Precursors to spatial language

The case of containment

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In this chapter we ask whether there are similar developmental trajectories for natural language phonology and auditory perception compared to natural language semantics and concepts. What is new about this approach with respect to the discussion of spatial entities is that it offers insight from a previously unstudied population. We look at preverbal infants who are at the beginning stages of learning about spatial entities. The rationale is that, when children construct new cognitive abilities, they build on component cognitive systems that have a long ontogenetic history (Spelke 2000). Furthermore young infants have limited experience with language, so in many ways they offer insight to a system that has not been influenced by linguistic categories.

There is new interest in questions that lie at the intersection of language and cognition, regarding the existence of a universal ontology of spatial and mechanical relationships. On one view, spatial language derives from universal, non-linguistic representations of objects and the spatial layout. Because all animals are subject to the same physical and geometrical laws, knowledge of these laws may be internalized in human perceptual and cognitive systems (Gibson 1979; Shepard 1984; Spelke, Breinlinger, Macomber, & Jacobson 1992) and available for language learning (Jackendoff 1983; Landau & Jackendoff 1993; Li & Gleitman 2002; Talmy 1983). On a contrasting view, spatial and mechanical categories are constructed by children as they learn their native language. Because different languages capture different spatial and mechanical relationships (Bowerman 1996; Levinson 1996; Sinha & Jensen de Lopez 2000), speakers of different languages may form different representations of space and objects (Boroditsky 2001; Levinson, Kita, Haun, & Rasch 2002; Li & Gleitman 2002; Whorf 1956). Intermediate views also are possible, whereby systems of spatial representation in language and in perception are partially independent or mutually interacting (Imai & Gentner 1997; Munnich, Landau, & Dosher 2001; Slobin 2000).

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Understanding spatial entities implies understanding properties of the spatial relations among them. This chapter focuses on the origins of understanding spatial entities and how they are distinguished in language and cognition. More specifically, we are concerned with how spatial entities are categorized. There are fundamental questions about whether the categories that come out of semantic analyses reflect more general cognitive distinctions or whether they emerge from language itself.

One way to gain insight into relationships between natural language semantics and concepts is to look at a different but related set of relationships, between natural language phonology and auditory perceptions. Research on phonological development has revealed a striking developmental trajectory in infants' abilities to discriminate the sounds of native languages (Jusczyk 1997; Werker 1989). Infants are born with universal phonetic sensitivity: to a first approximation, they can discriminate phonetic differences in any of the world's languages. The ability to make these perceptual discriminations may provide the base features out of which categories are constructed. Through multimodal (auditory, visual, and proprioceptive) experience children develop perceptual feature spaces where distinctions that signal phonemic contrasts are perceived as distinct, whereas differences within a single phonemic category are not (Eimas, Siqueland, Jusczyk, & Vigorito 1971; Jusczyk 1997; Kuhl 2004). Similar discrimination patterns have been found in animals that do not develop language (i.e., chinchillas and non-human primates), suggesting that the human language faculty is built on a foundation of preexisting auditory sensitivities (Kuhl & Miller 1975; Kuhl & Padden 1982; Ramus, Hauser, Miller, Morris, & Mehler 2000) Hauser et al., 2003). Over the course of development, there is a decline in sensitivity to many non-native phonemic distinctions, so that adults are differentially sensitive to the phonetic differences marked by their language (Werker & Tees 1984). These findings suggest that language experience is necessary for the maintenance, but not for the initial emergence, of auditory categories (Werker 1989).

Here we ask whether a similar developmental trajectory applies to the acquisition of natural language semantics. Human languages show considerable variation in the spatial and mechanical categories that are marked by closed-class morphemes. For example, the English particles *in* and *on* mark the mechanical distinction between support and containment, but no closed-class morphemes in Korean mark this distinction (Choi & Bowerman 1991; Choi, McDonough, Bowerman, & Mandler 1999). In Korean, morphemes appended to verbs of motion express a different distinction – the distinction between placing an object into a tight-fitting relationship (*kkita*) vs. a loose-fitting mechanical relationship (*nohta*). The tight fit/loose fit distinction cross-cuts the English distinction between containment and support: whereas English speakers put the slide "in the carousel" (containment), the ring "on the finger" or "on the table" (support), Korean speak-

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ers describe the first two actions as creating a tight-fitting relationships (*kkita*), and the third as creating a loose-fitting relationship (*nohta*). The existence of these cross-cutting semantic categories raises questions about the acquisition of natural language semantics and the development of concepts. Examples demonstrate that the same physical events can be conceptualized in different ways across languages. How do these conceptual distinctions emerge? How do children learn which distinctions are mapped by which expressions in their language? Do mature speakers of English and Korean differ in their spatial and mechanical concepts?

