The correlation between total score and age tends to be quite high, indicating a general tendency for the requisite abilities to be related to greater age. Looking at the correlations of the sub-scores (world, sub-photo, photographer) with age, the correlations for world and sub-photo tend to be somewhat higher than those for photographer.

This pattern, which holds up across MATCH photo 1 and MATCH photo 2, suggests that understanding and acting upon the photographer-specifying information in the TARGET photo ("where do I put myself to take the photo?") as measured by the photographer sub-scale is not so strongly correlated with age across the ages

observed in this study. It may be that understanding photographer-specifying information matures at a different rate from the abilities measured by either world ("what's this a picture of?") or sub-photo ("how do the things look?"). There are two possible accounts: the ability measured by the photographer score either peaks at an early age and does not show much of a developmental trend at later ages or develops at ages older than observed in this study. In either case, the correlation will tend to be lower than if there is a more or less constant rate of development across the age range. One way of determining which of these may be occurring would be to look at the changes that occur in individual items within each sub-scale and see how each of these changes as a function of age.

6. Analyses of Individual Measures for MATCH Photo 1

In this section the relationship between age and children's performance on individual measures for the first photo will be examined. The measures are organized by the sub-scales:

A. WORLD measures as reflected **in the child's reconstruction of the array** as it is specified by the task TARGET photo:

- the number of target objects (coding scheme: up to a maximum of six points for all six objects + two points for the objects being placed on the correct table + one point for the being oriented against the correct wall + one point for being appropriately oriented toward the corner + two points

if the table is accurately oriented in the corner = maximum score of 12);

- the number of extraneous objects (coding scheme: one point per object - considered as a negative value when calculating the sub-scale score);
- the number of interobject relationships (coding scheme: one point per relationship out of a maximum of 16 relationships);
- the number of intraobject relationships (coding scheme: one point per relationship out of a maximum of 14 relationships);

B. SUB-PHOTO measures as reflected **in the child's MATCH photo**:

- the correct table and corner appear in the MATCH photo (coding scheme: zero points if not, one point for correct table + one point for corner = maximum of two points);
- the number of target features (coding scheme: one point per target object up to a total of six objects + two points for the correct table + one point for the correct wall + one point if the corner is visible + two points if the table is accurately oriented in the corner);
- the number of extraneous features visible in the photo (coding scheme: one point per feature - considered as a negative value when calculating the sub-scale score);
- the number of interobject relations (coding scheme: one point per relationship out of a maximum of 16);
- the number of intraobject relationships (coding scheme: one point per relationship out of a maximum of 14);

C. PHOTOGRAPHER measures as reflected **in the child's MATCH photo**:

- centeredness of the composition (coding scheme: not centered is assigned zero, centered is assigned one point);
- height of the station point (coding scheme: high or low is assigned zero, correct is assigned one point);
- distance (based on size of objects in the frame; coding scheme: too close or too far is assigned 0, correct is assigned one point);
- appropriate occlusions (coding scheme: one point per occlusion out of four);
- accurate occlusions (coding scheme: one point per occlusion out of four).

A measure of randomness (or intentionality) was also included in the analysis of the task MATCH photo. Scoring on this item was based on both observation of the child and review of the MATCH photo. A thoroughly random photo (taken without apparent intention to match the TARGET) was scored 0. If the child took a photo of the TARGET photo, they received a score of 1. A score of 2 was given if the child placed herself at the side of the correct table, aimed the camera at the general pool of objects (which included the target objects) without attempting to reconstruct the array specified in the TARGET photo, and took a picture at least approximating the TARGET photo. If the child attempted a reconstruction of the target array, assumed a station point and aimed the camera so as to approximate the TARGET photo, a score of 3 was assigned.

It was hypothesized that the youngest subjects will approach the task at the level of

haptic engagement, that is, with kinesthetic objectives (Lowenfeld, 1939, 1945) much in the same way that Arnheim (1971) refers to the motor exploration in young children's early drawing. It was expected, therefore, that younger children would take "random" photos in the course of simply exercising the use of a tool (in this case, a camera rather than crayons) more frequently than older children. There is, in fact, a significant association with age (Gamma=.70, $p<.05$, Table 14), indicating that the frequency with which children take random photos decreases with age and the degree of intentionality (as reflected in the amount of "work" the child does to take the MATCH photo) increases with age. It should be noted that while only 32 first MATCH photos were scorable for sub-scale measures, all 47 first MATCH photos were scored for intentionality. As noted earlier, specific cell entries in the table represent the number of children in each age category achieving a particular score on the intentionality measure. The Gamma value of the Goodman-Kruskal statistic appears beneath the table.

Table 14

Intentionality of Attempt of MATCH Photo 1 by Age (Number of Subjects)

Intentionality of Photo 1	Code	Age (in years) 3	4	5	6	7	8	Total/ Percent
Random	0	1	1					2 4.3
Photo of TARGET Photo	1	1				1		2 4.3
Intentional w/o Reconstruction	2	3	4	3		1		11 23.4
Intentional w/ Reconstruction	3		6	3	8	10	5	32 68.1
Column Total		5	11	6	8	12	1	47
Column Percent		10.6	23.4	12.7	17.0	25.6	2.1	100.0

Statistic	Value	T-value	p-value
Gamma	.70505	4.59531	$p<.05$

"World" Sub-Scale for First MATCH Photo. As noted in Table 13, the "world" sub-scale showed a fairly high correlation with age ($r=.72$, $p<.001$). In fact, we find that all four measures in this sub-scale show significant associations with age. The number of target features the child includes in the reconstructed array (out of 12) increases with age (Gamma = .55, $p<.05$, Table 15); the number of extraneous features the child includes in the array decreases with age (Gamma = .63, $p<.05$, Table 16); the number of correct interobject relationships the child arranges in the array (out of 16) increases with age (Gamma = .75, $p<.05$, Table 17); and the number of correct intraobject relationships the child arranges (out of 14) increases with age (Gamma = .60, $p<.05$, Table 18).

Table 15

Number of Subjects Including Target Features in Array 1 by Age

# Target Features in Array 1	Age (in years) 4	5	6	7	8	Total/ Percent
1 Feature	1					1 3.1
2 Features	1					1 3.1
3 Features		1				1 3.1
4 Features	1		1			2 6.3
5 Features	1	1			1	3 9.4
6 Features	1		1	2		4 12.5
8 Features		1	1		1	3 9.4
9 Features	1		3	4		8 25.0
10 Features			1	2	1	4 12.5
11 Features				1		1 3.1
12 Features			1	1	2	4 12.5
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.0	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.55443	3.99380	$p<.05$

Table 16

Number of Subjects Including Extraneous Features in Array 1 by Age

# Extra Features in Array 1	Age (in years) 4	5	6	7	8	Total/ Percent
9 Features		1				1 3.1
6 Features	1					1 3.1
5 Features		1				1 3.1
3 Features			1	1		2 6.3
2 Features	2			1		3 9.4
1 Feature	2	1	1			4 12.5
0 Features	1		6	8	5	20 62.5
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.0	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.62825	5.05917	$p<.05$

Table 17

Number of Subjects Including Interobject Relationships in Array 1 by Age

Number of Interobject Relations in Array 1	Age (in years) 4	5	6	7	8	Total/ Percent
0 Relationships	2	1	1			4 12.5
3 Relationships	2	1				3 9.4
4 Relationships		1		1	1	3 9.4
5 Relationships	1					1 3.1
8 Relationships			2			2 6.3
11 Relationships	1		1			2 6.3
12 Relationships			3			3 9.4
13 Relationships			1			1 3.1
15 Relationships				1		1 3.1
16 Relationships				8	4	12 37.5
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.0	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.74737	8.22584	$p<.05$

Table 18

Number of Subjects Including Intraobject Relationships in Array 1 by Age

	Age (in years)					
Number of Intraobject Relations in Array 1	4	5	6	7	8	Total/ Percent
0 Relationships	1					1 3.1
1 Relationship	2	1				3 9.4
3 Relationships	1	2				3 9.4
4 Relationships			2	1		3 9.4
5 Relationships	1		1	2		4 12.5
6 Relationships			1	1		2 6.3
7 Relationships	1		1	4	2	8 25.0
8 Relationships				1	1	2 6.3
9 Relationships			2	1		3 9.4
10 Relationships			1			1 3.1
12 Relationships					1	1 3.1
14 Relationships					1	1 3.1
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.5	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.60000	4.66923	$p<.05$

"Sub-Photo" Sub-scale for First MATCH Photo. Recall from Table 13 that this sub-scale also showed a significant correlation with age ($r=.70$, $p<.001$). In fact, all five measures that make up this sub-scale show significant association with age: inclusion of the correct table and corner in the MATCH 1 photo increased with age (Gamma = .62, $p<.05$, Table 19); the number of target features (out of 12) the child captured in the MATCH 1 photo (out of 12) increased with age (Gamma=.55, $p<.05$, Table 20); the number of extraneous features present in the child's MATCH 1 photo decreased with age (Gamma=.35, $p<.05$, Table 21); the number of correct interobject relationships apparent in the MATCH 1 photo (out of 16) increased with age (Gamma = .71, $p<.05$, Table 22); and the number of accurate intraobject relationships captured in the MATCH 1 photo (out of 14) increased with age (Gamma=.56, $p<.05$, Table 23). Tables 19-23 present the data for these measures.

Although the measure of extraneous features present in the MATCH 1 photo (Table 21) is statistically significant, the magnitude of the Gamma is not as high as the other measures in this sub-scale, suggesting that this particular ability develops with age at a more modest rate.

Table 19

Table and Corner Appear in MATCH Photo 1 by Age (Number of Subjects)

Table and Corner in Photo 1	Code	Age (in years) 4	5	6	7	8	Total/ Percent
Neither	0	5	2	2	2	1	12 37.5
Table	1	1	1	4	3	1	10 31.3
Table & Corner	2			2	5	3	10 31.3
Column Total		6	3	8	10	5	32
Column Percent		18.8	9.4	25.5	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.61716	4.141139	$p < .05$

Table 20

Number of Subjects Including Target Features in MATCH Photo 1 by Age

	Age (in years)					
Number of Target Features in Photo 1	4	5	6	7	8	Total/ Percent
0 Features	1					1 3.1
1 Feature	1	1				2 6.3
3 Features		1	1			2 6.3
4 Features	2			1		3 9.4
5 Features	1	1			1	3 9.4
6 Features			1	1		2 6.3
7 Features			1	1		2 6.3
8 Features			2	1	1	4 12.5
9 Features	1		1	4		6 18.8
10 Features			1	1	1	3 9.4
11 Features				1		1 3.1
12 Features			1		2	3 9.4
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.0	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.54902	4.13259	$p<.05$

Table 21

Number of Subjects Including Extraneous Features in MATCH Photo 1 by Age

Number of Extra Features in Photo 1	Age (in years) 4	5	6	7	8	Total/ Percent
8 Features		1				1 3.1
7 Features			1			1 3.1
6 Features	1					1 3.1
5 Features	2	1		1	1	5 15.6
4 Features	1					1 3.1
3 Features	1			3		4 12.5
2 Features			4	1		5 15.6
1 Feature				2	1	3 9.4
0 Features	1	1	3	3	3	11 34.4
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.0	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.35121	2.40747	$p<.05$

Table 22

Number of Subjects Including Interobject Relationships in MATCH Photo 1 by Age

	Age (in years)					
Number of Interobject Relations in Photo 1	4	5	6	7	8	Total/ Percent
0 Relationships	2	2	1			5 15.6
3 Relationships	2	1				3 9.4
4 Relationships	1			1	1	3 9.4
7 Relationships			1	1		2 6.3
8 Relationships			2			2 6.3
11 Relationships	1		1			2 6.3
12 Relationships			2			2 6.3
13 Relationships			1			1 3.1
14 Relationships				1		1 3.1
16 Relationships				7	4	11 34.4
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.0	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.70984	8.33949	$p < .05$

Table 23

Number of Subjects Including Intraobject Relationships in MATCH Photo 1 by Age

	Age (in years)					
Number of Intraobject Relations in Photo 1	4	5	6	7	8	Total/ Percent
0 Relationships	1	1				2 6.3
1 Relationship	2					2 6.3
2 Relationships	1	1				2 6.3
3 Relationships		1	1			2 6.3
4 Relationships			2	1		3 9.4
5 Relationships	1			5		6 18.8
6 Relationships			1	3	1	5 15.6
7 Relationships	1		1	1	1	4 12.5
8 Relationships			2		1	3 9.4
9 Relationships			1			1 3.1
12 Relationships					1	1 3.1
14 Relationships					1	1 3.1
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.0	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.56049	3.97398	$p<.05$

"Photographer" Sub-scale for First MATCH Photo. As Table 13 indicated, this sub-scale showed a lower correlation with age than did the World and Sub-photo scales. This less powerful association with age could be due to three possibilities: either the children were responding "randomly" (which is not likely considering the degree of intentionality indicated, Table 14) or the items were either too difficult (everyone scores low) or too easy (everyone scores high). The results suggest that some of the items making up this sub-scale were difficult for most of the children. Only two items show significant associations with age: the number of appropriate occlusions captured in the MATCH 1 photo (out of 4) increased with age (Gamma=.81, $p<.05$, Table 27) as did the number of accurate occlusions (Gamma = .88, $p<.05$, Table 28). The other three measures do not show significant association with age: the centeredness of the compositional focus (Gamma = .18, Table 24), the accuracy of the height of the station point (Gamma = .26, Table 25), and the accuracy of the distance from the array to the photographer (Gamma = .42, Table 26). The relatively high percentages of children at all ages observed by this study unable to "master" these photographic elements suggest that either children between 3 and 9 years of age are not sensitive to the information about the photographer that photographs specify or the information about the photographer is more difficult to act upon than the information the photograph specifies about the world it represents, in fact too difficult to act upon at the ages considered here.

Tables 24-28 present the data for the five measures that constitute the Photographer sub-scale. The three non-significant measures were broken down

further in order to analyze errors at a finer level. The results of these measures reconsidered are presented in Section 8.

Table 24

Centeredness of the Objects in MATCH Photo 1 by Age (Number of Subjects)

		Age (in years)					
Centeredness of Photo 1	Code	4	5	6	7	8	Total
Not Centered	0	4	2	7	8	3	24 77.4
Centered	1	1	1	1	2	2	7 22.6
Column Total		5	3	8	10	5	31
Percent Centered by Age		20.0	33.3	12.5	20.0	40.0	

Statistic	Value	T-value	p-value
Gamma	.18367	.60254	ns

Table 25

Height of Station Point of MATCH Photo 1 by Age (Number of Subjects)

		Age (in years)					
Height of Station Point for Photo 1	Code	4	5	6	7	8	Total/ Percent
High or Low	0	4	3	3	8	1	19 59.4
Correct	1	2		5	2	4	13 40.6
Column Total		6	3	8	10	5	32
Percent Correct by Age		33.3	0.0	62.5	20.0	80.0	

Statistic	Value	T-value	p-value
Gamma	.26364	1.13366	ns

Table 26

Correct Distance (Size of Objects) for MATCH Photo 1 by Age (Number of Subjects)

		Age (in years)					
Distance from Array 1	Code	4	5	6	7	8	Total/ Percent
Too Close or Too Far	0	6	2	8	8	4	28 87.5
Correct Distance	1		1		2	1	4 12.5
Column Total		6	3	8	10	5	32
Percent Correct by Age		0.0	33.3	0.0	20.0	20.0	

Statistic	Value	T-value	p-value
Gamma	.42000	1.15187	ns

Table 27

Number of Subjects Including Appropriate Occlusions in MATCH Photo 1 by Age

	Age (in years)					
Number of Appropriate Occlusions in Photo 1	4	5	6	7	8	Total/ Percent
0 Occlusions	5	2	3	2		12 37.5
1 Occlusion	1	1	4			6 18.8
2 Occlusions			1	3	1	5 15.6
3 Occlusions				2	1	3 9.4
4 Occlusions				3	3	6 18.8
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.0	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.81143	9.82235	$p<.05$

Table 28

Number of Subjects Including Accurate Occlusions in MATCH Photo 1 by Age

	Age (in years)					
# Accurate Occlusions in Photo 1	4	5	6	7	8	Total/ Percent
0 Occlusions	6	3	8	8	3	28 87.5
1 Occlusion				2	1	3 9.4
2 Occlusions					1	1 3.1
Column Total	6	3	8	10	5	32
Column Percent	18.8	9.4	25.0	31.3	15.6	100.0

Statistic	Value	T-value	p-value
Gamma	.88235	2.30127	$p<.05$

In sum, then, older children took fewer random first MATCH photos and were more successful at reconstructing the array (World sub-scale) and capturing the visual content (Sub-photo sub-scale) from the information available in the TARGET photo than younger children. However, most of the children, regardless of age, had difficulty mastering the photographic elements that specify the uniquely correct station point from which to take the photo and that constitute the Photographer sub-scale. This finding suggests that children even as old as 8.11 years are either not sensitive to this information or the information about the photographer per se is more difficult to act upon than the information the photograph specifies about the world it represents.

