In C. Rovee-Collier, L. Lipsitt, + H. Haynes (Eds.) Advances in infancy research, Vol. 12. Stamford, CT: Ab 1998.

Chapter 5, Paper 10

The Use of Preferential Looking as a Measure of Semantic Development*

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INTRODUCTION

It has been generally agreed that spatial terms are mapped onto preverbal notions of spatial relations (e.g., Piaget, 1954). The initial research that supported this view was conducted using experimental tasks that are based on spatial terms in English and

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other languages that have similar meanings (e.g., Clark, 1983; Johnston, 1984; Johnston & Slobin, 1979). It was then assumed that the preverbal notions underlying spatial terms were defined in the same or highly similar manner as they are defined in these languages. However, we now know that languages differ widely in the way spatial relations are lexicalized (e.g., Bavin, 1990; Brown, 1994; Choi & Bowerman, 1991; Emmorey, 1996; Levinson, 1996). For example, instead of marking support or containment relations in the way English does with the terms *on* and *in*, the Korean language signifies a "tight-fitting" relation by the term *kkita* that cuts across both support and containment relations. Placing a ring tightly *on* a pole and putting a peg tightly *in* a hole are categorized as different relations in English but are categorized as the same relation in Korean. If spatial relations are already formed preverbally, then the "mapping" problem infants face between linguistic form and meaning seems complex. What are preverbal categories like, such that they can be used for learning many different languages, each making its own distinctions?

The research we present in this paper represents our first attempts at uncovering the complex interaction between preverbal spatial concepts and language acquisition. In the first experiment, we examine the age at which toddlers first begin to *comprehend* spatial terms in two languages: English and Korean. This research was originally proposed by Soonja Choi and Melissa Bowerman in order to extend their cross-linguistic investigations of the correct and incorrect (overgeneralized) *production* of the English terms *in* and *on*, and the Korean terms *kkita* (meaning "put [figure] into/onto/together with a tight-fitting [ground]"), *nehta* (meaning "put into a loose container"), and *nohta* ("put loosely onto a surface"). In the second experiment, we examine spatial cognition in preverbal infants. This stems from research by Laraine McDonough and Jean Mandler, who have been investigating preverbal cognition as it concerns concept formation and memory development (e.g., Mandler & McDonough, 1993; McDonough & Mandler, 1994).

In both studies, preferential looking was used as the dependent measure. We first used this measure to assess language comprehension in children learning either English or Korean by following the procedure set up by Golinkoff, Hirsh-Pasek and their colleagues (e.g., Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987). For Experiment 2, we adapted our preferential-looking procedure in order to test infants' preverbal categories of spatial relations. Although the details of the testing procedures differ in the two experiments (see Methods sections), the use of the same measure (preferential looking) allowed us to use similar test stimuli and, in some instances, the same test stimuli. We believe that the similarities in method and stimuli between these two studies allow us to make comparisons in the development of preverbal concepts and language acquisition in a more direct fashion than has been possible in previous research. We begin the next section with a discussion of the previous research on chil-

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Christina Gil, Laura Holmes, Miyong Kim, Tam Kozman, and Debbie Thompson for assistance in this project. Parts of this research were reported at the Biennial Meeting of the Society for Research in Child Development, Indianapolis, Indiana, 1995.

dren's understanding of spatial relations. Afterwards, the details of our testing procedures and the results are presented. We then conclude with a few suggestions on how preferential looking can be implemented in other research.

ISSUES

Children's perception of spatial relations

Recent research suggests that some spatial relations are readily perceived by 4- to 12-month-olds such as "above" versus "below" (Antell & Caron, 1985; Quinn, 1994), "left" versus "right" (Behl-Chada & Eimas, 1995), "support" versus "non-support" (Needham & Baillargeon, 1993), and "containment" versus "non-containment" (Kolstad & Baillargeon, in preparation). For example, Quinn (1994) tested "above" and "below" relations with 3- and 4-month-olds by showing them four exemplars in which a dot was depicted in a different location above a horizontal bar. They were then shown two novel displays, one in which the dot had been shifted to the right or left of the positions shown in the familiarization exemplars (but was still above the line), and one in which the dot was depicted below the line. Infants preferred to look at the dot below the horizontal line indicating that they distinguished the above relation shown in the familiarization stimuli from the below relation shown in the test display. This finding indicates that young infants discern the differences between "above" and "below" relations, at least when a single object is used.

Other research has used non-identical but highly similar objects (objects belonging to the same taxonomic category) to test spatial relations (e.g., Behl-Chada & Eimas, 1995). However, responding to a *change in the spatial relation* of one object or highly similar objects to a particular reference point is not the same as recognizing that various, unrelated objects can be in the *same spatial relation* relative to other objects. Adults understand spatial relations despite perceptual differences among the objects involved in these relations. For example, the relation expressed by the English word *above* applies equally to pictures hanging on walls "above" desks, tree branches hanging "above" fences, the sun "above" clouds, and heads "above" shoulders. The ability to understand that the same relative position applies to all these cases requires that one ignore the perceptual differences among these objects and attend instead to the constancy of their relation to each other by abstracting the relations themselves. The products of such abstractions are the concepts ABOVE and BELOW, which can then be used for generalizing across widely varying contexts (Mandler, 1996).