7. Analyses of Individual Measures for MATCH Photo 2

After children had an opportunity to examine and talk about their first MATCH photo, they were encouraged to make any changes they wanted before taking a second MATCH photo. As noted earlier, 32 first MATCH photos and 37 second MATCH photos were scorable on all measures. Observations and interviews suggest that several children may have approached the first MATCH photo opportunity as a practice trial. Interestingly, however, there is a clear and consistent pattern of findings for individual measures and sub-scales: all measures that showed significant association with age for MATCH photo 1 do so for MATCH photo 2, and those that were not significantly associated with age remain so. What children say about their first MATCH photo and what they do before taking their second will be detailed in a later section.

The intentionality measure for MATCH photo 2, measuring the degree to which the child attempts a specifically intended solution to the task, is significantly associated with age (Gamma = .76, $p < .05$, Table 29, Gamma for MATCH photo 1 = .70, Table 14). Again, please note that although there were only 37 second MATCH photos scorable on the sub-scale measures, 46 children out of the total sample of 47 produced second MATCH photos which were scored for intentionality.

Table 29

Intentionality of Attempt of MATCH Photo 2 by Age (Number of Subjects)

		Age (in years)						
Intentionality of Photo 2	Code	3	4	5	6	7	8	Total/ Percent
Random	0	2	1					3 6.5
Photo of TARGET Photo	1	1				1		2 4.3
Intentional w/o Reconstruction	2	2	1	1				4 8.7
Intentional w/ Reconstruction	3		8	5	8	11	5	37 80.4
Column Total		5	10	6	8	12	5	46
Column Percent		10.9	21.8	13.1	17.4	26.0	10.9	100.0

Statistic	Value	T-value	p-value
Gamma	.75668	3.29488	$p<.05$

Again, the remaining measures are organized by sub-scales "World," "Sub-photo," and "Photographer."

"World" Sub-scale for Second MATCH Photo. As noted in Table 13, this sub-scale shows a similar correlation with age for MATCH photo 2 ($r=.78$, $p<.001$) as for MATCH photo 1 ($r=.72$, $p<.001$). As with MATCH photo 1, all four items that make up this scale show significant associations with age: the number of target features the child included in the reconstructed array (out of 12) increased with age (Gamma = .52, $p<.05$, Table 28; Gamma for MATCH 1 = .55, Table 15); the number of extraneous features included in the array decreased with age (Gamma =

.72, $p<.05$, Table 31; Gamma for MATCH 1 = .63, Table 16); the number of correct interobject relationships arranged in the array (out of 16) increased with age (Gamma = .72, $p<.05$, Table 32; Gamma for MATCH 1 = .75, Table 17); and the number of correct intraobject relationships arranged in the array (out of 14) increased with age (Gamma = .63, $p<.05$, Table 33; Gamma for MATCH 1 = .60, Table 18).

Table 30

Number of Subjects Including Target Features in Array 2 by Age

	Age (in years)					
Number of Target Features in Array 2	4	5	6	7	8	Total/ Percent
2 Features	1					1 2.7
3 Features	2			1		3 8.1
4 Features	1	2				3 8.1
5 Features		2	1			3 8.1
6 Features	3			1		4 10.8
7 Features	1					1 2.7
8 Features					2	2 5.4
9 Features		1	3	3	1	8 21.6
10 Features			1	2		3 8.1
11 Features				1		1 2.7
12 Features			3	3	2	8 21.6
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.51685	4.56167	$p<.05$

Table 31

Number of Subjects Including Extraneous Features in Array 2 by Age

	Age (in years)					
Number of Extra Features in Array 2	4	5	6	7	8	Total/ Percent
9 Features	2	1				3 8.1
8 Features	1					1 2.7
7 features			1			1 2.7
5 Features	1					1 2.7
3 Features	2	1				3 8.1
2 Features	1	1		2		4 10.8
1 Feature		1				1 2.7
0 Features	1	1	7	9	5	23 62.2
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.71739	5.78400	$p < .05$

Table 32

Number of Subjects Including Interobject Relationships in Array 2 by Age

Number of Interobject Relationships in Array 2	Age (in years) 4	5	6	7	8	Total/ Percent
0 Relationships	2	1	1			4 10.8
1 Relationship	3	1				4 10.8
2 Relationships		1				1 2.7
3 Relationships	1			2		3 8.1
4 Relationships	1	1				2 5.4
6 Relationships	1					1 2.7
7 Relationships			1			1 2.7
8 Relationships			2			2 5.4
10 Relationships			1			1 2.7
11 Relationships		1	1	1		3 8.1
12 Relationships			1			1 2.7
13 Relationships					1	1 2.7
14 Relationships				1		1 2.7
15 Relationships				2		2 5.4
16 Relationships			1	5	4	10 27.0
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.71691	10.62723	$p < .05$

Table 33

Number of Subjects Including Intraobject Relationships in Array 2 by Age

Number of Intraobject Relationships in Array 2	Age (in years) 4	5	6	7	8	Total/ Percent
0 Relationships	3	1				4 10.8
1 Relationship	1	1		1		3 8.1
2 Relationships	1					1 2.7
3 Relationships		1				1 2.7
4 Relationships	1					1 2.7
5 Relationships	2	1				3 8.1
6 Relationships			3	2	1	6 16.2
7 Relationships				3		3 8.1
8 Relationships		1				1 2.7
9 Relationships			3	2	1	6 16.2
10 Relationships			1	1	1	3 8.1
11 Relationships			1	1	1	3 8.1
13 Relationships				1	1	2 5.4
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.62976	6.75756	$p < .05$

"Sub-Photo" Sub-scale for Second MATCH Photo. Again, Table 13 indicated that a significant correlation with age for this sub-scale for second MATCH photos as well. The correlation was even stronger for MATCH photo 2 ($r=.77$, $p<.001$) than MATCH photo 1 ($r=.70$, $p<.001$). Again, all five measures making up this sub-scale show significant associations with age: inclusion of the correct table and corner in the MATCH 2 photo increased with age (Gamma = .60, $p<.05$, Table 34; Gamma for MATCH photo 1 = .62, Table 19); the number of target features captured in MATCH photo 2 (out of 12) increased with age (Gamma = .55, $p<.05$, Table 35; Gamma for MATCH photo 1 = .55, Table 20); the number of extraneous features decreased with age (Gamma = .55, $p<.05$, Table 36; Gamma for MATCH photo 1 = .35, Table 21); the number of correct interobject relationships captured in the photo (out of 16) increased with age (Gamma = .68, $p<.05$, Table 37; Gamma for MATCH photo 1 = .71, Table 22); and the number of intraobject relationships captured in the photo (out of 14) increased with age (Gamma = .69,, $p<.05$, Table 38; Gamma for MATCH photo 1 = .56, Table 23).

The increases in Gamma values for the extraneous features measure (which was significant but relatively weak for MATCH photo 1) and the intraobject relationships measure support the hypothesis that the first MATCH photo may have served as a practice trial for the younger children. The increases also suggest there may be practice effects across MATCH photos in addition to developmental differences shown by children at different age levels.

Tables 34-38 present the data for these MATCH photo 2 measures.

Table 34

Table and Corner Appear in MATCH Photo 2 by Age (Number of Subjects)

Table and Corner in Photo 2	Code	Age (in years) 4	5	6	7	8	Total/ Percent
Neither	0	8	4	1	2		15 40.5
Table	1		1	2	2	3	8 21.6
Table & Corner	2			5	7	2	14 37.8
Column Total		8	5	8	11	5	37
Column Percent		21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.60391	5.15655	$p<.05$

Table 35

Number of Subjects Including Target Features in MATCH Photo 2 by Age

	Age (in years)					
Number of Target Features in Photo 2	4	5	6	7	8	Total/ Percent
0 Features				1		1 2.7
2 Features	2					2 5.4
3 Features	1	1				2 5.4
4 Features	3	2		1		6 16.2
5 Features	1		1			2 5.4
6 Features	1	1				2 5.4
7 Features			1			1 2.7
8 Features		1		2	2	5 13.5
9 Features			2	2	1	5 13.5
10 Features			1	2		3 8.1
11 Features			1	1		2 5.4
12 Features			2	2	2	6 16.2
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.54862	4.77133	$p<.05$

Table 36

Number of Subjects Including Extraneous Features in MATCH Photo 2 by Age

	Age (in years)					
Number of Extra Features in Photo 2	4	5	6	7	8	Total/ Percent
10 Features	1		1			2 5.4
7 Features	2	1				3 8.1
6 Features	2	1				3 8.1
4 Features				1		1 2.7
3 Features	1					1 2.7
2 Features	2			2		4 10.8
1 Feature		3	1	1	2	7 18.9
0 Features			6	7	3	16 43.2
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.54701	5.74588	$p < .05$

Table 37

Number of Subjects Including Interobject Relationships in MATCH Photo 2 by Age

	Age (in years)					
Number of Interobject Relations in Photo 2	4	5	6	7	8	Total/ Percent
0 Relationships	3	1	1	2		7 18.9
1 Relationship	2	1				3 8.1
2 Relationships		1				1 2.7
3 Relationships	2	1				3 8.1
4 Relationships	1		1			2 5.4
6 Relationships		1				1 2.7
7 Relationships			2	1		3 8.1
8 Relationships			1			1 2.7
11 Relationships			1	1	1	3 8.1
12 Relationships			1	2		3 8.1
13 Relationships					1	1 2.7
14 Relationships				1		1 2.7
16 Relationships			1	4	3	8 21.6
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.68073	7.74618	$p < .05$

Table 38

Number of Subjects Including Intraobject Relationships in MATCH Photo 2 by Age

	Age (in years)					
Number of Intraobject Relations in Photo 2	4	5	6	7	8	Total/ Percent
0 Relationships	3			1		4 10.8
1 Relationship	1	2				3 8.1
2 Relationships	2					2 5.4
3 Relationships	1	1				2 5.4
4 Relationships	1	1	1	1		4 10.8
5 Relationships		1	1	1	1	4 10.8
6 Relationships			2	2		4 10.8
7 Relationships				2		2 5.4
8 Relationships				1		1 2.7
9 Relationships			4	1	1	6 16.2
10 Relationships				1	1	2 5.4
11 Relationships					1	1 2.7
13 Relationships				1	1	2 5.4
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.69424	7.734498	$p < .05$

"Photographer" Sub-scale for Second MATCH Photo. Finally, Table 13 indicated that this sub-scale showed relatively weaker, though statistically significant, correlations with age than the other two sub-scales. Although the correlation between the Photographer sub-scale and age is higher for MATCH photo 2 ($r=.57$, $p<.001$) than for MATCH 1 ($r=.59$, $p<.001$), again only two component measures, the same two as for MATCH photo 1, show a significant association with age: the number of appropriate occlusions captured in MATCH photo 2 (out of four) increased with age (Gamma = .74, $p<.05$, Table 42; Gamma for MATCH photo 1 = .81, Table 27) as does the number of accurate occlusions (Gamma = .83, $p<.05$, Table 43; Gamma for MATCH photo 1 = .88, Table 28). Most of the children performed relatively poorly on the remaining measures (Tables 39 - 41), again suggesting that children in the studied age groups are either not sensitive to the photographer-specifying information in the TARGET photo or this aspect of the task is too difficult for most of them.

Tables 39 - 43 present the data for the five measures that constitute the Photographer sub-scale. Section 8 provides a finer breakdown of the errors on the measures that showed no significant association with age.

Table 39

Centeredness of the Objects in MATCH Photo 2 by Age (Number of Subjects)

		Age (in years)					
Centeredness of Photo 2	Code	4	5	6	7	8	Total/ Percent
Not Centered	0	4	2	5	8	4	23 62.2
Centered	1	4	3	3	3	1	14 37.8
Column Total		8	5	8	11	5	37
Percent Centered by Age		50.0	60.0	37.5	27.3	20.0	

Statistic	Value	T-value	p-value
Gamma	-.32192	-1.61096	ns

Table 40

Height of Station Point of MATCH Photo 2 by Age (Number of Subjects)

		Age (in years)					
Height of Station Point for Photo 2	Code	4	5	6	7	8	Total/ Percent
Too High or Too Low	0	7	4	6	10	4	31 83.8
Correct	1	1	1	2	1	1	6 16.2
Column Total		8	5	8	11	5	37
Percent Correct by Age		12.5	20.0	25.0	9.0	20.0	

Statistic	Value	T-value	p-value
Gamma	.07229	.26072	ns

Table 41

Correct Distance (Size of Objects) for MATCH Photo 2 by Age (Number of Subjects)

		Age (in years)					
Distance from Array in Photo 2	Code	4	5	6	7	8	Total/ Percent
Too Close or Too Far	0	8	4	6	10	3	31 83.8
Correct	1		1	2	1	2	6 16.2
Column Total		8	5	8	11	5	37
Percent Correct by Age		0.0	20.0	25.0	9.0	40.0	

Statistic	Value	T-value	p-value
Gamma	.34545	1.24719	ns

Table 42

Number of Subjects Including Appropriate Occlusions in MATCH Photo 2 by Age

	Age (in years)					
Number of Appropriate Occlusions in Photo 2	4	5	6	7	8	Total/ Percent
0 Occlusions	7	3	6	3		19 51.4
1 Occlusion	1	2		1		4 10.8
2 Occlusions				3		3 8.1
3 Occlusions			2	1	2	5 13.5
4 Occlusions				3	3	6 16.2
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.73522	7.30668	$p < .05$

Table 43

Number of Subjects Including Accurate Occlusions in MATCH Photo 2 by Age

	Age (in years)					
Number of Accurate Occlusions in Photo 2	4	5	6	7	8	Total/ Percent
0 Occlusions	8	5	8	8	3	32 86.5
1 Occlusion				1	2	3 8.1
2 Occlusions				1		1 2.7
3 Occlusions				1		1 2.7
Column Total	8	5	8	11	5	37
Column Percent	21.6	13.5	21.6	29.7	13.5	100.0

Statistic	Value	T-value	p-value
Gamma	.82781	2.81571	$p<.05$

To summarize, the pattern of findings regarding the sub-scale measures for MATCH photo 2 parallel those found for MATCH photo 1: all four items comprising the World sub-scale were significantly related to age and the measures constituting the Sub-photo sub-scale were even more strongly associated with age on the second MATCH photo than the first. Finally, the same two items in the Photographer sub-scale that showed significant relationship to age on MATCH photo 1 did so again on MATCH photo 2 (inclusion of appropriate and of accurate occlusions) and the remaining three items were again not significant (horizontal centeredness, height of the station point, and distance from the array).

However, the correlations of the three sub-scales to age were generally stronger and the Gamma values higher for MATCH photo 2 than MATCH photo 1. This suggests there may be practice effects across MATCH photos in addition to developmental differences shown by children at different age levels.

8. Analyses of "Photographer" Errors

The three component measures of the Photographer sub-scale that showed no significant association with age focus on the information in the TARGET photo that specifies from where the photograph was taken. Tables 44-52 present the breakdown of positional errors by age for "scorable" pretask MATCH, task MATCH 1, and task MATCH 2 photos (random photographs were dropped for the purposes of these calculations; only one task MATCH photo 1 was scored "unreadable" by all three coders). Since positional error is not a truly ordered variable, Gamma coefficients would not be the appropriate test. However, it is possible to calculate a Chi Square test for the difference in frequency of the different bias errors that can occur: too much to the right versus too much to the left (horizontal centeredness); too high versus too low (vertical centeredness of height of the station point); and too close versus too far (distance).

The Chi Square tests for horizontal centeredness for the pretask (Table 44), MATCH 1 (Table 45), and MATCH 2 (Table 46) photos show no bias in favor of right versus left. No particular error of height of station point appears favored by children across age for the pretask MATCH photo (Table 47). However, children

committed the "too low" error more frequently on task MATCH photo 1 (Table 48, $\chi^2(1)=5.26$, $p=.02$) and MATCH photo 2 (Table 49, $\chi^2(1)=4.65$, $p=.03$).

Finally, there is a strong bias in favor of being too close to the array on the pretask MATCH photo (Table 50, $\chi^2(1)=23.08$, $p<.001$). Interestingly, this bias drops off in the task: though children still tended to be too close to the array when they took their first and second task MATCH photos, the difference between the incidence of too close vs. too far errors was not statistically significant (Tables 51 and 52).

Table 44

Horizontal Centeredness Errors on Pretask MATCH Photo by Age (Number of Subjects)

		Age (in years)						
Centeredness Errors on Pretask Photo	Code	3	4	5	6	7	8	Total/ Percent
Left	1	1	3	2	3	3	2	14 35.0
Right	2	3	5	1	4	2	1	16 40.0
Centered	3			1	1	6	2	10 25.0
Column Total		4	8	4	8	11	5	40
Percent Centered by Age		0.0	0.0	25.0	12.5	54.5	40.0	

Table 45

Horizontal Centeredness Errors on Task MATCH Photo 1 by Age (Number of Subjects)

		Age (in years)					
Centeredness Errors on MATCH Photo 1	Code	4	5	6	7	8	Total/ Percent
Random	0	1					1 3.1
Left	1	3	1	3	3		10 31.3
Right	2	1	1	4	5	3	14 43.8
Correct	3	1	1	1	2	2	7 21.9
Column Total		6	3	8	10	5	32
Percent Correct by Age		16.7	33.3	12.5	20.0	40.0	

Table 46

Horizontal Centeredness Errors on Task MATCH Photo 2 by Age (Number of Subjects)

		Age (in years)					
Centeredness Errors On MATCH Photo 2	Code	4	5	6	7	8	Total/ Percent
Left	1	2		2	4	2	10 27.0
Right	2	2	2	3	4	2	13 35.1
Correct	3	4	3	3	3	1	14 37.8
Column Total		8	5	8	11	5	37
Percent Correct by Age		50.0	60.0	37.5	27.2	20.0	

Tables 47 - 49 present the frequencies of errors of height of station point (vertical centeredness) on the pretask MATCH, task MATCH 1, and MATCH 2 photos by age.

Table 47

Height of Station Point Errors on Pretask MATCH Photo by Age (Number of Subjects)

		Age (in years)						
Height Errors on Pretask Photo	Code	3	4	5	6	7	8	Total/ Percent
High	1	1	4	1	2	3	2	13 32.5
Low	2	3	2	3	5	6	1	20 50.0
Correct	3		2		1	2	2	7 17.5
Column Total		4	8	4	8	11	5	40
Percent Correct by Age		0.0	25.0	0.0	12.5	18.0	40.0	

Table 48

Height of Station Point Errors on Task MATCH Photo 1 by Age (Number of Subjects)

		Age (in years)					
Height Errors on MATCH Photo 1	Code	4	5	6	7	8	Total/ Percent
High	1	2			2		4 12.5
Low	2	2	3	3	6	1	15 46.9
Correct	3	2		5	2	4	13 40.6
Column Total		6	3	8	10	5	32
Percent Correct by Age		33.3	0.0	62.5	20.0	80.0	

Table 49

Height of Station Point Errors on Task MATCH Photo 2 by Age (Number of Subjects)

		Age (in years)					
Height Errors on MATCH Photo 2	Code	4	5	6	7	8	Total/ Percent
High	1	2	1	2	4		9 24.3
Low	2	5	3	4	6	4	22 59.5
Correct	3	1	1	2	1	1	6 16.2
Column Total		8	5	8	11	5	37
Percent Correct by Age		12.5	20.0	25.0	9.0	20.0	

Tables 50 - 52 present the frequencies of distance errors made on the pretask MATCH, task MATCH 1, and MATCH 2 photos by age.

Table 50

Distance Errors on Pretask MATCH Photo by Age (Number of Subjects)

		Age (in years)						
Distance Errors on Pretask Photo	Code	3	4	5	6	7	8	Total/ Percent
Too Close	1	4	8	4	7	10	2	35 87.5
Too Far	2				1	1	2	4 10.0
Correct	3						1	1 2.5
Column Total		4	8	4	8	11	5	40
Percent Correct by Age		0.0	0.0	0.0	0.0	0.0	20.0	

Table 51

Distance Errors on Task MATCH Photo 1 by Age (Number of Subjects)

		Age (in years)					
Distance Errors on MATCH Photo 1	Code	4	5	6	7	8	Total/ Percent
Too Close	1	4	1	4	4	2	15 46.9
Too Far	2	2	1	4	4	2	13 40.0
Correct	3		1		2	1	4 12.5
Column Total		6	3	8	10	5	32
Percent Correct by Age		0.0	33.3	0.0	20.0	20.0	

Table 52

Distance Errors on Task MATCH Photo 2 by Age (Number of Subjects)

Distance Errors on MATCH Photo 2	Code	Age (in years) 4	5	6	7	8	Total/ Percent
Too Close	1	7	3	3	4	1	18 48.6
Too Far	2	1	1	3	6	2	12 35.1
Correct	3		1	2	1	2	6 16.2
Column Total		8	5	8	11	5	37
Percent Correct by Age		0.0	20.0	25.0	9.0	40.0	

9. Analyses of Experimenter-Judged Accuracy Errors, Children's Comments About What They Would Have to Do to Improve the Accuracy of Their MATCH Photos, and What Children Do to Correct Accuracy Errors

This section first presents the results of analyses of what the Experimenter judged to be the errors of accuracy, what children said they would have to do to make the next MATCH photo look more like the TARGET, and what children did to correct the accuracy of the MATCH photos. This is followed by a presentation of the analysis of the correlation between children's comments about what changes they would need to make and what adjustments they actually made before taking their next MATCH photo.

Accuracy errors, children's verbal assessments of the errors of their own photos, and the types of adjustments they made were categorized and coded to constitute ordered variables reflecting levels of sophistication of response. Types of errors, comments, and actions were crosstabulated with age and Gamma coefficients were calculated. Because all children were asked about their MATCH photos and encouraged to take additional ones, these measures were applied to the total sample in the study.

Experimenter-Judged Errors, Child Comments, and Child Adjustments. Based on the finding that children were better at accurately reconstructing the array from the information available in the TARGET photo than they were at assuming the uniquely correct station point (as reflected in higher and more age-related "world" scores than "photographer" scores), the errors of the MATCH photos as judged by the Experimenter were categorized and coded as follows:

- no judgeable photographic image = 0
- errors of array **and** station point = 1
- error of array only = 2
- error of station point only = 3
- no errors = 4

The comments children made about what they would have to do to make the next MATCH photo look more like the TARGET were categorized and coded as follows:

- no comment or irrelevant comment = 0

- relevant assessment of array correction = 1
- relevant assessment of station point correction = 2
- relevant assessment of array- **and** station point corrections = 3

The actions children undertook to make the next MATCH photo look exactly like the TARGET photo were categorized and coded as follows:

- no action or irrelevant action = 0
- relevant actions to correct array = 1
- relevant actions to correct station point = 2
- relevant actions to correct array **and** station point = 3

Tables 53-57 present the breakdown by age of:

- what the Experimenter judged to be the error of the first MATCH photo (Table 53);
- the children's descriptions, after reviewing MATCH photo 1, of what they would have to do to make the next MATCH photo more accurate (Table 54);
- what adjustments the child actually makes after the first effort (Table 55);
- the Experimenter-judged error of MATCH photo 2 (Table 56); and,
- the children's comments, after reviewing MATCH photo 2, about what they would have to do to make the next MATCH photo look more exactly like the TARGET photo (Table 57).

We find significant associations with age for the level of sophistication of the assessments children make about what in their MATCH photos needs to be fixed (Table 54, Gamma = .53, $p<.05$; Table 57, Gamma = .48, $p<.05$) and for the level of sophistication of what children do to make the next MATCH photo more exactly like the TARGET photo (Table 55, Gamma=.61, $p<.05$).

The level of sophistication of the errors of MATCH photo 2 as judged by the Experimenter also shows a significant association with age (Table 56, Gamma = .63, $p<.05$). It is interesting to note that the errors become more diverse from MATCH photo 1 (Table 53) to MATCH photo 2 (Table 56). This suggests some sort of practice effect: the child's first MATCH photo is an initial approximation of the TARGET photo; subsequent MATCH photos are more fine-tuned efforts.

Although there are similar age trends for what children say they would need to do to fix their first MATCH photo and what they actually adjust (Table 54 and Table 55), what they do to correct errors is in general more sophisticated than what they say is wrong. That is, there are more responses at the upper level of the coding scheme for what they do to fix the first MATCH photo (60.9%, Table 55) than there are for what they say they should do (21.3%, Table 54). This suggests that children's ability to identify and act on the information in their MATCH photos that is dissonant with the TARGET photo is more advanced than their ability to explain the nature of the dissonance. This finding will be discussed later.

Table 53

Experimenter-Judged Error of MATCH Photo 1 by Age (Number of Subjects)

Error of MATCH Photo 1	Code	Age (in years) 3	4	5	6	7	8	Total/ Percent
No Judgeable Photo	0	2	1			1		4 8.5
Array and Station Point Errors	1	3	10	6	8	11	5	43 91.5
Array Error Only	2							
Station Point Error Only	3							
No Error	4							
Column Total		5	11	6	8	12	5	47
Column Percent		10.6	23.4	12.7	17.0	25.6	10.6	100.0

Statistic	Value	T-value	p-value
Gamma	.55975	1.44379	ns

Table 54

What Child Says to Do to Fix MATCH Photo 1 by Age (Number of Subjects)

		Age (in years)						
Fix Talk About MATCH Photo 1	Code	3	4	5	6	7	8	Total/ Percent
Irrelevant or No Comment	0	3	5	2	1	1		12 25.5
Relevant Array Comment Only	1	1	6	3	3	7	3	23 48.9
Relevant Station Pt Comment Only	2			1	1			2 4.3
Relevant Array and Station Comment	3	1			3	4	2	10 21.3
Column Total		5	11	6	8	12	5	47
Column Percent		10.6	23.4	12.7	17.0	25.6	10.6	100.0

Statistic	Value	T-value	p-value
Gamma	.53049	4.07379	$p<.05$

Table 55

What Child Does to Fix MATCH Photo 1 by Age (Number of Subjects)

		Age (in years)						
Do to Fix MATCH Photo 1	Code	3	4	5	6	7	8	Total/ Percent
Irrelevant or No Action	0	5	2			1		8 17.4
Relevant Array Action Only	1		3	2		1	1	7 15.2
Relevant Station Point Action Only	2			1	2			3 6.5
Relevant Array and Station Action	3		5	3	6	10	4	28 60.9
Column Total		5	10	6	8	12	5	46
Column Percent		10.9	21.8	13.1	17.4	26.0	10.9	100.0

Statistic	Value	T-value	p-value
Gamma	.61497	3.82390	$p < .05$

Table 56

Experimenter-Judged Error of MATCH Photo 2 by Age (Number of Subjects)

Error of MATCH Photo 2	Code	Age (in years) 3	4	5	6	7	8	Total/ Percent
No Judgeable Photo	0	3	1			1		5 10.9
Array and Station Point Error	1	2	9	6	7	11	4	39 84.8
Array Error Only	2				1			1 2.2
Station Point Error Only	3							
No Error	4						1	1 2.2
Column Total		5	10	6	8	12	5	46
Column Percent		10.9	21.8	13.1	17.4	26.0	10.9	100.0

Statistic	Value	T-value	p-value
Gamma	.63359	2.236635	$p < .05$

Table 57

What Child Says to Do to Fix MATCH Photo 2 by Age (Number of Subjects)

		Age (in years)						
Fix Talk About MATCH Photo 2	Code	3	4	5	6	7	8	Total/ Percent
Irrelevant or No Comment	0	3	5	3	2		2	15 32.6
Relevant Array Comment Only	1	2	5	2	4	8	2	23 50.0
Relevant Station Pt Comment Only	2			1	2			3 6.5
Relevant Array and Station Comment	3					4	1	5 10.9
Column Total		5	10	6	8	12	5	46
Column Percent		10.9	21.8	13.1	17.4	26.0	10.9	100.0

Statistic	Value	T-value	p-value
Gamma	.48282	3.37399	$p<.05$

Further Analysis of the Relation Between What Children Say and What Children Do. The comparison of what children say they would have to do to fix their first MATCH photo with what they actually do further supports the finding that what children do to make their next MATCH photo look more exactly like the TARGET photo tends to be much more sophisticated than their talk about what they need to do. The association between what they say and what they do is significant (Gamma = .53, $p<.05$, Table 58), but, again, the physical adjustments (reflected in what they do after reviewing the first MATCH photo, Table 55) tend to be more sophisticated than the children's explanations of what should be corrected (reflected in their talk about

how to fix the first MATCH photo, Table 54). For example, as shown in Table 58, there are 11 children who offer irrelevant verbal comments about what to do to fix the first MATCH photo but only 4 make irrelevant adjustments. Seven of the 11 children made at least some relevant adjustment before taking their next MATCH photo. Looking at the data in Table 58 as though the table were a scattergram, we see frequencies occurring on the diagonal, showing that there is agreement between what the children said and what they actually did, but we also see many children represented above the diagonal. These are the children who exhibited more complex actions to fix the MATCH than they were able to talk about.