When does such flexibility first develop? Some evidence for flexibility has been demonstrated by Kolstad and Baillargeon (in preparation) in their recent studies on containment with 10-month-olds. These researchers used a familiarization preferential looking paradigm similar to that used by Quinn. They showed infants various familiarization objects that were similar in shape (all were cylindrical) and then test-

ed them with two displays: one with a cylindrically shaped non-container that was similar to the familiarization objects in shape, but not function, and another with a box-shaped container that was similar to the familiarization objects in function, but not shape. According to our traditional views on familiarization and preferential looking tasks, one would predict that infants would examine the box-shaped object longer than the cylinder because it was more novel in overall appearance. If, however, infants attended more to the function of the objects than their shape, then the cylindrical non-container should appear novel. After the demonstration of the test objects' functions (note that despite the appearance that the test cylinder was bottomless, it was shown to "magically" function as a container by means of a transparent bottom), infants were found to look longer at the cylinder, thus suggesting that they detected the discrepancy between the familiarization and test objects in terms of containment relations, not simply in terms of the overall shapes of the objects (but see also MacLean & Schuler, 1989).

The results of research such as this presents some interesting questions. How widely are generalizations made? If toddlers have concepts for spatial relations then they should be able to understand such relations across many unrelated and dissimilar objects. The data showing that infants as young as 3 months can distinguish relations such as above and below (Quinn, 1994) and then by 10 months can distinguish containment from non-containment based on functional rather than shape similarity (Kolstad & Baillargeon, in preparation) suggest that as an understanding of spatial relations develops, that understanding becomes more flexible. But the extent to which preverbal infants generalize functional or relational properties across perceptually dissimilar objects is not well understood at either the younger or older ages. With few exceptions (e.g., Kolstad & Baillargeon, in preparation), researchers have tested spatial relations in narrow and highly constrained contexts. If infants engage in perceptual analysis of the functional and spatial relations among objects that would allow them to conceptualize such relations (Mandler, 1992), then it is likely that they would generalize various relations across a variety of objects. Our goal is to determine *when* in development these generalizations are made and *whether* such early accomplishments form the foundation on which language is based. The experiments we present below only begin to bridge our understanding of the complex relation between early cognition and language acquisition.

ACQUISITION OF SPATIAL TERMS

Production data

Researchers studying language acquisition have often hypothesized that the order in which spatial terms (locatives) are acquired reflects the order in which the concepts they express emerge. For example, Clark (1983) observed that spatial terms are generally learned in a consistent order in English. Terms for functional/topo-

logical containment (*in*), support and contiguity (*on*) are produced early in development, whereas terms expressing proximity relations (*next to, beside, between*) as well as projective relations (*in front of, behind*) are produced much later (Johnston, 1984). It is also important to note that this order is consistent across languages (Johnston & Slobin, 1979).

The range of contexts across which spatial terms are extended provides us with an indication of the early meanings children assign to such terms. Research has shown that even though these words are learned in specific contexts, they are often rapidly generalized across several contexts (e.g., McCune-Nicolich, 1981; Nelson, 1974). Recent data collected by Bowerman and Choi (1994) suggest that children seem quickly to hone in on the correct extensions of the spatial terms of their language. To give the reader a clearer view of how differently English and Korean lexicalize spatial relations, a Venn diagram displaying some of these differences is shown in Figure 1. The solid line drawn around the object relations in the center of the figure represents the classification pattern of the Korean term *kkita* whereas the dotted lines represent the classification patterns of English terms meaning "to put in," "to put on," and "to put together." For example, putting a cassette in a case or a bookmark in a book are described by English speakers as *in* and putting glasses on or placing a top on a pen are described as *on*. Korean does not distinguish these two categories with terms equivalent to *in* or *on* but lexicalizes all these relations with the term *kkita*. The way these two languages crosscut spatial relations poses an interesting challenge to researchers studying language acquisition. If infants form universal prelinguistic spatial categories onto which spatial terms are mapped, then one might expect that children will initially extend spatial terms in similar ways regardless of the language they are learning.

Bowerman and Choi (1994) tested children's extensions of spatial terms by having an experimenter hold up various objects and start a particular action with them. Then, they asked English- and Korean-speaking adults and children (aged 2 to 3.5 years) to describe what to do to complete the action. For example, the experimenter held up two magnetic train cars and started to put them together but stopped short of completing the action of attaching them. The subject was then asked what to do next. The spatial terms used by the subjects in their descriptions provided data showing how the spatial terms in English and Korean are generalized. For example, English-speaking adults and children typically responded by telling the experimenter to put the train cars *together* or put one car *on* the other. Comparisons were then made across age groups and languages. The main finding was that children as young as two years of age gave descriptions that were more similar to the adult speakers of the language they were learning than to children learning the other language. That is, Korean-speaking children extended spatial terms in a manner more similar to Korean-speaking adults than to English-speaking children. In the same manner, English-speaking children extended spatial terms in a manner more similar to English-speaking adults than to Korean-speaking children. This finding shows that at least by two years of age, the influence of the language children are learning is quite strong.