Table 58

What Child Says to Do to Fix MATCH Photo 1
by What Child Does to Fix MATCH 1 (Number of Subjects)

		Do to Fix MATCH Photo 1				
		Irrelevant or No Action	Relevant Array Action Only	Relevant Station Pt Action Only	Relevant Array and Station Action	
Fix Talk About MATCH Photo 1	Code	0	1	2	3	Total/ Percent
Irrelevant or No Comment	0	4	4		3	11 23.9
Relevant Array Comment Only	1	3	3	1	16	23 50.0
Relevant Station Point Comment Only	2			2		2 4.3
Relevant Array and Station Comment	3	1			9	10 21.7
Column Total		8	7	3	28	46
Column Percent		17.4	15.2	6.5	60.9	100.0

Statistic	Value	T-value	p-value
Gamma	.53380	2.87876	$p<.05$

While there is also a significant association between what children said about what to do on MATCH photo 1 and what they said about what to do on MATCH photo 2 (Gamma = .88, $p<.05$, Table 59), less change in the level of sophistication of the explanations from MATCH photo 1 to MATCH photo 2 is noted, in contrast to the change from what children said they would have to do to fix their MATCH photo 1 to what adjustments they actually made (Table 58). There is much less "scatter" to the pattern of the "fix talk" by "fix talk" data in Table 59 than in the "fix talk" by "fix

do" data in Table 58, suggesting that children's talk does not change much across trials; talk appears unaffected by doing. This is confirmed by the very high Gamma statistic (Gamma=.88, $p<.05$, Table 59) obtained for the "fix talk" by "fix talk" analysis and suggests there is little discernable practice effect or micro-development for explanations across the task trails.

Table 59

What Child Says to Do to Fix MATCH Photo 1
by What Child Says to Do to Fix MATCH Photo 2 (Number of Subjects)

		Fix Talk About MATCH Photo 2				
		Irrelevant or No Comment	Relevant Array Comment Only	Relevant Station Pt Comment Only	Relevant Array & Station Pt Comment	Total/ Percent
Fix Talk About MATCH Photo 1	Code	0	1	2	3	
Irrelevant or No Comment	0	9	2			11 23.9
Relevant Array Comment Only	1	6	16		1	23 50.0
Relevant Station Pt Comment Only	2			2		2 4.3
Relevant Array & Station Pt Comment	3		5	1	4	10 21.7
Column Total		15	23	3	5	46
Column Percent		32.6	50.0	6.5	10.9	100.0

Statistic	Value	T-value	p-value
Gamma	.87976	6.686470	$p<.05$

Further Analyses of Experimenter-Judged Errors, What Children Say and What They Do to Fix the Next MATCH Photo. A look at the relationship between the errors of their MATCH photos and what children said needed to be fixed again supports the findings regarding children's talk about their MATCH photos being less sophisticated than what they do. As can be seen in Tables 60 and 61, no significant association is found between the error of the MATCH photo and what children said was the error even though the Gamma coefficients are rather high. This appears to be due to the lack of variability in the types of errors on MATCH photo 1. As a result, there is no discernable relationship between what is wrong and what children say needs to be fixed.

Table 60

Experimenter-Judged Error of MATCH Photo 1
by What Child Says to Do to Fix MATCH Photo 1 (Number of Subjects)

		Fix Talk About MATCH Photo 1				
		Irrelevant or No Comment	Relevant Array Comment Only	Relevant Station Pt Comment Only	Relevant Array & Station Pt Comment	Total/ Percent
Experimenter-Judged Error of MATCH Photo 1	Code	0	1	2	3	
No Judgeable Photo	0	3	1			4 8.5
Array and Station Point Errors Action	1	9	22	2	10	43 91.5
Column Total		12	23	2	10	47
Column Percent		25.5	48.9	4.3	21.3	100.0

Statistic	Value	T-value	p-value
Gamma	.85366	1.93725	ns

Table 61

Experimenter-Judged Error of MATCH Photo 2
by What Child Says to Do to Fix MATCH Photo 2 (Number of Subjects)

		Fix Talk About MATCH Photo 2				
		Irrelevant or No Comment	Relevant Array Comment Only	Relevant Station Pt Comment Only	Relevant Array & Station Pt Comment	Total/ Percent
Experimenter-Judged Error of MATCH Photo 2	Code	0	1	2	3	
No Judgeable Photo	0	4	1			5 10.9
Array and Station Point Errors	1	10	21	3	5	39 84.8
Array Error Only	2		1			1 2.2
No Error	4	1				1 2.2
Column Total		15	23	3	5	46
Column Percent		32.6	50.0	6.5	10.9	100.0

Statistic	Value	T-value	p-value
Gamma	.47594	1.37869	ns

Given that children's explanations of the errors of their MATCH photos were less complex (and less thorough) than what they actually did to fix the next MATCH photo and that the complexity of their talk did not change across trials, a further look at the relationship between errors of the MATCH photos and what children actually did to fix the subsequent MATCH photos and between the errors of the first MATCH photos and the errors of the subsequent MATCH photos proves informative.

The relationship between the error of the first MATCH photo and what the

children did to fix the subsequent MATCH photo is significant (Gamma = 1, $p<.05$, Table 62): what children did to fix the next MATCH photo tended to be more relevant to the error of the reviewed MATCH photo or more sophisticated than their verbal explanations of what they would have to do. In other words, although children did not fully articulate what was wrong with the MATCH photo, they tended to go about fixing it in relevant ways (defined in terms of array and station point).

Table 62

Experimenter-Judged Error of MATCH Photo 1
by What Child Does to Fix MATCH Photo 1 (Number of Subjects)

		Do to Fix MATCH Photo 1				
		Irrelevant or No Action	Relevant Array Action	Relevant Station Pt Action	Relevant Array & Station Pt Action	Total/ Percent
Experimenter-Judged Error of MATCH Photo 1	Code	0	1	2	3	
No Judgeable Photo	0	4				4 8.7
Array and Station Point Errors	1	4	7	3	28	42 91.3
Column Total		8	7	3	28	46
Column Percent		17.4	15.2	6.5	60.9	100.0

Statistic	Value	T-value	p-value
Gamma	1.0000	2.2984	$p<.05$

If we find a significant association between the errors of the first and second MATCH photos, we may say that the child's actions to fix the first MATCH photo were, at least to some degree, effective. However, if the association is not significant, it could be that the child's actions were in the right direction but not sufficient to completely repair the problem. Table 63 presents the comparison of the errors of the first MATCH photo with those of the second. In fact, the photos tend to have the same types of errors: the pattern of the data shows most children were on the diagonal indicating they were making the same kinds of errors.

Table 63

Experimenter-Judged Error of MATCH Photo 1
by Experimenter-Judged Error of MATCH Photo 2 (Number of Subjects)

		Experimenter-Judges Error of MATCH Photo 2				
		No Judgeable Photo	Array & Station Point Errors	Array Error Only	No Error	Total/ Percent
Experimenter-Judged Error of MATCH Photo 1	Code	0	1	2	4	
No Judgeable Photo	0	4				4 8.7
Array and Station Point Errors	1	1	39	1	1	42 91.3
Column Total		5	39	1	1	46
Column Percent		10.9	84.8	2.2	2.2	100.0

Statistic	Value	T-value	p-value
Gamma	1.0000	2.30981	$p<.05$

A comparison of what children do after reviewing their MATCH photo in preparation for their next and the Experimenter-judged error of the next MATCH photo (Table 64) shows that the more sophisticated their actions the less serious the errors on the subsequent MATCH photo: the more sophisticated the "fix" is, the more successful the resulting MATCH photo is.

Table 64

What Child Does to Fix MATCH Photo 1
by Experimenter-Judged Error of MATCH Photo 2 (Number of Subjects)

		Experimenter-Judged Error of MATCH Photo 2				
		No Judgeable Photo	Array + Station Point Errors	Array Error Only	No Error	Total/ Percent
Do to Fix MATCH Photo 1	Code	0	1	2	4	
Irrelevant or No Action	0	5	3			8 17.4
Relevant Array Action	1		7			7 15.2
Relevant Station Pt Action	2		3			3 6.5
Relevant Array & Station Pt Action	3		26	1	1	28 60.9
Column Total		5	39	1	1	46
Column Percent		10.9	84.8	2.2	2.2	100.0

Statistic	Value	T-value	p-value
Gamma	1.0000	3.06608	$p<.05$

When we compare what children did after reviewing their first MATCH photo to fix the next one with what they did after reviewing the second MATCH photo to fix the subsequent one we see from the pattern of the data that, while their talk about fixes did not change much (Table 59), what they did changed dramatically (Table 65). (It is important to keep in mind that what children did to fix MATCH photo 1 refers to actions taken to prepare a more accurate Match photo 2 and that what children did to fix MATCH photo 2 refers to actions that led to the production of MATCH photo 3.)

Looking at the pattern of the data in Table 65, we see that children carried out more varied and sophisticated adjustments after reviewing the second photo (in preparation for the third) than they did after reviewing the first MATCH photo: they exhibited a broader and more sophisticated range of adjustments (in regard to array and station point) in the second instance. In other words, we cannot predict what they will do in the second instance based on what they did in the first. The low Gamma statistic confirms this. Again, this reconfirms the finding that what children did to fix their MATCH photos tended to be more advanced than their talk about what would fix the photos. It also appears to suggest a strong learning effect from reviewing and acting on MATCH photo 1 to acting on MATCH photo 2 in preparation for the third photo.

Table 65

What Child Does to Fix MATCH Photo 1
by What Child Does to Fix MATCH Photo 2 (Number of Subjects)

		Do to Fix MATCH Photo 2				
		Irrelevant or No Action	Relevant Array Action	Relevant Station Point Action	Relevant Array & Station Pt Action	Total/ Percent
Do to Fix MATCH Photo 1	Code	0	1	2	3	
Irrelevant or No Action	0	5			1	6 17.1
Relevant Array Action	1		1		5	6 17.1
Relevant Station Pt Action	2	1			1	2 5.7
Relevant Array & Station Pt Action	3	1	5	1	14	21 60.0
Column Total		7	6	1	21	35
Column Percent		20.0	17.1	2.9	60.0	100.0

Statistic	Value	T-value	p-value
Gamma	.49345	1.8937	ns

To summarize, the level of sophistication of both what children said needed to be fixed in their MATCH photos and what they actually did to make the next MATCH photo more accurate were significantly associated with age. Moreover, the Experimenter-judged error measure suggests a practice effect: children's first MATCH photos appeared to be initial approximations and their subsequent MATCH photos represented more fine-tuned efforts.

In general, what children did to correct errors was more sophisticated than what they articulated was wrong about the picture. This suggests that children's ability to

act on what is dissonant between their MATCH and the TARGET is more advanced than their ability to explain the nature of the dissonance. This finding is re-confirmed by additional analyses. First, most of the children who made irrelevant comments about what needed to be fixed actually went on to make relevant adjustments to the array and/or their station point. Second, there was comparatively limited "scatter" to the pattern across trials of children's talk about what needed to be fixed which suggests that acting did not affect their subsequent ability to articulate what they should do next. In other words, micro-development for explanations across task trials was not evident.

Further, no significant association between the error of the MATCH photo, as judged by the Experimenter, and what children said was the error was found. Also, what children did to fix the next MATCH photo tended to be more relevant to the error as judged by the Experimenter and more sophisticated than their verbal explanations of what they would have to do.

Finally, children carried out more varied and sophisticated repairs in response to their assessment of the second MATCH photo than they did after reviewing their first. This suggests a strong learning effect for the actions carried out to fix the next MATCH across task trials.

10. Analyses of Children's Choice of Best MATCH Photo and Adult-Judged Best MATCH Photo

When each child was either satisfied with the MATCH photos or had taken the

maximum (four), the Experimenter asked the child to select "the photo that looks most exactly like" the TARGET photo and then to explain why they selected the MATCH photo they did. Again, types of responses were coded into categories reflecting increasing levels of complexity and sophistication:

- "don't know" ("I don't know why, it just looks exactly the same"), and aesthetic explanations ("Because the colors are good and pretty") were coded 0;
- explanations having to do only with the contents of the array ("Because the same things are there") or general object relationships ("The things are in the same places") were coded 1;
- explanations that considered contents of the array **and** the relationships among (and/or within) objects ("It's the best because all the same things are where they should be next to each other") were coded 2;
- explanations that appreciated the coordination of array, object relationships **and** station point ("Well, see how everything is right. I got it to look exactly right: all the right pieces next to each other in the right way and facing the right way out, and I was standing right to get it all the same") were coded 3.

There is a significant association between the types of reasons children gave to justify their choice of "best" MATCH photo and age (Gamma = .50, $p < .05$, Table 66): older children were more likely to reflect on multiple objective criteria when explaining their choice of the best MATCH photo than younger children.

Table 66

Child's Explanation for Best MATCH Photo Pick by Age (Number of Subjects)

Why Pick This MATCH Photo?	Code	Age (in years) 3	4	5	6	7	8	Total/ Percent
Don't Know, Aesthetic Explanation	0	3	3			2		8 17.0
Contents/Object Relations Explanation	1	2	7	4	1	5	1	20 42.6
Array + Object Relations Explanation	2		1	2	4	2	3	12 25.5
Array + Obj. Rel. + Stat. Pt. Explanation	3				3	3	1	7 14.9
Column Total		5	11	6	8	12	5	47
Column Percent		10.6	23.4	12.7	17.0	25.6	10.6	100.0

Statistic	Value	T-value	p-value
Gamma	.49859	4.20987	$p<.05$

The Experimenter also selected the MATCH photo of each child that most closely reproduced the photographic image of the TARGET photo. Then, each MATCH photo was coded on what can be referred to as the "Pick" variable as:

- 3 if the photo was selected by both the child and adult as the best match;
- 2 if only the adult selected it;
- 1 if only the child selected it; and
- 0 if neither the adult nor the child selected it.

One could hypothesize that the photo picked by both the child and the adult as that child's best match to the TARGET (Pick 3) will have the highest sub-scores and total score of all the MATCH photos taken by that child, those selected by neither (Pick 0) will have the lowest scores, and those chosen by the child only (Pick 1) might have scores at an intermediate level.

Tables 67 - 70 present Total and sub-scale scores for MATCH photos by age across "best match" (or Pick) categories. MATCH photos selected as the best match by both the child and the adult (Pick 3) and those that neither picked (Pick 0) predominate. This is expected because these photos are complementary to one another (i.e., if both adult and child agree on one photo, then the others will necessarily be picked by neither and coded as 0). The "2" and "1" photos are much less frequent and seem to occur mostly in the middle age range (between 5 and 7 years). Children in the middle age range were, in fact, observed to focus on a particular dimension of the photo as they analyzed the degree of match. For example, some singled out and gave great weight to the size of the objects depicted in the frame, others settled on positional specifics. It may be that 5- to 7-year-olds are especially sensitive to particular aspects or dimensions of photos which, when assessing sameness with the TARGET, dominate their judgment.

Since not all Pick categories were represented at all age levels, we cannot compare the means for each Pick category directly. Taking only those age categories where all four Pick types were present (ages 5, 6, 7, and 8), we can compute a weighted average for each category of Pick.

Table 67 presents a summary of the mean Total scores for the MATCH photos by age across Pick categories. Similar summaries for World, Sub-photo, and Photographer sub-scale scores follow. The findings are the same for Total and all sub-scale scores: those photos chosen by both the adult and the child as the best match to the TARGET photo (Pick type 3) have the highest scores of all the MATCH photos taken. While it is not clear why in each case the photos not chosen by both the adult and the child (Pick type 0) do not have the lowest scores, the pattern of the data supports the notion that the features that underwrite a perception of "good match" are salient for and shared by both children and adults.

More specifically, the findings suggest that the properties reflected in the Sub-photo and Photographer sub-scales, namely the objects and relationships captured in the photographic frame, similarly and heavily contribute to children's and adults' determination of the degree of match between photographs. The World sub-scale was designed to give a child "credit" for figuring out and physically acting on the information about the real world in the TARGET photo. As such, this sub-scale has to do with what children do to the physical environment independent of how and from where they take their MATCH photo. The findings suggest that what actually appears on the photograph, which is significantly determined by the degree to which one is able to figure out what was there in the first place and from where the photo was actually taken, contribute most powerfully to children's and adults' sense of the similarity between the MATCH and TARGET photographs.

Table 67

Summary of Total Scores on MATCH Photos by Pick Type Category

	Pick Type							
	3 (Chosen by Both)		2 (Chosen by Adult)		1 (Chosen by Child)		0 (Not Chosen)	
Age (in years)	Mean	N	Mean	N	Mean	N	Mean	N
5	17.67	3	22.50	2	12.00	2	13.33	3
6	40.14	7	43.00	1	39.00	1	31.62	8
7	44.33	9	30.67	3	39.50	2	35.83	12
8	49.25	4	61.00	1	60.00	1	46.60	5
Weighted Mean	40.43		34.43		33.67		34.14	

Table 68

Summary of World Sub-Scale Scores on MATCH Photos by Pick Type Category

	Pick Type							
	3 (Chosen by Both)		2 (Chosen by Adult)		1 (Chosen by Child)		0 (Not Chosen)	
Age (in years)	Mean	N	Mean	N	Mean	N	Mean	N
5	10.00	3	18.00	2	10.00	3	12.50	2
6	31.00	7	14.00	1	28.00	1	24.12	8
7	33.40	9	25.30	1	31.00	2	28.00	12
8	35.50	4	42.00	1	42.00	1	32.60	5
Weighted Mean	29.98		23.46		23.14		26.55	

Table 69

Summary of Sub-Photo Sub-Scale Scores on MATCH Photos by Pick Type Category

	Pick Type							
	3 (Chosen by Both)		2 (Chosen by Adult)		1 (Chosen by Child)		0 (Not Chosen)	
Age (in years)	Mean	N	Mean	N	Mean	N	Mean	N
5	7.30	3	12.50	2	3.00	2	7.00	2
6	28.00	7	30.00	1	28.00	1	24.12	7
7	30.10	9	18.67	3	26.50	2	26.27	11
8	33.50	4	42.00	1	42.00	1	31.20	5
Weighted Mean	27.08		21.86		21.50		25.11	

Table 70

Summary of Photographer Sub-Scale Scores on MATCH Photos by Pick Type Category

	Pick Type							
	3 (Chosen by Both)		2 (Chosen by Adult)		1 (Chosen by Child)		0 (Not Chosen)	
Age (in years)	Mean	N	Mean	N	Mean	N	Mean	N
5	7.00	3	7.00	2	6.00	2	6.67	3
6	7.71	7	8.00	1	6.00	1	6.62	8
7	9.67	9	8.30	3	8.00	2	7.58	12
8	11.25	4	14.00	1	13.00	1	11.00	5
Weighted Mean	9.00		8.70		7.83		7.82	

To summarize, older children were more likely to simultaneously reflect on several objective criteria when explaining their choice of photo that best matched the TARGET. Children in the middle age range especially, focused on particular dimensions or aspects of photos which appeared to dominate their judgment of sameness with the TARGET photo.

The photos chosen as best matches by both the child and the adult (Pick type 3) had higher Total and sub-scale scores than the photos chosen by one or the other or neither.

11. Order Effects for Total and Sub-scale Scores for Children Who Complete at Least Three and Four Match Photos

In Section I it was shown that the number of Match photos children take is significantly correlated with their age and intentionality on the first MATCH photo and that a bias in terms of the attrition of the sample across MATCH photos was found. That is to say, the children who go on to take the maximum number of MATCH photos (four) are not necessarily representative of those who start at the first MATCH photo. This precludes looking at differences as a function of photo order since any possible differences are confounded with the attrition bias.

Nevertheless, practice or learning effects can be explored by looking at only those children who complete at least three MATCH photos. Though the problem of the sub-samples not being representative of the total sample persists, at least we can look for changes as a function of trials, that is, across the series of MATCH photos for

this particular sub-sample. Some "positive" change would suggest there is some learning or practice effect across trials, within the task session.

Tables 71 - 74 present the mean Total and World, Sub-Photo, and Photographer sub-scale scores for all children who completed at least three MATCH photos. Looking at Table 71 we see a steady increase in Total scores across MATCH photos (from 32.09 to 34.40 to 36.70). Tables 72 - 74 show a similar steady increase for World and Sub-Photo scores across MATCH photos. However, no discernible change in the Photographer score appears until MATCH photo 3. That there is a less consistent practice effect for the Photographer sub-scale supports our earlier suggestion that the items making up the Photographer sub-scale are more difficult for the children in the age range considered than the items measured by the other sub-scales.

Table 71

Mean Total Scores for 3 MATCH Photos Completed

Total Score		
MATCH Photo 1 Mean Score	MATCH Photo 2 Mean Score	MATCH Photo 3 Mean Score
32.09	34.40	36.70
(N=23)		

Table 72

Mean World Sub-Scale Scores for 3 MATCH Photos Completed

World Sub-Scale Score		
MATCH Photo 1 Mean Score	MATCH Photo 2 Mean Score	MATCH Photo 3 Mean Score
24.50	26.77	29.86
(N=22)		

Table 73

Mean Sub-Photo Sub-Scale Scores for 3 MATCH Photos Completed

Sub-Photo Sub-Scale		
MATCH Photo 1 Mean Score	MATCH Photo 2 Mean Score	MATCH Photo 3 Mean Score
22.81	24.81	27.33
(N=21)		

Table 74

Mean Photographer Sub-Scale Scores for 3 MATCH Photos Completed

Photographer Sub-Scale Score		
MATCH Photo 1 Mean Score	MATCH Photo 2 Mean Score	MATCH Photo 3 Mean Score
7.59	7.59	7.68
(N=22)		

The comparison of Total and sub-scale scores for children who took four MATCH photos shows a similar trend (Tables 75 - 78). There are steady increases across trials in Total, World and Sub-Photo scores. The pattern of Photographer scores is

slightly different in that there is a small decrease between MATCH photos 1 and 2 followed by small increases for MATCH photos 3 and 4. Again, the increases are not as appreciable or as steady as the increases in the other scales. The decline from MATCH photo 1 to 2 represents more supporting evidence that getting the station point right is a difficult task even for older, more sophisticated, and more persevering children.

Table 75

Mean Total Scores for 4 MATCH Photos Completed

Total Score			
MATCH Photo 1 Mean Score	MATCH Photo 2 Mean Score	MATCH Photo 3 Mean Score	MATCH Photo 4 Mean Score
34.50	36.69	38.00	39.88
(N=16)			

Table 76

Mean World Sub-Scale Scores for 4 MATCH Photos Completed

World Sub-Scale Score			
MATCH Photo 1 Mean Score	MATCH Photo 2 Mean Score	MATCH Photo 3 Mean Score	MATCH Photo 4 Mean Score
24.75	27.38	29.25	30.63
(N=16)			

Table 77

Mean Sub-Photo Sub-Scale Scores for 4 MATCH Photos Completed

Sub-Photo Sub-Scale Score			
MATCH Photo 1 Mean Score	MATCH Photo 2 Mean Score	MATCH Photo 3 Mean Score	MATCH Photo 4 Mean Score
24.00	26.47	27.93	28.93
(N=15)			

Table 78

Mean Photographer Sub-Scale Scores for 4 MATCH Photos Completed

Photographer Sub-Scale Scores			
MATCH Photo 1 Mean Score	MATCH Photo 2 Mean Score	MATCH Photo 3 Mean Score	MATCH Photo 4 Mean Score
8.13	7.87	8.00	8.73
(N=15)			

In sum, a learning or practice effect is reflected in increasing Total, World, and Sub-Photo scores across MATCH photo trials. The absence of evidence for such an effect on the Photographer sub-scale score once again confirms that the constituent information for and assumption of the correct station point are more difficult for the children.

12. Photographs vs Drawings: Children's Thinking

After selecting and discussing which MATCH photo was closest to the TARGET photo, the children were asked several questions designed to explore children's notions about the comparative nature of photographs and drawings were asked. The qualitative responses were coded to constitute ordered variables so they could be crosstabulated with age and a Gamma coefficient could be calculated. Tables 79 - 84 present the data and Gamma coefficients calculated for these items.

Analysis of the data of children's responses to the question, "Could you draw a picture that looked exactly like my [TARGET] photo?" by age appears in Table 79. Table 80 presents the data by age of responses to the follow-up question, "Would your drawing look exactly like my photo?" Table 81 presents the data by age of the explanations children offered for their response ("How come?").

While there is no pattern, relative to age, to children's responses to the question of whether they could draw a picture to match the TARGET photo, significant age associations are found when we look at what children said about whether their drawing could look exactly like the photo (Gamma = .47, $p<.05$, Table 80) and why ("How come?") (Gamma = .76, $p<.05$, Table 81). Older children were more likely to express doubt that a drawing could match a photograph: they were more likely to say, "No, it can't look exactly like the photo," or "It can match it exactly only part way. It can't be perfectly the same." And older children were more likely to explain the "shortcomings" of their drawings in terms of their personal performance and

drawing skills, for example, "Well, you'd have to be an incredible drawer. I'm not that good." Younger children usually were unable to explain why their drawings would or would not look exactly like the photo.

Table 79

Could You Draw a Picture That Looked Exactly Like the TARGET Photo? by Age (Number of Subjects)

		Age (in years)						
Draw TARGET?	Code	3	4	5	6	7	8	Total/ Percent
Don't Know, Maybe	0	1	1	1	1	2	1	7 14.9
Yes	1	2	3	3	3	5		16 34.0
No	2	2	7	2	4	5	4	24 51.1
Column Total		5	11	6	8	12	5	47
Column Percent		10.6	23.4	12.7	17.0	25.6	10.6	100.0

Statistic	Value	T-value	p-value
Gamma	.05333	.31846	ns

Table 80

Would Your Drawing Look Exactly Like the TARGET Photo? by Age (Number of Subjects)

		Age (in years)						
Draw Perfect?	Code	3	4	5	6	7	8	Total/ Percent
Don't Know	0	2	3	1	1			7 14.9
Yes	1	1	3	3	3	1		11 23.4
No	2	2	4	1	4	6	4	21 44.7
Partially	3		1	1		5	1	8 17.0
Column Total		5	11	6	8	12	5	47
Column Percent		10.6	23.4	12.7	17.0	25.6	10.6	100.0

Statistic	Value	T-value	p-value
Gamma	.47429	4.39005	$p<.05$

Table 81

How Come? (Explanation of, "Would your drawing look exactly like the TARGET photo?") by Age (Number of Subjects)

		Age (in years)						
How Come?	Code	3	4	5	6	7	8	Total/ Percent
Don't Know	0	4	2	3				9 19.1
Reference to Personal Performance	1	1	9	3	8	12	5	38 80.9
Column Total		5	11	6	8	12	5	47
Column Percent		10.6	23.4	12.7	17.0	25.6	10.6	100.0

Statistic	Value	T-value	p-value
Gamma	.75926	3.59452	$p<.05$

The data by age of children's responses to the question, "What are the differences between photographs and drawings?" appear in Table 82. Table 83 presents the data by age of responses to the question, "If you wanted something that looked exactly like my [TARGET] photograph, which would you do, make a drawing or take a picture with the camera?" Table 84 presents the data by age of the explanations children offer for their response ("How come?").

Here, we find an association between age and children's expressed ideas about the differences between photographs and drawings (Gamma = .77, $p < .05$, Table 82). Starting from about five years on, children talked about the mechanical and veridical differences: photographs are "made with a camera, it's like a thing that does it; drawings are made by hand," and a photograph is "a picture of the thing: it's, like, real." Only younger children talked about aesthetic preferences, for example, "I like drawings, they're pretty," or "Photographs are prettier."

Interestingly, Table 83 shows that 75% of the children chose to take a photograph rather than draw when asked what they would do to get something to look exactly like the Experimenter's photograph. It may be that even very young children believe in the veridicality of photographs, their ability to depict things the way they are, precisely. Unfortunately, we did not ask children what they would do if the model were itself a drawing rather than a photograph, and so we may only speculate here.

Finally, while we did not obtain a significant association between age and children's explanations of why they would chose to photograph rather than draw the model (Table 84), there was a tendency for older children to cite the veridicality of

photographs more frequently than younger children ("Because you could get something wrong if you draw it, you know, you might not be able to draw it perfectly but the camera does get it perfectly.")

Table 82

What Are the Differences Between Photos and Drawings? by Age (Number of Subjects)

		Age (in years)						
Differences Between Photos & Drawings	Code	3	4	5	6	7	8	Total/ Percent
Don't Know, Irrelevant or Aesthetic Response	0	5	6	2	1	1		15 31.9
Reference to Veridicality or Mechanics	1		5	4	7	11	5	32 68.1
Column Total		5	11	6	8	12	5	47
Column Percent		10.6	23.4	12.7	17.0	25.6	10.6	100.0

Statistic	Value	T-value	p-value
Gamma	.77333	5.06251	$p<.05$

Table 83

If You Wanted Something That Looked Exactly Like the TARGET, Would You Draw or Photograph? by Age (Number of Subjects(

		Age (in years)						
Draw or Photograph?	Code	3	4	5	6	7	8	Total/ Percent
Draw	1	1	3	2	1	2	2	11 25.0
Photograph	2	3	6	4	7	10	3	33 75.0
Column Total		4	9	6	8	12	5	44
Column Percent		9.1	20.5	13.7	18.2	27.2	11.4	100.0

Statistic	Value	T-value	p-value
Gamma	.12991	.55366	ns

Table 84

How Come? (Explanation of "...would you draw or photograph?") by Age (Number of Subjects)

		Age (in years)						
How Come?	Code	3	4	5	6	7	8	Total/ Percent
Reference to Personal Performance	1	1	1	1	2	5	2	12 33.3
Reference to Aesthetic Appeal	2		2	2	2	1	1	8 22.2
Reference to Photo Veridicality	3		1	3	4	6	2	16 44.4
Column Total		1	4	6	8	12	5	36
Column Percent		2.8	11.2	16.7	22.2	33.7	13.9	100.0

Statistic	Value	T-value	p-value
Gamma	.06812	.37324	ns

To summarize, older children are more likely to doubt that a drawing can match a photograph and to doubt the adequacy of their own drawing skills to match a photograph. From about five years of age, children comment on the mechanical and veridical "advantages" of photographs over drawings when one is trying to "match" to a standard.

13. Analyses of the Strategies Children Use and the Depth of Their Solution of the Task

Children's talk and actions during the experimental session clearly reflected particular approaches or strategies for solving the task. Spontaneous talk, interview responses, actions and the observational records together reveal eight strategic approaches of increasing sophistication. Based on these data streams, a composite strategy level was identified for each child. These were coded and analyzed. The least sophisticated approach reflects no systematic strategy for solving the task. This is followed by an approach that considers the TARGET photo as the subject of the match. There are then three levels of "nominal inclusion" strategies where matched objects are named without regard for orientation. Finally, the most sophisticated strategies are driven by "relational inclusion" where the particular objects and their relationships are considered. There are three levels of such strategies. The eight strategic approaches were coded and defined as:

- 0 = a random approach which appears intended simply to produce a photograph without regard to matching the TARGET photo. Children who did

not examine the TARGET photo and made no comparisons between their photos and the TARGET photo were considered to be non-strategic in terms of the specific task.