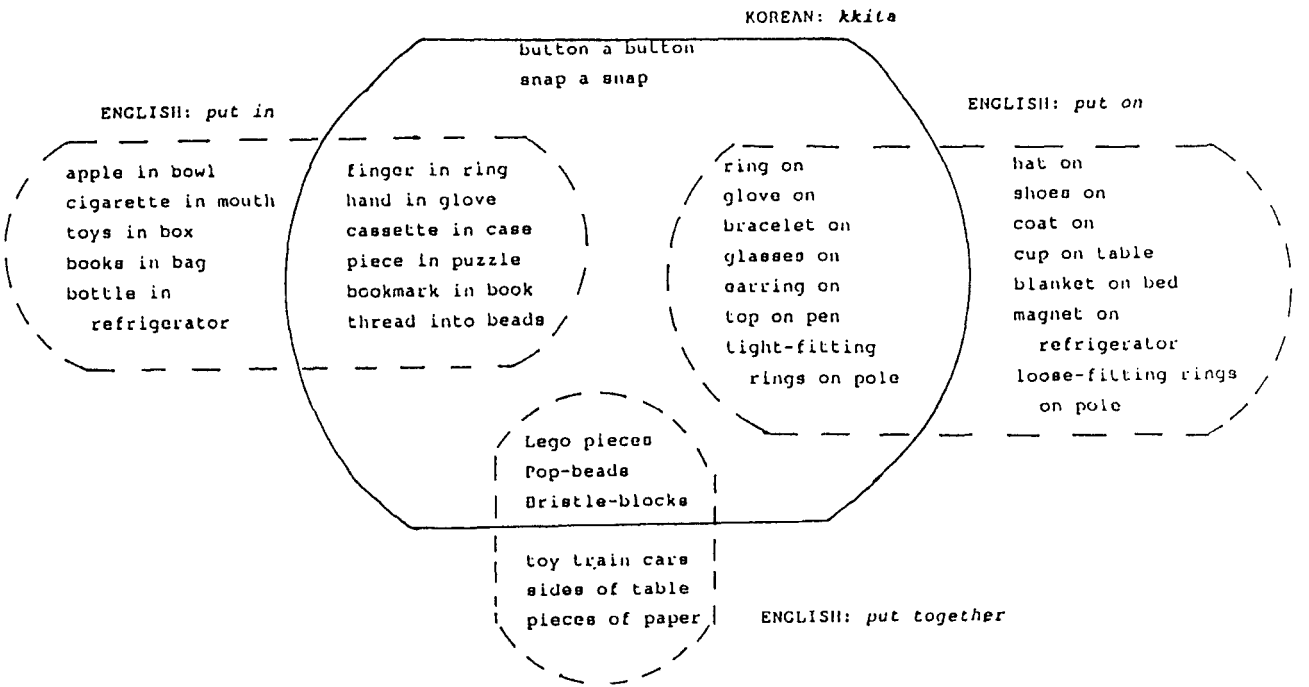

FIGURE 1. The category of *kkita* meaning to "put into a relationship of tight fit or attachment" compared to English put *in/on/together.*

Not surprisingly, some errors in extension were found. For example, young English learners overextended *in* to placing a log on a train whereas all English-speaking adults described the same activity using the spatial term *on*. In another example, Korean learners overextended *kkita* to hanging a towel on a hook whereas Korean-speaking adults describe the same activity using the term *kelta* [meaning "to hang" or "hook"]. With development, children learning either English or Korean tune up their spatial categories and label them more precisely (see Bowerman, 1996).

Why Comprehension Data are Needed

Given that languages differ in how spatial relations are semantically categorized, children have the challenge of figuring out how to apply the spatial terms they learn. The above study was based on production: The data were obtained by asking subjects to anticipate and describe spatial relations. However, comprehension often precedes production, and discrepancies may arise between what children produce and what they comprehend. For example, young children might distinguish an "on" relation from a "together" relation, but if they only know the term *on* they might extend it to include instances from both categories. Alternatively, they might have difficulty remembering the terms they have learned for each relation, but would recognize them if they heard them. Whether the problem is due to limited vocabulary or limited memory, young children may substitute a word whose meaning they think is similar enough to the meaning they want to express (Bloom, 1973).

Another frequently reported finding in production data is that children underextend some words, using them in more limited contexts than adults would (e.g., Clark, 1983). For example, Bowerman's daughter Eva first used *off* only in the context of removing clothing and other items from the body. Underextensions may occur because children cannot remember the term in new contexts but would recognize its appropriateness if it were used by others, or because they have not yet generalized the term to other contexts and so would not know that it is appropriate (Reich, 1976). Thus, it is not clear whether overextensions and underextensions are *conceptual* problems, in which case they should occur in both production and comprehension, or whether they are simply restricted to vocabulary and memory constraints. Clearly, what is required is a method to test children's *comprehension* of spatial terms.

EXPERIMENT 1: COMPREHENSION OF SPATIAL TERMS IN ENGLISH AND KOREAN

Our first study examined English-speaking toddlers' comprehension of the word *in* and Korean-speaking toddlers' comprehension of the word *kkita*. These two terms dissect spatial relations in an overlapping way (see Figure 1). In English, actions demonstrating containment and support relations are distinguished with the words *in* and *on*, whereas in Korean, the differences between containment and support relations are

ignored in situations where the action involves tight-fitting contact (lexicalized as *kkita*). Our question was: When in development do toddlers begin to comprehend the correct extension of the spatial terms they learn? That is, when do children learning English extend the word *in* to containment relations, ignoring the degree to which the contained object fits tightly or loosely in the container, and when do children learning Korean extend the word *kkita* to tight-fitting relations, ignoring the differences between containment and support? We showed toddlers two scenes in which "in" and "kkita" relations were demonstrated with various objects. During the test trials, an auditory presentation described one of the two scenes. We predicted that children who comprehend the spatial terms in the audio descriptions would look longer at the scene that matched the description than at the scene that did not match.

We began testing 14-month-olds and then tested successively older children. We found no clear evidence for comprehension of either *in* or *kkita* with toddlers younger than 18 months of age using this particular task, so the data we report below are from toddlers from 18 to 23 months. Data collected from infants 14 months of age and younger are presented in Experiment 2, regarding infants' *prelinguistic* comprehension of spatial categories.