- 1 = the child photographs the TARGET photo and claims a match. This reflects a strategy in which the TARGET photo is approached as the subject of the task. Operating with this strategy means one simply has to photograph the TARGET photograph itself to achieve a match.
- 2 = the child names a single object in the TARGET photo and compares the MATCH photos taken to the TARGET only in terms of that identified object. These children claimed a match between their photos and the TARGET on the basis of the inclusion in their photos of the single object: "Mine is like yours because, you see, it has the blue block. The blue block is the same." These children were considered to be at the first stage of "nominal inclusion" in which the presence of one item satisfies the match requirement without regard to intra- or inter-object orientation and specificity.
- 3 = the child talks about, selects and manipulates several, but not all, objects from the TARGET array, often simply lining them up. These children compared the MATCH photos to the TARGET by naming (listing or verbally checking-off) the sub-set of objects. They claimed a match with the TARGET on the basis of the inclusion of the sub-set of objects and were considered to express a somewhat more complex stage of nominal inclusion: "Well, it's got

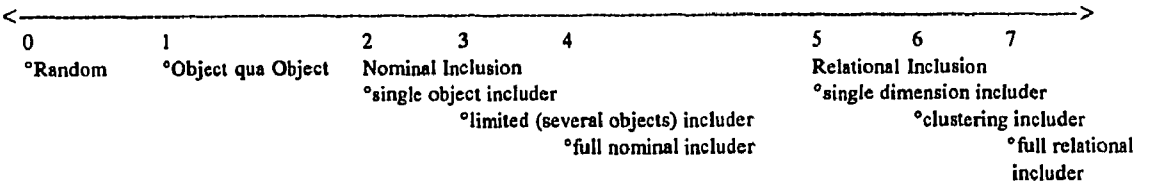
the tower thing, the oval, the triangle, and the blocks." Again, there is no appreciation for orientations or relationships.

- 4 = the final stage of nominal inclusion in which the child systematically collects all the objects in the TARGET photo but still does not make an effort to arrange them with any particular regard for the orientations and relationships specified in the TARGET. These children claimed a match on the basis of having simply included all the same objects and named them, again as a kind of verbal check-listing, without regard to organization.
- 5 = the first stage of "relational inclusion" where the child focuses on a single relational dimension: either intra- or inter-object specifics. For example, a single-dimension relational includer may have tried to get one or more objects to face the right way: "The tower has the thunderbolt side facing me."
- 6 = in the next stage of relational inclusion, children collect all the objects included in the TARGET photo but work on the intra- and inter-object relationships of only a section of the array. These children were considered to be "limited" or "clustering" relational includers.
- 7 = the most sophisticated strategic approach to the task in which all the objects are included and organized with an appreciation for all the relationships specified.

Figure 5 presents the eight strategies along a continuum.

Figure 5

Strategic Approaches to the Task



Older children employed strategies of increasing complexity than younger children. Table 85 presents the data of the types of strategies employed by age (Gamma = .77, $p. < .05$, Table 85).

Table 85

Type of Strategy by Age (Number of Subjects)

Strategy	Code	Age (in years) 3	4	5	6	7	8	Total/ Percent
Random	0	1	1					2 4.3
Object qua Object	1	1						1 2.1
Single Object Nominal Inclusion	2	3	2	1				6 12.8
Limited Nominal Inclusion	3		2	2				4 8.5
Full Nominal Inclusion	4		1			1		2 4.3
Single Dimension Relational Inclusion	5		2	2	1			5 10.6
Limited/Clustering Relational Inclusion	6		2	1		1	1	5 10.6
Full Relational Inclusion	7		1		7	10	4	22 46.8
Column Total		5	11	6	8	12	5	47
Percent "Full Inclusion" Strategists by Age		0.0	9.0	0.0	87.5	83.3	80.0	

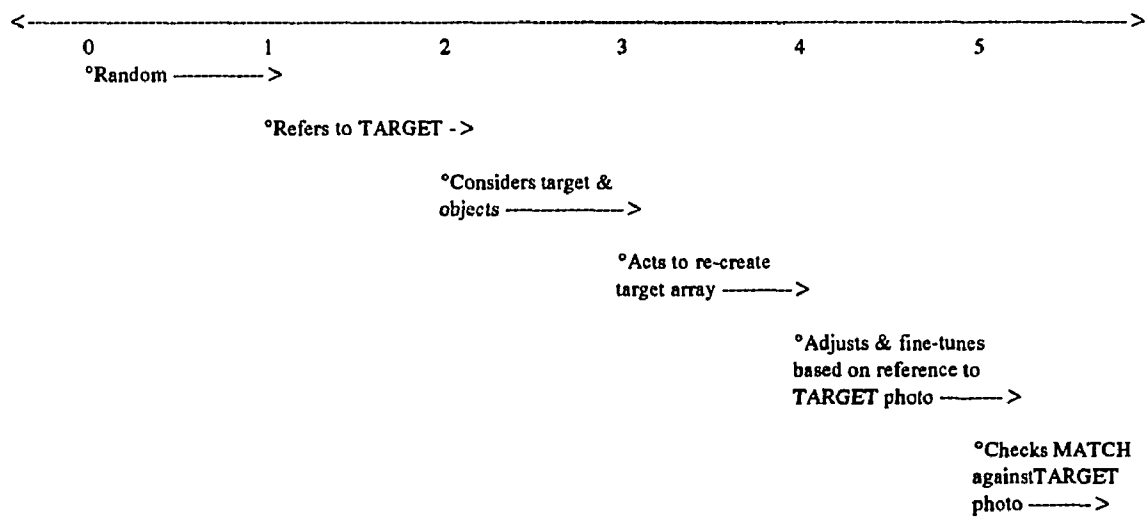
Statistic	Value	T-value	p-value
Gamma	.77045	9.96878	$p<.05$

As noted in Chapter 2, the task of making a photo that matches another requires understanding and coordinated action at several levels. Based on a composite of their talk, observed behavior, and MATCH photos, the degree or depth to which the children demonstrated comprehension of the requisite levels was also coded and reflects a continuum. The continuum represents levels of grasping the solution to the

problem. Every child identified at a level of 2 or higher was observed to engage in all behaviors that mark earlier levels. That is to say, each level reflects and incorporates mastery of the previous levels. This continuum is represented in Figure 6.

Figure 6

Depth of Comprehension of the Task



Analysis of the Depth of Comprehension scores by age (Table 86) indicates a significant positive trend to increase with age: as children get older what they do to solve the task reflects a deeper, more complex grasp of what it takes to make a photo so that it looks exactly like another.

Table 86

Depth of Comprehension Scores by Age (Number of Subjects)

Depth Score	Code	Age (in years) 3	4	5	6	7	8	Total/ Percent
Random	0	1	1					2 4.3
Refers to TARGET	1	2		1				3 6.4
...and Considers TARGET & Objects	2		1					1 2.1
...and Acts to Recreate Target Array	3	2	6	4	1	1		14 29.8
...and Adjusts w/ Reference to TARGET	4		3	1	2	5	1	12 25.5
...and Checks MATCH Against TARGET ("Full Depth")	5				5	6	4	15 31.9
Column Total		5	11	6	8	12	5	47
Percent "Full Depth" by Age		0.0	0.0	0.0	62.5	50.0	80.0	

Statistic	Value	T-value	p-value
Gamma	.76010	11.11884	$p<.05$

Finally, correlations between Strategy, Depth of Comprehension, and Total and Sub-scale scores for first MATCH photos proves informative. (First MATCH photos include more of the sample, however, the pattern of correlations is the same when calculated for second MATCH photos.) Strategy and Depth of Comprehension scores are highly correlated with each other and with World, Sub-photo, and Total scores. They are less correlated with age which suggests that age in itself does not explain

cognitive ability or sophistication in this task. Correlations with Photographer sub-scale scores are even lower. This is not surprising since the measures that make up this sub-score showed limited variability. Table 87 presents the correlations for Strategy and Depth scores with each other and Total and sub-scale scores.

Table 87

Correlations Between Strategy and Depth Scores With Total and Sub-Scale Scores

	Strategy Score	Age	Total Score	World Score	Sub-Photo Score	Photographer Score
Strategy Score	1.0000	.7609	.7755	.8393	.7860	.4911
Depth Score	.8912	.7194	.8247	.8417	.8290	.5693

To summarize, the children's talk and actions clearly reflected a range of strategic approaches to solving the task. The data show that older children employed strategies of greater complexity and the actions they undertook to solve the task reflected a deeper, more complex grasp of the nature of the relationship between a photograph and the world it represents than younger children. The degree to which the children grasped the nature of the task and the level of sophistication they demonstrated in their strategic approach to solving the task were highly correlated with each other and with Total, World, and Sub-Photo scores.

14. Summary of Key Findings

Analyses of the various data streams, including children's photographs, their spontaneous talk during the session and interview responses, as well as observational records, support the key hypotheses of the study. A brief review of the key findings follows:

- Total, World, and Sub-photo sub-scale scores were strongly correlated with age, while the Photographer sub-scale score was relatively weakly correlated with age.
- Most children, regardless of age, scored comparatively lower on the Photographer-related measures.
- Photographer sub-scale scores did not change significantly across task trials.
- Older children demonstrated greater mastery at reconstructing the array (World sub-scale) and capturing the visual content (Sub-photo sub-scale) than younger children.
- The correlations of the three sub-scales, World, Sub-photo, and Photographer, to age and the Gamma values for each were generally higher for MATCH photo 2 than MATCH photo 1, suggesting a practice effect across the task.
- Experimenter-judged errors across the MATCH photos supports the practice effect finding: children's first MATCH photos are less accurate than subsequent ones.
- Total, World, and Sub-photo scores increased across task trials, further reflecting a learning or practice effect.

- Both what children said needed to be fixed and what they actually did to improve the accuracy of subsequent MATCH photos were significantly associated with age.
- What children actually did to correct errors was more relevant to the Experimenter-judged errors, more sophisticated, and more successful than what they said was wrong.
- What children did to "fix" their MATCH photos increased in variety and sophistication across task trials, suggesting a strong learning effect.
- Older children were more likely to reflect on several objective criteria simultaneously when explaining their choice of best match, while single, particular dimensions dominated judgment of sameness for children in the middle age range.
- The photos chosen by both the Experimenters and the children as the best match had the highest Total and sub-scale scores of each child's output.
- Older children were more likely to doubt that a drawing can match a photograph and to doubt their own ability to draw a match to a photograph.
- Children five years of age and older commented on the mechanical and veridical advantages of photographs over drawings when one is trying to match to a standard.
- Older children employed more complex strategies and demonstrated a deeper grasp of the complex relationship between a photograph and the world it represents than younger children.

V. DISCUSSION AND CONCLUSIONS

This study was undertaken to explore the early development of representational functioning in the context of children's working to make a photograph that looks just like another one. The design of the study allowed children to express what they understand about the relationship between photographic representations and the world, and about how photographic representations are constructed, through practice and through talk. This approach offered opportunities to further understand children's knowledge of the world as expressed through the artifacts made by them and intended to represent the world, as well as their theory of photographic practice per se.

In order to decode photographs, as examples of pictorial representations, children must grasp a set of formal relationships that comprise a symbolic code. That is to say that the representation has encoded in it information specifying it as both form (an object in and of itself) and as content (a representation of something else). The degree to which children crack the code determines the degree to which they are able to operate on the information in the representation about what it is of (content) and how it was made (form). To examine children's coordination of these two streams of specifying information, children were asked to make a photograph that looks just like a target one.

Proposed hypotheses were organized around three considerations: children as perceivers and analyzers of the TARGET photo; children as transformers and reconstructors of the environment pictured in the TARGET photo; and, children as

photographers, that is, as decoders of the unique station point from which to take their matching photograph. Specifically, one of the hypotheses stated that with age children are increasingly intentional about the photographs they take, and sensitive and accurate about the inclusion of appropriate objects and exclusion of extraneous ones. The data show that older children took fewer random photographs, and more accurately reconstructed and captured the relationships between objects in the target array (expressed as higher World and Sub-photo sub-scale scores) than younger children. These findings reflect an increasing understanding of the nature of the task and the relationships between and within objects specified by the TARGET photo.

The findings suggest that children who took random photographs without attempting to include and arrange objects did not understand that photographs are in a symbolic relationship to what is depicted nor that there is information available in a photograph upon which they can act. What they did do was confirm that children's early graphic productions serve what Lowenfeld (1939, 1945) refers to as a more haptic, or kinesthetic, purpose. Arnheim (1971), in discussing the nature of children's early artistic expression, similarly observes that young children use representational media (crayons, paints, etc.) in the service of satisfying an abundant need for movement. In this study we saw the youngest children use the camera the way they might scribble with crayons. Those children who made unsystematic attempts to include and arrange objects demonstrated a global, as yet undifferentiated concept of relationship between the pictorial representation and the world pictured.

It was also hypothesized that older children achieve increasing accuracy in their assumption of the specifically correct station point and horizontal/vertical orientation of the photographic frame, but that this ability lags behind children's ability to systematically reconstruct the environment. That is to say, it was expected that younger children's World and Sub-Photo sub-scale scores would be higher than their Photographer sub-scale scores because, according to Piagetian theory on perspective taking, the ability to decenter is a developmental achievement. The ability to assume the correct station point (and horizontal and vertical centering) requires decentering and the ability to understand symbolic relationships as independent of a self-referencing viewpoint. The data showed that, compared to World and Sub-Photo sub-scale scores, Photographer scores were weakly correlated to age, confirming the hypothesis, but that most children in the study scored comparatively lower on this sub-scale score. Further, this score did not change across task trials, as did the others. The children who produced MATCH photos that were relatively accurate in terms of the objects shown and their relationship to one another, but which were taken from the wrong station point (and/or were not correctly oriented on the vertical and horizontal axes), understood the symbolic relationship between the TARGET photo and the environment pictured. They extracted and acted upon the information available about that environment, but were either not sensitive to or were unable to act upon the information available about the photograph itself as a constructed object. In regard to the latter, it was the older children who commented on station point-related errors when talking about what needed to be fixed in their photos, and

attempted station point-related repairs before taking their next photo. Based on the Experimenter-judged error data, the repairs, however, fall short of adequately correcting the problem. This suggests that sensitivity to the issue of station point, which reflects on the representation as form, and/or the ability to coordinate and act on station point-specifying information develops somewhat later than sensitivity to the content-specifying properties of the photograph. Being able to act on form-specifying information remains a challenge even for eight-year-olds.

Piaget's work on the coordination of perspectives (1948) is consistent with and helps explain this finding. His discussion of the nature of the mechanism that leads to the coordination of perspectives is also consistent with the levels of strategic approaches identified in this study. First, Piaget (in Gruber and Voneche, 1977) also finds the child slow to master simple perspective relations. He argues that the child does so only when able to coordinate a number of possible viewpoints: "...the development of perspectives requires a comprehensive, global construct, one which enables objects to be linked together in a coordinate system, and viewpoints to be linked by projective relations corresponding to various potential observers (p.621)." The problem posed by both Piaget's three mountains task and the present task has to do not simply with the positions of objects relative to one another, but relative to one another from a specific viewpoint (station point) other than the one from which the child is introduced to the array. Piaget describes a developmental progression in children's ability to distinguish between their own point of view and that of others, and to coordinate theirs' with others', a progressive discrimination and coordination

of perspectives. He finds children in the earlier stages of development (before age 7-8) hardly able to distinguish their point of view and that of others, and only around 12 years of age does Piaget find children are able to master perspective-taking: up until 8 to 9 years, "certain relationships are varied with changes in the position of the observer, but there is still no comprehensive coordination of viewpoints (p.624)." The child comes to understand that some relations are relative to others, that they vary according to the particular station point of the observer, but their efforts, in Piaget's three mountains task and in the present photographic one, remain, for the most part, only partially successful, occasionally coming close to the externally specified viewpoint. Before the age of 7 or 8, Piaget says, children are transitional between spatial egocentrism and true relativity:

> The relationships of left-right, before-behind are therefore not yet real to the child. That is to say, they are not yet subject to changes of sequence and reversals dependent upon the observer's position. They are still immutable, intrinsic properties of the group...which define once and for all the pattern of the group as a whole. The child has not yet begun to think in terms of "groupings" of projective relations and correspondences, to discern the invariance of the correspondences amid the endless transformations of the projective relationships. (p. 625)

Not surprisingly perhaps, the present study finds most children making errors in centeredness (left-right errors) and distance (too close-too far). Also, the earliest

strategies to emerge are those referred to as nominal inclusion, which reflect the child's grasp of the content of what is pictured, but they are listing, figuratively and operationally, the constituent parts of the grouping. As Piaget states, "The groupings involved in this process consist of additions and subdivisions of proximities and separations, the formation of ordered series... (p. 626)"

Some 8-year-olds come quite close to matching the TARGET photo, that is, they successfully act upon the information about the group of objects pictured, their relationships to one another, and their relationships relative to the specified station point. These most developmentally advanced children demonstrate strategies referred to as full relational inclusion and reflect the comprehensive coordination of viewpoints. Piaget describes this stage of development in children 10 years or older, so it is not surprising, from a Piagetian model, that the elements measured by the Photographer score (the ability to act on the information in the photo that specifies the unique perspective from which the photograph was taken) lag behind both World and Sub-photo scores. What is important is that the developmental progression from "actual centration to virtual decentration" which Piaget suggests "is brought about by the subject coordinating his own viewpoint with all possible viewpoints (p.627)" is demonstrated in this study, making the transition from egocentric realism to relational coordination visible.

Several other works support and help explain the finding that children's comprehension of the elements of information that specify the photograph as form, and that are reflected in the Photographer score in this study, lags behind their

comprehension of the information specifying content. Sigel (1976, 1978, 1983, 1991) argues that recognition of a depicted object precedes, and does not constitute, comprehension of the representation of that object. In a similar vein, Bower (1977) proposes that for young children, a picture is a "surrogate object" before it is a representation of reality. For example, he cites a study in which younger children, though able to recognize a lifesize picture of a real cup, had trouble finding candy in the real cup when presented with a photograph of the cup tilted to reveal the candy. In the present study, random photographs suggest that the child has not yet developed the ability to recognize the object in its photographic representation. Non-random, intentional efforts to take a photo to match the presented one suggest recognition of the depicted objects: at the earliest stages, children at least turn toward the objects they recognize as present in the TARGET photo. Then, children's increasing ability to reconstruct the array as depicted reflects the development of what Sigel (1991) calls representational competence, in which the meaning of a world instance is conserved across changing forms of symbolic representation of the instance. The meaning of the instance is conserved, and increasing understanding of the representational relationship and how the representation is constructed (medium-specific knowledge) are expressed.

In experiments designed to explore children's understanding of the representational nature of photographs, Kose, Beilin and O'Connor asked 3- to 6-year-olds to mimic poses of children depicted in photographs, drawings, modelled by a doll, and modelled live. They found that 3- and 4-year-olds had difficulty extracting action

information from photographs despite their ability to recognize static items depicted in photographs. They also found that imitating the live model was easier than imitating represented poses even for 5- and 6-year-olds. The Kose, Beilin, O'Connor finding that young children do not take the information in photographs as information to be acted upon despite the ability to recognize the content in the photograph, is consistent with the present findings concerning children's abilities to act upon the photographer-specifying information in the photograph. This ability reflects the most developmentally sophisticated comprehension of the representational nature of the photograph as more than recognizable content, more than conservable meaning. It speaks to the child's developing theory of photographic practice as a coordination of the perceptual and cognitive functions underlying representational competence.

Based on the theory that development moves toward greater differentiation of function from the global and undifferentiated to a state of hierarchical integration (Harris, 1963; Werner, 1964; Werner and Kaplan, 1984) and that graphic development in particular moves toward increasing concern for representational authenticity (Goodnow, 1977), it was hypothesized that older children will take into consideration ever finer distinctions as they evaluate their own photographs and are less easily satisfied with their products than younger children. As a result, older children were expected to take more MATCH photos in an effort to get closer and closer to the TARGET. The age of the child, which represents a rough measure of cognitive and emotional maturity, and the child's intentionality on the first MATCH photo both correlate significantly with the number of MATCH photos produced. In

other words, younger children behaved as though "close enough is as good as a match," whereas older and/or more developmentally sophisticated children engaged in the task as though "close is not good enough."

The findings from this study, and particularly those concerning what children say is the problem with their MATCH photographs and what they actually do to repair inaccuracies, speak to the very nature of symbolic representation. What children said needed to be fixed and what they actually did to improve the accuracy of the subsequent photo were significantly associated with age. What they did was more relevant to what was wrong (as judged by adults) than what they said was wrong. Moreover, what they did to make the next photo a closer match was more sophisticated than what they talked about. In fact, what they talked about as wrong showed very little variability across age and trials: most talk was relatively unsophisticated.

As noted earlier, while Vygotsky (1962) and others (Church, 1961; Taylor, 1970) have argued the supremacy of language as an effective, even universal, symbol system, clearly, language is not the only symbol system children use effectively. Mandler (1983) proposes that representation embodies both what is known and the structure of that knowledge in symbolic relationship with one another. Piaget (1962, 1971, 1976, 1978) reflected extensively on the period of 2 to 8 years of age during which the child is "rapidly developing not only language, but all other aspects of the symbolic function" including "the ways in which the individual represents his world, his actions, and his experiences to himself (Gruber & Voneche, 1977, p. 483)." The

present study, together with the Seidmen and Beilin (1984) finding that subjects at all ages talk more when drawing than photographing, suggests that the employment of any given representational system may be uniquely accompanied by other semiotic systems, but that the system in which knowledge has been constructed originally may take precedence over others. Of particular interest in the context of the present findings, Piaget (1978) noted that children were able to demonstrate what he referred to as performance success before they expressed understanding. In a series of tasks, Piaget found that children were able to solve the task in action (success) before they were able to explain what they had to do to solve the task and why (understanding). Piaget considered "success" as behavioral competence and suggested that based on his findings, success leads or precedes "understanding" measured as children's ability to verbally express what they know. In the present study we saw children construct knowledge about the TARGET photo and its relationship to the external world and their own MATCH photos. The study design also offered opportunities for children to express this knowledge in both the symbol system in which it was originally constructed (photography) and an alternate one (language). The findings on children's talk and action demonstrate that children were better able to express what they know about the task through their actions in the effort of making their MATCH photos than when they had to translate this knowledge into another system and talk about what they know about the task. The present findings suggest that symbolic transfer cannot be assumed and that logical equivalents embodied in different symbol systems are more than simply different and not necessarily equivalent: there is an advantage to

operating within the symbol system in which the knowledge has been constructed. Children express greater competence in the original system. In the case of the task presented in this study, children constructed and re-constructed their knowledge photographically; as a result they perform better in the photographic medium than when they attempt to express what they know about the photographic task in another symbol system (language). Talking about what they did photographically represents a transmodal shift and it becomes "harder" for the children to operate in the alternate mode, to express their knowledge in a mode other than the one in which it was constructed.

Children's theory of photographic practice is reflected best in what they do within the photographic symbol system. They start out "gamboling" with a camera (random photographs). They move relatively quickly to understanding that there is a symbolic relationship between a photograph and the external world and are able to act on their knowledge of this relationship as content (intentional reconstruction of the originally pictured array and production of MATCH photographs that are reasonably similar to the original). In this study we did not see a fully evolved theory of photographic practice. Such a theory develops, presumably after eight years of age, in which children understand that there is a symbolic relationship and specifying information upon which they can act in terms of both content and form (photographs that capture a matching external world from the uniquely specified station point of the original). The unanticipated finding is that at any point along the way, children are able to work "better," to more competently express what they know about what they are doing,

when they operate in the same symbol system in which they constructed the knowledge than in another.

As noted earlier, photographs have been the object of some study and reflection. While some investigators (e.g., DeLoache, 1989b) have used photographs as an instantiation of pictorial representation, others (e.g., Barthes, 1977; Beilin, 1991; Hagen, 1980; Gibson, 1980) have argued that photographs embody a symbol system with unique properties differentiated from pictorial representation in general, other forms of pictorial representation (for example, drawings, paintings, cartoons, caricatures, and video) in particular, and other non-pictorial symbol systems. This study attempted to shed light on how the perceiver interprets and comprehends the photograph as form and content through the exercise of a system of symbolic optics that helps unpackage the relationship between the photograph and that which it represents. As such, this study extends what we have learned from previous pictorial research in general, and the work examining photographic representation in particular.

That all measures of constructed photographic content (intentionality, World and Sub-Photo scores) and approach to the task (strategy and depth of comprehension scores) demonstrated increases with age suggest that representational understanding develops. As noted above, the reflected representational thinking undergoes change consistent with a Piagetian understanding. The strategy and depth of comprehension scores, in particular, demonstrate change in accord with a Wernerian understanding that development requires increasingly complex differentiation and hierarchical integration of the elements embodied in the task. In this study we see children's

progress from failure to appreciate the TARGET photograph as a representation of an instance, to isolating and acting upon the information in the photograph so as to reconstruct the originally depicted instance. This enables them to then consider and construct their MATCH photographs as content and as form. The hierarchical integration of content information with formal properties allowed the oldest children to very closely replicate the originally presented photograph.

Children's Photographer scores reflect most specifically on the nature of their knowledge of the camera. The more behavioral measures included in this score (where one stands, how one orients the camera to the array) reflect developing skills with manipulating a camera. The understanding of station point relies on perceptual-cognitive processes and motor skills including identifying and then assuming a particular height, distance, and orientation of the frame. These formal elements of the task were most problematic for children at all ages. It may be that children must first master what Sigel (1978) calls the representational rule, that objects or events can be represented in alternative forms (the TARGET is a photograph of some real objects). Next, the child must conserve the meaning of the represented objects despite the transformations of form (even though it is a two-dimensional object in and of itself, there is information in the photograph that specifies real objects and their relationships to one another that can be reconstructed). The greatest challenge remains the making of the replicate representation. Individual differences manifested themselves in the context of various patterns captured in the description of the strategies employed to complete the task. That patterns of strategic approach were

identifiable suggest that there may be some ordered and categorical variability within the development of representational thinking as captured in the present study. Motor skills, knowledge of the camera, and cognitive understanding of the representational nature of photographs are not independent, but must be integrated to complete the task. The study shows that the matter of understanding photographs and taking photographs entails important systems, each of which undergoes individual development and is part of an integrated totality that leads to photographic comprehension.

This position is consistent with Vygotsky's (1987) notion of the developing systematization of concepts without which independent conceptual understandings cannot be coordinated. Vygotsky argues that what distinguishes what he refers to as scientific concepts from everyday concepts is the possibility of organizing scientific concepts into a system. What is relevant to the findings of this study is the framework Vygotsky articulates to explain what the child has in mind about the relationships of objects to one another, objects to concepts, and concepts to one another which we may apply to the development of representational thinking as characterized by the present work. Without a system, "the only possible connections between concepts are those that exist between the objects themselves, that is, empirical connections (p.234)." In fact, outside, or more appropriately, prior to systematization, the child's concepts are in a closer and more immediate relationship to the objects themselves than the adult's. Vygotsky explains that with systematization, relationships between concepts themselves are possible:

> Within a system, relationships between concepts begin to emerge. These relationships mediate the concept's relationship to the object through its relationship to other concepts. A different relationship between the concept and the object develops. Supra-empirical connections between concepts become possible. (p.234)

Outside a system of concepts, Vygotsky says, the child's judgements about a process are made as a series and are not synthesized into a coherent whole. We see evidence of this in the earliest strategies of nominal inclusion employed by the youngest children in the photographic task and which have a serial quality to them. Within this framework, Vygotsky also offers insight into why children accept non-matching photos as "good enough of a match":

> We can also show that the absence of need to avoid contradiction inherently appears where individual concepts are not subordinated to a single superordinate concept. For contradiction to be sensed, the two contradictory judgements must be viewed as particular cases of a single, more general concept. ...[T]his type of relationship among concepts is absent where concepts are not included in some system. (p. 235)

The findings concerning children's ability to take more sophisticated action than they are able to able to talk about may suggest that the children's actions are expressions of a nascent system of concepts about space, perspective, and geometric

projection before it can be captured in language. The representational system in which the child constructs knowledge is the first to become systematized around that knowledge. Vygotsky (1987) suggests that the structure of thought determines the operations one can master. The development of increasingly complex and coordinated operations would therefore require a changing structure to support them:

> Since the meaning of a word belongs to a certain type of structure, only a certain range of operations will be possible within this structure. A different range of operations requires a different structure. In the development of thinking we must deal with several very complex internal processes that change the internal structure of the fabric of thought. (p. 238)

Though he associates language with thought, Vygotsky's idea that certain structures support certain operations can be applied to the present findings: the structure of children's knowledge of the task allows more sophisticated action operations than verbal ones. Vygotsky (1987) recalls that while some assume that "the concept is ready when the word is ready, Tolstoy correctly states that 'the word is almost always ready when the concept is (p. 241).'" The present study suggests that the word is not always ready when the knowledge is constructed if the knowledge is constructed in a symbol system other than language.

The study also raises some questions which future research could address. Children were only asked in this study to make a photograph that looks exactly like

the one they were presented. Children were also asked, however, to comment on the differences between photographs and drawings and on which offers the best chances of creating a match to a photographic standard. Children expressed their belief in the veridicality of photographs and referred to the mechanical advantages available in the way photographs are made: the camera does the work, and it captures what is there, whereas drawing a match requires skills many children did not believe they had. In a study of children's belief in photographic fidelity, O'Connor, Beilin, and Kose (1981) found that the representational medium significantly influences judgments of fidelity: six-year-old children treated photographs as having greater fidelity to the reality depicted than they did drawings. Seidman and Beilin (1984) assigned preschoolers, school-age children, and adults to either a photographic or drawing task in which the subject took photographs or drew pictures of their choice. While doing so, subjects talked about what they were doing and thinking. This study found awareness at all ages of the controllable aspects of drawing but a developmental progression in beliefs about what the photograph captures. Preschoolers viewed photography as only reflecting the real object whereas school-age children and adults viewed photography as a controllable medium that can alter reality's appearance. Asking children to both photograph and draw an exact match and comparing their productions, behavior, and beliefs would be informative.

Because even older children were challenged by the station point-related information available in the TARGET photo, it would be enlightening to look at older subject samples, including an adult population, to compare to the oldest children in

the present study. The question of whether most adults achieve the highest levels of photographic practice is open. Finally, photographs are but one pictorial symbol system and we have seen how transmodal shifts affect one's ability to express what one knows. A comparison of other pictorial and non-pictorial symbol systems (for example, written and spoken language) in a systematic way would allow more rigorous tests of Piaget's (1976, 1978) hypotheses concerning success and understanding. For example, the TARGET and the MATCH could be embodied in different systems, as suggested above but including paintings, caricatures, cartoons, and video as well as drawings and other non-pictorial symbol systems. Then, the TARGET and MATCH could be presented in the same system and each system examined in separate conditions. In such a study, children and adults would be asked to make a drawing that matched a target drawing in one condition. In other conditions children and adults would be asked to make a painting that matched a painting, make a video that matched a video, etc. Then, children and adults could be asked to draw a photograph, paint a photograph, etc. Such a study, or series of studies, would offer an opportunity to examine whether the "success" advantage always falls on the side of action or on the side of the system in which the knowledge is constructed, and particularly, if the advantage falls to non-verbal systems.

The present study was intended to inform us about the photograph as a particular pictorial representation, and about symbolic representations in a general way. Photographic practice involves symbolic functions and knowledge of the world, including knowledge of how photographs are made. Analyses of the photographs

children take in an effort to "duplicate" a TARGET photo, the way they go about taking them, and what they say about them illuminates for us the theory children have about photographic practice. This in turn adds to an understanding of symbolic functions in general and how they develop.