Method

Children were selected to participate on the basis of their exposure to only one language: English (n = 20) or Korean (n = 10). Their ages ranged from 18 months, 3 days to 23 months, 27 days; mean age = 20 months, 6 days. Children were tested individually, seated on the parent's lap facing two video monitors. Located between the monitors was a speaker which presented auditory input. Parents wore opaque glasses during the session so that they could not inadvertently cue their children. The children's looking patterns were videotaped for later coding.

Children were presented with three kinds of trials: two familiarization trials, a control trial, and two test trials. During the test trials, the auditory stimulus matched (i.e., described) the action shown on only one of the monitors and urged the child to find the action. Between each trial, a ring of small flickering colored lights located between the two monitors flashed to draw the child's gaze back to the center point. The four pairs of scenes were professionally videotaped and edited onto two tapes synchronized for trial duration and inter-trial intervals. In Table 1 is a list of the four pairs of test pairs used in this experiment along with the English and Korean terms listed below the appropriate scene. The scene that matches the target word in English and Korean is the same for two of the test pairs (*pegs, books*) but different for the remaining two pairs (*Legos™, rings*). As can been seen, for the first and third pairs (*pegs* and *books*) the term *in* in English and *kkita* in Korean are used to describe the same scenes which depict tight-fitting, containment relations. In the remaining two pairs (*Legos™, rings*), the relations are split so that *in* and *kkita* apply to different scenes within each pair. The "in" relation in the Legos™ scene shows the model placing Lego™ pieces loosely inside a container whereas the "kkita" (tight-fitting)

TABLE 1.

Scenes used to test children's comprehension of the terms *in* and *kkita*. Note that the left and right side of presentation were counterbalanced among subjects in both groups.

	Left scene	Right scene
Pair 1 (**pegs**)	Wooden pegs placed tightly in holes in a wooden block	Wooden pegs placed on top of a wooden block
Audio during test trials	"in" / "kkita"	No matching audio
Pair 2 (**Legos™**)	Legos™ placed on top of each other making a tight fit	Legos™ placed loosely inside a plastic container
Audio during test trials	"kkita"	"in"
Pair 3 (**books**)	Books stacked one on top of another	Books placed tightly inside covers
Audio during test trials	No matching audio	"in" / "kkita"
Pair 4 (**rings**)	Plastic rings placed inside a large basket	Plastic rings placed tightly on a pole
Audio during test trials	"in"	"kkita"

relation shows the model tightly attaching Legos™ onto one another. The "in" relation in the rings scene shows the model placing the rings inside a basket whereas the "kkita" (tight-fitting) relation shows the model placing rings tightly onto poles. These four pairs of scenes were chosen because they allowed us to examine the differential effect of the two languages in terms of how the relations (containment or tight-fit) are labeled.

In each scene, a person was shown performing an activity (containment or tight-fit) three times in succession. Only the model's hands and arms were shown on the video to increase the salience of the action and exclude irrelevant distractions. Within each pair of scenes, we tried to make both scenes as similar as possible in nonlinguistic salience by using the same objects or using objects with the same colors. We also matched the cadence in which the model performed the actions between the two scenes within a given pair. For example, at the same time one could see the model's hand placing a peg inside the wooden block in one scene, one could see the model's hand placing a peg on top of the wooden block in the other scene.

Before the test trials, children were first given two familiarization trials in which the two scenes within a pair were shown sequentially. For example, on the first familiarization trial, a subject was shown one scene in which a hand inserts pegs into the hole in the wooden block on the left monitor and, for the next familiarization trial, the subject was shown the scene of the hand placing the pegs on top of the solid wooden block on the right monitor. During each familiarization trial, a prerecorded voice encouraged the child to look at the scene. For example, on the first trial the auditory

message was: "Look! See the pegs. What is she doing with the pegs?" Then, during the next familiarization trial, in which the contrasting scene was shown on the opposite monitor, a similar vocalization was played: "Now look! More pegs. What is she doing with these pegs?" Since the children in this study typically did not produce the terms *in* or *kkita* (according to the parental reports we collected at the beginning of the session), we did not expect them to answer such questions. The vocalizations were offered simply to entice them to examine the scenes.

Following the two familiarization trials, children were given a control trial in which both of the scenes were presented simultaneously. During the control trial, children heard the prerecorded voice say, "Oh look! You see both of them now!" The control trial allowed us to measure children's preferences by their looking time within a given pair of scenes. Even though we had designed the scenes to control for nonlinguistic salience in terms of the objects used, we could not control for any preferences the children might have for the actions depicting the spatial relations. For example, we thought that children might prefer to look at the containment relations when they were paired with support relations (as in the *Pegs* and *Books* pairs). This expectation was based on Clark's (1973) observations that when given a choice, children prefer to perform containment rather than support relations. Since the vocalization accompanying the control trial did not instruct the children where to look, we could calculate a preference score independent of specific linguistic input. In this way, we could compare children's looking preferences during the control trial to their looking preferences during the test trials when they were instructed to look at one particular scene.

Two test trials were given next. As in the control trial, the scenes were shown simultaneously, but this time children were explicitly asked to look at a particular scene. The English children heard "Where is she putting it IN?" and the Korean children heard the Korean equivalent of "Where is she putting it TIGHTLY?" during the presentation of both test trials. Each scene was presented on the same monitor during the familiarization, control, and test trials in case children anticipated where the matching scene would appear before the test trial began. That is, on hearing "Where is she putting it IN?", a child might remember that the scene matching the vocalization was presented on the left scene during the control trials. We predicted that if children comprehended the terms, they would look longer at the scene that matched the auditory instructions during the test trials than during the control trials.

This procedure, showing two familiarization trials, then a control trial followed by two test trials, was then repeated until all four pairs had been shown. Trial duration was 7 seconds and the intertrial interval was 3 seconds. The dependent measure was the time children spent looking at each scene.

The video of each child's gaze was coded offline by at least two coders using a button-press box ("looks left," "looks right," "looks center," "looks away"). Coders did not know on which side the match scenes were shown. Reliability between coders was considered acceptable if both agreed on which scene was looked at longer on

every trial (100% agreement) and discrepancies did not exceed 0.5 seconds. Discrepancies larger than this were resolved by a third or fourth coder until agreement was reached.

Results and Discussion

The looking time data were analyzed in a mixed-design analysis of variance for repeated measures with Language (English, Korean) as the between-group factor, and Pair (*pegs*, *Legos™*, *books*, *rings*), Trial (control, test), and Scene (matching, nonmatching) as within subject factors. A two-way interaction involving Trial and Scene was found, F (1, 28) = 5.02, $p < .05$, and is displayed in Figure 2. The first two columns on the left represent the test trials (the overall mean of both test trials is used). Tests of simple main effects by analyses of variance indicated that subjects looked significantly longer at the matching than at the nonmatching scene in the test trials (matching $M = 2.92$ > nonmatching $M = 2.29$; F (1, 29) = 14.26, $p < .001$), but not in control trials (matching $M = 2.84$ = nonmatching $M = 2.69$; $p = .43$). That significant differences were found for the test but not the control trials indicates that preference

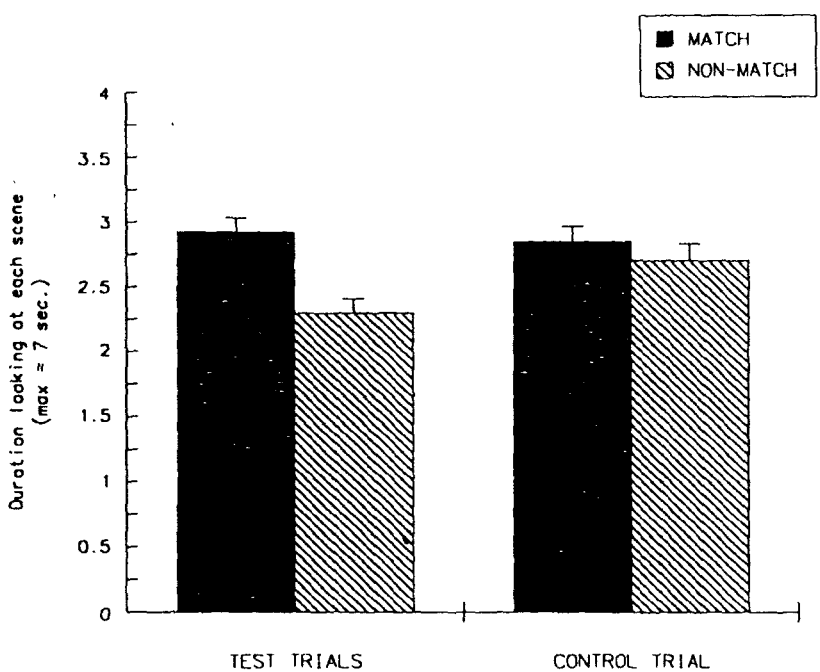

FIGURE 2. Mean duration of looking at the matching and nonmatching scenes during the test and control trials in Experiment 1.

for the matching scene during test trials was not simply due to non-linguistic salience; rather, the toddlers attended to the vocalizations and adjusted their looking patterns appropriately. Looking time at the matching scene did not in fact differ between control and test trials ($p = .53$), but looking at the *non*matching scene decreased significantly, $F(1, 29) = 11.19, p < .01$. That is, with each opportunity to examine the scenes, infants looked less at the nonmatching scene but maintained their interest in the matching scene.

We also examined the data to see how many children fit the predicted pattern of looking relatively longer at the matching than the nonmatching scene during test than during control trials. Overall, 70 percent of the children in each group responded to the verbal instructions by looking longer at the books being placed tightly inside the covers (described in English using *in* and in Korean using *kkita*) than at the scene showing the books being placed one on top of another. In the rings task, 70 percent of the children in the English-learning group hearing "Where is she putting it in?" looked relatively longer at the scene showing the rings being placed inside a basket. Yet, 80 percent of the children in the Korean-learning group looked longer at the opposite scene showing the rings being placed tightly onto poles when they heard the Korean equivalent of "Where is she putting it tight-fitting?" Thus, the word *in* is comprehended as containment by the majority of English children and the word *kkita* is comprehended as tight-fitting by the majority of the Korean children.

Only half of the children in each language group responded preferentially to the matching scene in the pegs pair and only the Korean learners responded preferentially to the matching scene in the Legos™ pair (80%). At this time, we cannot be certain why either of these results was found. Since both the board and pegs were unpainted wood, it is possible that children may have either not noticed the holes in the one board or may have only examined the end state of the actions. That is, they may have construed the scenes as short versus long pegs sitting atop a board. The finding that the Korean- but not the English-speaking children responded in the predicted direction to the Legos™ scenes poses an interesting finding. During the control trial, children showed no preference for one scene over the other. Both the Korean and English learners looked equally at the scene showing Legos™ being placed into a container and the scene showing Legos™ being attached tightly to one another. During the test trials, Korean learners (but not English learners) looked longer at the Legos™ attached tightly to one another. It is possible that the reason why this test pair worked for the Korean learners is because the term *kkita* highlights a relation that is not precisely marked in English. Whereas the English learners understood *in* as it related to the rings task, they may have not have preferentially looked to the *in* in the Legos™ task because they found the affinity of the tight-fitting relation intriguing but did not know exactly how to categorize it (see Choi, McDonough, Bowerman, & Mandler, in preparation).