APPENDIX A: PRE-PRE-TASK INTRODUCTION AND INSTRUCTIONS

Photographic Practice: Representation & World Knowledge

PRE-PRE-TASK PROTOCOL: INTRODUCTION AND INSTRUCTIONS

Name:_____ Date:_____

Source:_____ D.O.B:_____

C.A:_____

M ( ) F ( )

Parents' Occupation:_____

Experimental Setting:_____

I. INTRODUCTION and rapport building...

We are going to do some fun things today, but before we get started, let's talk about what I have here [show camera]:

	Yes	No
A. Do you know what this [camera] is?	( )	( )
B. Do you know what you can do with this [camera]?	( )	( )
C. Have you ever used a camera before?	( )	( )
D. Do you know what this [picture] is?	( )	( )
E. Does anyone in your family have a camera?	( )	( )

F. Who?_____

G. Does anyone in your family take pictures?	( )	( )

H. Who?_____

II. INSTRUCTIONS:

E: This is the camera you will be using to take some pictures today. It is very easy to use, and I will show you how to use it to take your pictures.

E: This is the front of the camera with the printing on it. It faces toward what you want to take a picture of. It has a button here that you will push in when you want to take a picture. When you push it in, the camera will take the photograph and send the picture out the front, here. Then we will give it some time to show up on the paper. That's when the picture will be developing. When it's done developing, we'll have a picture!

E: This is the back of the camera. It has one window which you look through.

E: The first thing to remember is how to hold the camera. With your left hand put your fingers in front and your thumb on the back to hold the camera. Then with your right hand put your thumb in back and your second and third fingers below the button.

Hold your pointer finger by the button here but do not push it yet.

[Show the child which hand is the left and which hand is the right.] [Demonstrate.]

E: The next thing to remember is where to look. Look into the back window here. Close one eye and look through the window with the other eye. What you see in the window is what the picture you take will look like. When you're ready to take your picture, be sure exactly what you want in the picture fits exactly inside the window.

E: The last thing to remember is when to push the button. While holding the camera and looking through the window, push the button when what you see inside the window is what you want your picture to look like. If it doesn't look the way you

want it to come out, you don't have to push the button. When you do push the button, we'll hear a noise and the paper that the picture will be on will come out the front, here.

[Child appears to understand? . . . . . Yes ( ) No ( )]

(Make sure camera is loaded, and place camera aside.)

E: Now, why don't you take a picture! You can take a picture of anything you like!

[Allow child to "play" with camera and take 1 picture.]

APPENDIX B: PRE-TASK PROTOCOL

Photographic Practice: Representation & World Knowledge

PRE-TASK PROTOCOL: BASELINE MEASURE

Name:_____ Date:_____

Subject Number: _____

E: I'd like us to do something a little different now.

[SHOW PRE-TASK TARGET PHOTO]

Yes No

1. Could you take a picture that would look exactly like this one? . . . . . ( ) ( )

How could you do that?_____

_____

_____

_____

Can you take one now that will look exactly like this one? You can move anything in this room if you want to.

[SHOW PRE-TASK TARGET PHOTO]

[Observational record follows]

[RECORD ORIGINAL PLACEMENT OF OBJECT AND SELF AND ALL REPOSITIONINGS OF OBJECT AND SELF]

[Child takes Pre-Task MATCH Photo]

2. What do you think about your picture?_____

_____

_____

_____

3. Does it look the way you wanted it to look?_____

_____

_____

_____

4. Does it look just like this one?_____

_____

_____

_____

5. How are they the same?_____

_____

_____

_____

6. How are they different?_____

_____

_____

_____

7. What could you do to get it to look exactly like this one? _____

_____

APPENDIX C: EXPERIMENTAL TASK PROTOCOL

Photographic Practice: Representation & World Knowledge

EXPERIMENTAL TASK PROTOCOL

Name:_____ Date:_____

Subject Number: _____

I. E: Now, I want you to look at this picture.

[Show TARGET Photo]

1. What's in this picture?_____

_____

_____

_____

2. Where do you think this picture was taken?_____

_____

_____

_____

3. What makes you think that?_____

_____

_____

_____

_____

4. Are the things in this picture here?_____

_____

_____

5. Can you take a picture that will look just like this one?

Yes ( ) No ( )

6. What would you do to take a picture that would look exactly like this one?_____

_____

_____

_____

_____

_____

E: I'd like you to take a picture that will look exactly like this one. Again, you can move anything in this room you want to!

[Observational record follows]

[RECORD PLACEMENT OF OBJECTS AND SELF AND ALL REPOSITIONINGS OF OBJECTS AND SELF]

II. When FIRST MATCH Photo is produced:

1. What do you think about the picture you took?_____

_____

_____

_____

2. Does it look the way you wanted it to look?_____

_____

_____

_____

(PROBE IF NECESSARY: Tell me about that.)_____

_____

_____

_____

3. What could you do to make it to look the way you wanted it to?_____

_____

_____

_____

4. Does it look exactly like this [TARGET] picture?_____

_____

_____

_____

(PROBE IF NECESSARY: Tell me about that.)_____

_____

_____

_____

5. **ASK ONLY IF CHILD IS DISSATISFIED WITH MATCH:** What would you have to do to take a picture that looks just like this one?_____

_____

_____

_____

E: Do you want to try to do that?

[IF CHILD DECLINES, GO TO VI]

[Observational record follows]

[RECORD POSITIONING OF OBJECTS AND SELF AND ALL REPOSITIONINGS OF OBJECTS AND SELF]

III. When SECOND MATCH Photo is produced:

1. What do you think about this picture?_____

_____

_____

_____

2. Does it look the way you wanted it to look?_____

_____

_____

_____

(PROBE IF NECESSARY: Tell me about that.)_____

_____

_____

3. What could you do to make it to look the way you wanted it to?_____

_____

_____

_____

4. Does it look exactly like this [TARGET] picture?_____

_____

_____

_____

(PROBE IF NECESSARY: Tell me about that.)_____

_____

5. **ASK ONLY IF CHILD IS DISSATISFIED WITH MATCH:** What would you have to do to take a picture that looks just like this one?_____

_____

_____

_____

E: Do you want to try to do that?

[IF CHILD DECLINES, GO TO VI]

[Observational record follows]

[RECORD POSITIONING OF OBJECTS AND SELF AND ALL REPOSITIONING OF OBJECTS AND SELF]

IV. When THIRD MATCH Photo is produced:

1. What do you think about this picture?_____

_____

_____

_____

2. Does it look the way you wanted it to look?_____

_____

_____

_____

(PROBE IF NECESSARY: Tell me about that.)_____

_____

_____

3. What could you do to make it to look the way you wanted it to?_____

_____

_____

_____

4. Does it look exactly like this [TARGET] picture?_____

_____

_____

_____

(PROBE IF NECESSARY: Tell me about that.)_____

_____

5. **ASK ONLY IF CHILD IS DISSATISFIED WITH MATCH:** What would you have to do to take a picture that looks just like this one?_____

_____

_____

_____

E: Do you want to try to do that?

[IF CHILD DECLINES, GO TO VI]

[Observational record follows]

[RECORD PLACEMENT OF OBJECTS AND ALL REPOSITIONINGS OF OBJECTS AND SELF]

V. When FOURTH MATCH Photo is produced:

1. What do you think about this picture?_____

_____

_____

_____

2. Does it look the way you wanted it to look?_____

_____

_____

_____

(PROBE IF NECESSARY: Tell me about that.)_____

_____

_____

3. What could you do to make it to look the way you wanted it to?_____

_____

_____

_____

4. Does it look exactly like this [TARGET] picture?_____

_____

_____

_____

(PROBE IF NECESSARY: Tell me about that.)_____

_____

5. **ASK ONLY IF CHILD IS DISSATISFIED WITH MATCH:** What would you have to do to take a picture that looks just like this one?_____

_____

_____

_____

VI. WHEN CHILD IS SATISFIED WITH MATCH OR HAS TAKEN 4 PHOTOS:

1. Let's look at all the pictures you took. Which one do you think looks most like mine? [If only one pic, say, "Does it look like mine?"]

[INDICATE PICK WITH "KIDPIK" ON BACK]

What makes you pick that one? [If only one pic, "What makes you say that?"] _____

_____

_____

_____

_____

2. How is it like mine?_____

_____

_____

_____

Why do you think that is?_____

_____

3. How is it different from mine?_____

_____

_____

_____

Why do you think that is?_____

_____

_____

_____

4. Could you **draw** a picture that looked exactly like my photo [TARGET]?_____

_____

Would your drawing look exactly like my photo?_____

_____

_____

_____

How come?_____

_____

_____

_____

5. What are the differences between photographs and drawings?_____

_____

_____

_____

6. If you wanted something that looked exactly like my photograph, which would you do, make a drawing or take a picture with the camera?

___ Drawing ___ Photo

How come?_____

_____

_____

_____

7. If you had to explain to someone what you did here with me, what would you tell them?__

_____

_____

_____

_____

What was this about?_____

_____

_____

_____

E: We have to stop now. You've been terrific! Did you enjoy doing this?_____

_____

_____

_____

APPENDIX D: PRETASK TABLES

Table 2

Number of Subjects Including Target Objects in Pretask Array by Age

	Age (in years)						
Number of TARGET Objects in Array	3	4	5	6	7	8	Total/ Percent
1 Object	1						1 2.5
2 Objects	3	6	3	1	2		15 37.5
3 Objects		1					1 2.5
4 Objects		1	1	7	9	5	23 57.5
Total	4	8	4	8	11	5	40
Percent	10.0	20.0	10.0	20.0	27.5	12.5	100.0

Statistic	Value	T-value	p
Gamma	.84925	7.96320	$<.05$

Table 3

Number of Subjects Including Extraneous Objects in Pretask Array by Age

	Age (in years)						
Number of Extra Objects In Array	3	4	5	6	7	8	Total/ Percent
13 Extraneous Objects		2	2		1		5 12.5
One Extraneous Object	2	1		2	1		6 15.0
O Extraneous Objects	2	5	2	6	9	5	29 72.5
Total	4	8	4	8	11	5	40
Percent	10.0	20.0	10.0	20.0	27.5	12.5	100.0

Statistic	Value	T-value	P
Gamma	.47500	2.81019	$<.05$

Table 4

Number of Subjects Including Interobject Relationships in Pretask Array by Age

	Age (in Years)						
Number of Interobject Relations In Array	3	4	5	6	7	8	Total/ Percent
1 Relationship	4	6	3	1	2		16 40.0
2 Relationships		1					1 2.5
4 Relationships				1	1		2 5.0
5 Relationships					1		1 2.5
6 Relationships		1	1	6	7	5	20 50.0
Total	4	8	4	8	11	5	40
Percent	10.0	20.0	10.0	20.0	17.5	12.5	100.0

Statistic	Value	T-value	p-value
Gamma	.77011	7.61856	$< .05$

Table 5

Number of Subjects Including Intraobject Relationships in Pretask Array by Age

Number of Intraobject Relationships In Array	Code	Age (in years) 3	4	5	6	7	8	Total/ Percent
0 Relationships	0		2	1				3 7.5
1 Relationship	1	4	5	2	1	2		14 35.0
2 Relationships	2			1				1 2.5
3 Relationships	3		1		7	9	5	22 55.0
Column Total		4	8	4	8	11	5	40
Column Percent		10.0	20.0	10.0	20.0	27.5	12.5	100.0

Statistic	Value	T-value	p-value
Gamma	.81019	9.65540	$<.05$

Table 6

Number of Subjects Including Target Objects in Pretask MATCH Photo by Age

Number of TARGET Objects in Pretask Photo	Code	Age 3	4	5	6	7	8	Total/ Percent
2 Objects	2	1	4	3		1		9 22.5
3 Objects	3	2	3		2	1		8 20.0
4 Objects	4	1	1	1	6	9	5	23 57.5
Column Total		4	8	4	8	11	5	40
Column Percent		10.0	20.0	10.0	20.0	27.5	12.5	100.0

Statistic	Value	T-value	p-value
Gamma	.67981	6.23955	$<.05$

Table 7

Number of Subjects Including Extraneous Objects in Pretask MATCH Photo by Age

Number of Extra Objects in Pretask MATCH Photo	Code	Age (in years) 3	4	5	6	7	8	Total/ Percent
13 Objects	-13		1					1 2.5
7 Objects	-7		1		1			2 5.0
6 Objects	-6			1				1 2.5
5 Objects	-5		1	1				2 5.0
4 Objects	-4	1				1		2 5.0
3 Objects	-3		1	1		1		3 7.5
2 Objects	-2	2			3	2	3	10 25.00
1 Object	-1	1	3		3	6	2	15 37.5
0 Objects	0		1	1	1	1		4 10.0
Column Total		4	8	4	8	11	5	40
Column Percent		10.0	20.0	10.0	20.0	27.5	12.5	100.0

Statistic	Value	T-value	p-value
Gamma	.19292	1.55431	ns

Table 8

Number of Subjects Including Interobject Relationships in Pretask MATCH Photo by Age

Number of Interobject Relations in Pretask MATCH Photo	Code	Age (in years) 3	4	5	6	7	8	Total/ Percent
1 Relationship	1	1	4	3		1		9 22.5
2 Relationships	2	1	3		2	1		7 17.5
3 Relationships	3	1						1 2.5
4 Relationships	4	1			2	3		6 15.0
6 Relationships	6		1	1	4	6	5	17 42.5
Column Total		4	8	4	8	11	5	40
Column Percent		10.0	20.0	10.0	20.0	27.5	12.5	100.0

Statistic	Value	T-value	p-value
Gamma	.61364	6.55596	$<.05$

Table 9

Number of Subjects Including Intraobject Relationships in Pretask MATCH Photo by Age

Number of Intraobject Relationships in Pretask MATCH Photo	Code	Age 3	4	5	6	7	8	Total/ Percent
0 Relationships	0		1	1				2 5.0
1 Relationship	1	1	5	2		1		9 22.5
2 Relationships	2	2	1	1	2	1		7 17.5
3 Relationships	3	1	1		6	9	5	22 55.0
Column Total		4	8	4	8	11	5	40
Column Percent		10.0	20.0	10.0	20.0	27.5	12.5	100.0

Statistic	Value	T-value	p-value
Gamma	.69869	6.72233	$<.05$

Table 10

Centeredness of the Objects in Pretask MATCH Photo by Age (Number of Subjects)

		Age (in years)						
Centeredness of Photo	Code	3	4	5	6	7	8	Total/ Percent
Not Centered	0	4	8	3	7	5	3	30 75.0
Centered	1			1	1	6	2	10 25.0
Column Total		4	8	4	8	11	5	40
Percent Centered by Age		0.0	0.0	25.0	12.5	54.5	40.0	

Statistic	Value	T-value	p-value
Gamma	.69065	3.54487	<.05

Table 11

Height of Station Point of Pretask MATCH Photo by Age (Number of Subjects)

		Age (in years)						
Height of Station Point	Code	3	4	5	6	7	8	Total/ Percent
High Or Low	0	4	6	4	7	9	3	33 82.5
Correct	1		2		1	2	2	7 17.5
Column Total		4	8	4	8	11	5	40
Percent Correct by Age		0.0	25.0	0.0	12.5	18.2	40.0	

Statistic	Value	T-value	p-value
Gamma	.28155	.97626	ns

Table 12

Correct Distance (Size of Objects) by Age (Number of Subjects)

		Age (in years)						
Distance From Array	Code	3	4	5	6	7	8	Total/ Percent
Too Close or Too Far	0	4	8	4	8	11	4	39 97.5
Correct Distance	1						1	1 2.5
Column Total		4	8	4	8	11	5	40
Percent Correct by Age		0.0	0.0	0.0	0.0	0.0	20.0	

Statistic	Value	T-value	p-value
Gamma	1.00000	1.03819	ns

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