EXPERIMENT 2: INFANT COMPREHENSION OF SPATIAL CATEGORIES

The results of Experiment 1 suggest that by the time children are 18 months of age they can comprehend spatial terms according to the language they are learning. How is it possible for children to link spatial words to language-specific semantic categories at such an early age? One possibility is that preverbal infants conceptualize many spatial relations, even those that are not expressed in the language they are learning. In this case, the infants' task is to identify the concepts that are picked out by the words they are learning (Mandler, 1996). Regardless of which part of speech is used to denote the relation (e.g., preposition or verb), the words should be easily learned provided that they are salient in the speech stream (see Bowerman, de Leon, & Choi, 1995). Another possibility is that a given language may make distinctions preverbal infants do not. In this case, toddlers may need to attend to the contexts in which a particular spatial term is used and then analyze the similarities among these contexts in order to determine the meaning of the term (Bowerman, 1996).

For our first study on preverbal spatial categories, we decided to test a contrast that is found in *both* Korean and English (as well as many other languages): tight-fitting containment versus loose support. Note that in this experiment, the fittingness relation (tight versus loose) is conflated with the containment relation (containment versus support). We are still in the early stages of our work on preverbal categories. We have started our research with the categories that both languages make because if our application of the preferential looking technique proves useful in testing spatial categories that are distinguished in most languages, the technique should also be useful in testing the unique distinctions that are made in some languages but not others. For example, we can use this measure to test a "tight-fitting" category (as lexicalized in Korean as *kkita*) that extends across containment and support relations and a "containment" category (as lexicalized in English as *in*) that extends across tight- and loose-fitting relations.

Previous research showing that infants distinguish various spatial relations has used perceptually similar and/or taxonomically related objects to depict the relations during familiarization and test trials (e.g., Behl-Chada & Eimas, 1995; Quinn, 1994). We decided to extend these findings by familiarizing infants to a spatial relation using a wide variety of objects that are not only perceptually dissimilar but also drawn from different classes (see method). If infants are found to respond to the relational similarities across widely varying objects, then they must have analyzed and abstracted these relations (Mandler, 1996). Following familiarization, infants were given test trials consisting of two pairs of scenes using objects that had not appeared in the familiarization trials. Within each test pair, one scene showed the familiarized relation (e.g., loose support) and the other showed a new relation (e.g., tight-fitting containment). In this experiment, it is the concepts rather than the terms that are important and so a nonlinguistic auditory stimulus (i.e., music) accompanied the presentation of the familiarization and test scenes. We played one tune during the famil-

iarization trials ("Oh Mathilda!") and then changed to a different tune during test trials ("Mexican Hat Dance"). The music was added to keep subjects from becoming restless during the familiarization trials and the change in music during test trials was to alert them to attend closely to the test scenes. If infants then looked longer at the scene showing the novel relation, this would show that they distinguished it from the relation shown in the familiarization trials.

Method

A total of 24 infants aged 9 to 14 months have been tested. A total of 48 infants will be required to complete counterbalancing, but the results to date are presented here to show that this method is suitable for testing the nature of preverbal spatial concepts. Half the infants were familiarized with a loose support relation (9-month-olds: N = 4; 11-month-olds: N = 4; 14-month-olds: N = 4), and the other half with a tight-fitting containment relation (9-month-olds: N = 3; 11-months-olds: N = 5; 14-month-olds: N = 4). Each infant was tested individually, seated on the parent's lap, facing two video monitors. As in Experiment 1, parents wore opaque glasses during the session so they would not influence the looking patterns of their infants. Infants' looking behaviors during both the familiarization and test trials were videotaped for later scoring. Coding was conducted in the same manner as in Experiment 1.

Six dynamic scenes were used as familiarization stimuli for each of the relations tested (see Table 2). In each scene, a person demonstrated either a loose support relation or a tight-fitting containment relation. Within each scene, the same relation was demonstrated three times. Perceptual qualities such as the size, color, shape, form, and texture of the objects that were acted on changed from scene to scene. Each familiarization scene was paired with another (e.g., letters were paired with Lego™ people, blocks with teacups, frogs with phones). We paired the scenes so that our subjects would come to expect different scenes on different monitors. Each pair of scenes was presented twice. On one familiarization trial, a particular scene was presented in the left monitor and three trials later, this same scene was presented on the right monitor. A total of six familiarization trials were given, each of which was 8 seconds long with 2 second intervals (black screen) between trials.

Immediately after the familiarization trials, we showed the test pairs. For the group familiarized with loose support relations, the test pairs were two of the tasks used in the previous experiment (books, pegs). The first test trial showed the books test pair (familiar relation: books stacked loosely on top of one another; novel relation: books placed tightly into covers). The second test trial showed the pegs test pair (familiar relation: pegs loosely placed on top of a wooden plank; novel relation: pegs placed tightly into holes in a wooden block). For the group familiarized with tight-fitting containment relations, the two pairs of test scenes were different.[1] The objects used in both scenes of the first test pair were soft, pastel colored, three-dimensional letters (S, E, T). In the familiar relation scene (i.e., tight-fitting containment), each letter was

TABLE 2.
Scenes used to test preverbal categorization of "tight-fitting in" versus "loose-fitting on" relations.

Familiarization: Loose-fitting on	
Left scene	Right scene
Sponge letters (S-E-T) placed on mats	Lego™ persons placed on stair steps
Teacup and coffee cups on small table	Geometric blocks balanced atop poles
Bean bag frogs placed on table	Phone receivers placed on phone bases
Lego™ persons placed on stair steps	Sponge letters (S-E-T) placed on mats
Geometric blocks balanced atop poles	Teacup and coffee cups on small table
Phone receivers placed on phone bases	Bean bag frogs placed on table
Test scenes (from Verbal task)	
Familiar relation:	Novel relation:
Books stacked atop one another	Books placed in tight fitting covers
Novel relation:	Familiar relation:
Pegs placed in holes in board	Pegs placed atop board
Familiarization: Tight-fitting in	
Left scene	Right scene
Geometric shapes placed into form box	Nesting cups placed one inside the other
Keys placed in locks	Lego™ persons placed in cars
Corks placed in transparent bottles	Books placed in covers
Nesting cups placed one insider the other	Geometric shapes placed into form box
Lego™ persons placed in cars	Keys placed in locks
Books placed in covers	Corks placed in transparent bottles
Test scenes	
Familiar relation:	Novel relation:
Sponge letters (S-E-T) placed in mats	Letters (S-E-T) placed upright on paper
Novel relation:	Familiar relation:
Shapes stacked one on top of the other	Sticks placed inside the hole of each shape

snugly placed into a matching hole in one of three mats. In the novel relation scene (i.e., loose support), each letter was placed one by one in a standing position on one of three sheets of paper. The objects used in both scenes of the second test pair were a plastic circle, triangle, and square, each with a small hole through its center. The familiar relation scene showed small sticks placed one at a time into the hole in each shape. The novel relation scene showed the three shapes being stacked one on top of the other. In one test trial, the novel relation was shown on the right monitor and on the other test trial, it was shown on the left monitor.

Results and Discussion

The total looking times to the novel and familiar relations during the two test trials were entered into an analysis of variance with age (9, 11, 14 months) and familiarization (loose support, tight-fitting containment) as the between-group variables and scene (novel relation, familiar relation) as the within-subject variable. No significant main effects were found; however, a two-way interaction involving age and scene, $F(2, 21) = 3.89$, $p < .05$ was statistically significant. To determine the locus of this interaction, we examined each age separately. These data are displayed in Figure 3. Note first that the 9-month-olds looked longer at the familiar test scenes ($M = 6.31$ s) than at the novel ones ($M = 3.63$ s), whereas the 11- and 14-month-olds looked longer at the novel test scenes (11 mo. $M = 5.8$ s; 14 mo. $M = 6.39$ s) than at the familiar ones (11 mo. $M = 4.05$ s.; 14 mo. $M = 3.88$ s). One-way analyses of variance comparing looking time to each of the test scenes were not significant for the 9- and 11-month-olds, but was marginally significant for the 14-month-olds, $F(1, 7) = 4.69$, $p = .06$). Looking longer at the novel scene with age (and conversely looking less at the familiar scene with age) can also be seen in this figure. One-way ANOVAs showed that

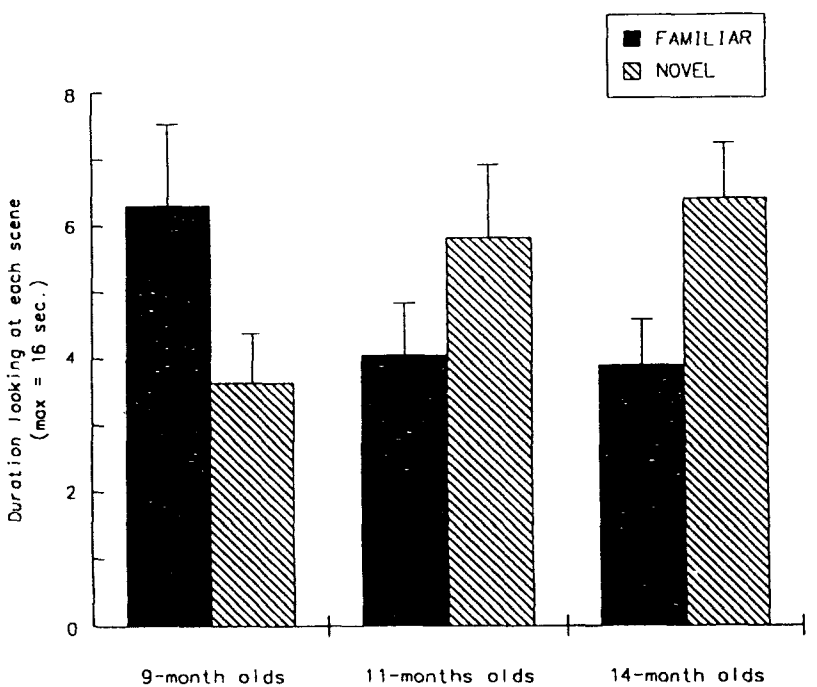

FIGURE 3. Mean duration of looking at the scenes showing the familiar and novel relations during the test trials for the 9-, 11-, and 14-month-olds in Experiment 2.

looking increased significantly to the novel scenes from 9 to 14 months of age and looking decreased significantly to the familiar scenes from 9 to 14 months of age (both p's $\leq .05$). The percentage of subjects who looked longer at the novel than the familiar test scenes are as follows: 9 months = 43 percent; 11 months = 78 percent; 14 months = 88 percent. Based on a binomial distribution, the percentage of 14-month-olds is significantly greater than chance ($p = .03$).

These preliminary results suggest that by the age of 14 months (and perhaps 11 months), infants distinguish loose support from tight-fitting containment relations, even when the perceptual characteristics of the objects used to demonstrate these relations vary widely. Although 14-month-olds appear not to comprehend the spatial terms that can be used to describe the relations tested here (recall that we could not demonstrate comprehension of *in* or *kkita* in toddlers younger than 18 months with the four pairs of scenes in Experiment 1), the results from this nonverbal task indicate that preverbal children raised in an English-speaking environment conceptualize at least two spatial relations: tight-fit containment and loose-fit support.

GENERAL CONCLUSIONS

The results from both experiments show that the preferential looking technique can be used to allow comparisons of infants' and children's preverbal and verbal spatial categories. In our first experiment, we found that toddlers learning English associate the term *in* with a spatial concept that crosscuts the concept that toddlers learning Korean associate with *kkita*. When shown one scene in which books were placed tightly into covers and another scene in which rings were placed onto poles, children learning Korean recognized them both as instances of the same relation, described as *kkita* (tight-fitting) whereas children learning English distinguished them as two instances of different relations. Conversely, children learning English recognized the scene in which books were placed tightly in covers and the scene in which rings were placed loosely in a basket as instances of the same relation ("in") whereas children learning Korean distinguished them. Using a related preferential-looking method in our second experiment (adapted from the first to allow testing of infants' preverbal categorization of space), we found that infants were able to detect spatial relations demonstrated with a variety of perceptually varied objects. After viewing several scenes showing either a tight-fitting containment relation or a loose support relation, infants looked longer at a scene showing a novel spatial relation. Note, however, that although tight-fitting containment relations are included in the semantic categories *in* and *kkita*, the extensions of these two terms contrast considerably. Loose-fitting containment relations are included in the semantic category *in* but not in the semantic category *kkita* and tight-fitting support relations are included in the semantic category *kkita* but not *in*. Thus, even though we have only a partial account of preverbal concepts, the technique appears to be an excellent way of continuing this research.

What is crucial to our understanding of language acquisition is the degree to which the various spatial relations that are made in different languages are also categorized by preverbal infants. Following Mandler's view (1996), children learning English will need to ignore a distinction between tight- and loose-fitting when learning the spatial terms of their language, whereas children learning Korean can map the terms they learn onto such a distinction (but need to ignore containment). Thus, some categories distinguished in early infancy may become less salient with development because children learn to ignore such distinctions. Investigation of this possible developmental pattern is currently under way.

The preverbal task also has the potential for providing a test of how language influences the salience of spatial categories. If some spatial categories become less salient with language learning, then adults may not show preferential looking in a task that contrasts relations not lexicalized in their language. Such a finding would be consistent with the kind of linguistic influence proposed by Whorf (1956). In order to see how adults would respond to a preferential looking task, we conducted a pilot study by giving adult speakers of English the same task we gave to infants in the Experiment 2. Of course, we needed to tell adults something about what we wanted them to do, but we kept our instructions to a minimum: We simply asked them to watch the scenes on the television monitors. Adult speakers of English looked significantly longer at the novel scenes showing that they recognized the differences between tight containment and loose support relations. After the experimental session, they also reported that they were aware of the difference between the containment and support relations shown in the test pairs. Some volunteered the information right away. Those who did not volunteer this information were given an oddity task in which they were shown four of the object sets used in the familiarization and test scenes. With three of the sets, we demonstrated the relation shown in the familiarization trials. With the remaining set, we demonstrated the novel relation. All adults told us that the novel relation contrasted with the familiarization relation by using the terms *in* and *on*. Interestingly, none of the adults commented on the simultaneous change from tight to loose, or loose to tight, which might well be reported by adult Korean speakers. Since we have yet to conduct such a test with Korean adults, we cannot make any conclusions regarding the Whorfian hypothesis at this point.

To summarize, preferential looking is a technique that can be used to examine early language comprehension. It can also be used to compare the acquisition of terms that are lexicalized differently across various languages. Not only were we able to assess comprehension, but we were also able to compare two groups of children who were learning either English or Korean exclusively (Experiment 1). With some adaptation, this technique is also valuable in assessing comprehension of spatial relations without verbal instructions. The use of dynamic scenes allows experimenters to examine relations that can be demonstrated using several varied objects. Dynamic scenes allow us to demonstrate relations that would be difficult to test using static images or pictures. The use of varied objects allows us to get a better understanding of early spatial categorization in terms of its flexibility (or perhaps in some cases, its rigidity). The

results of Experiment 2 (in which the test scenes were not accompanied with language) suggest that infants can analyze spatial relations such as tight-fitting containment and loose-fitting support across a wide variety of objects. Our next goal is to test relations that are semantically distinct in some languages but not others.

Our preliminary work with adults also suggests a promising way to explore the degree to which language might continue to influence adult spatial categories (see Levinson, 1996, for a good description of the difficulty of translating the spatial relations of some languages into others). Thus, the preferential looking paradigm has the potential to be used to examine spatial categories across ages (infancy through adulthood), both with and without linguistic input as well as across languages that define spatial relations in different ways. As suggested by the other papers in this chapter, preferential looking has the potential to clarify some of the major unresolved issues in cognitive and linguistic development—issues that have previously been difficult to address empirically.

NOTE

[1] Ideally, the same test scenes should be used for both groups in order to control for preferences infants may have for one scene over another within a given pair. By the time this chapter went to press, all 48 subjects had been tested and the test scenes had been used equally often for each familiarization task. None of the objects used in the familiarization scenes were used in the test scenes for any participant. The results of the final analyses are consistent with those reported: 9-month-olds looked longer at the familiar than the novel test scenes ($p = .07$) and 14-month-olds looked longer at the novel than the familiar test scenes ($p = .02$).

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