Investigations into the emergence of spatial terms in children's vocabulary reveal that children are quite adept at learning the spatial distinctions particular to their language (Bowerman 1996; Choi & Bowerman 1991; Richards, Coventry, & Clibbens in press). Choi and Bowerman (1991) showed that Korean children learn the morphemes that express the tight and loose distinction as quickly as English children learn *in* and *on*, although, like English children, their initial categories are not identical to those of adults. Korean children do not go through a stage in which they try to fit the terms of their language into the spatial categories of containment and support to which American infants are sensitive, suggesting that the support/containment distinction has no special status. These findings do not, however, address the above questions. It is possible that language guides the development of spatial concepts from a very early point in development, and that English and Korean children use their linguistic input to construct spatial categories appropriate to their language (Bowerman & Choi 2003). Alternatively, it is possible that all the relevant spatial categories exist prior to language learning, and English and Korean children use their linguistic input to learn mappings from some of these concepts to particular linguistic forms (Mandler 1998).

What is new about this approach with respect to the discussion of spatial entities is that it offers insight from a previously unstudied population. We look at preverbal infants who are at the beginning stages of learning about spatial entities. The rationale is when children construct new cognitive abilities they build on component cognitive systems that have a long ontogenetic history (Spelke 2000). Furthermore young infants have limited experience with language, so in many ways they offer insight to a system that has not been influenced by linguistic categories.

With the revival of the Sapir-Whorf hypothesis, a wealth of new research on effects and non-effects of linguistic categories on conceptual distinctions has been undertaken (Boroditsky 2001; Gentner & Goldin-Meadow 2003; Slobin 2000), and some of it speaks to the above questions. This research, however, has yielded mixed results. On one hand, McDonough et al. (2003) have found that adult speakers of English & Korean differ in their categories of in/on and tight/loose. More specifically, English-speaking adults in preferential looking and oddity tasks reacted to the in/on distinction and did not discriminate the tight/loose difference

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whereas the Korean-speaking adults showed the reverse pattern of behavior. These data contrast with infants who, regardless of the ambient language, discriminated both the in/on and tight/loose category changes. In addition, Casasola & Cohen (Casasola & Cohen 2002; Casasola, Cohen, & Chiarello 2003) provide evidence suggesting that the categories are constructed slowly in children. They describe a developmental progression of spatial categories over the first two years of life that starts with learning to recognize the objects, then recognition of the spatial relationships between specific objects, and finally formation of the spatial category that is comprised of recognizing the spatial relationship independent of the particular objects. On the other hand, research by Munnich et al. (2001) suggests that these spatial categories influence "thinking for speaking" (Slobin 1996) but not non-linguistic thought or concepts. Munnich et al. (2001) asked adult native speakers of English, Japanese, or Korean a set of memory and naming questions in their native language focusing on contact/support relationships. The speakers' native language influenced performance when tested in the linguistic task but not when tested in the non-linguistic task, leading Munnich et al. (2001) to conclude that spatial language and spatial memory captured the same kinds of relationships but functioned independently. Other experiments, however, reveal effects of the spatial categories in one's native language on perceptual categorization in purely non-linguistic tasks (Boroditsky & Ramscar 2002) and in tasks presented in a non-native language that lacks the relevant categories (e.g., Boroditsky 2001).

One reason for the divergence in findings across laboratories may stem from variability in the nature of the events used to test for the mechanical concepts. Both McDonough et al. (2003) and Casasola & Cohen (Casasola & Cohen 2002; Casasola et al. 2003) used complex and widely varying sets of events, analogous to a speech perception experiment testing discrimination of /b/ from /d/ by presenting the words "finding", "divergence", and "McDonough" and testing for generalization to "Mandler" vs. "Bowerman." Continuing to follow the lead of speech perception researchers, we have tested infants' categorization of simpler and more minimally contrastive events, in hopes of presenting a more sensitive test of their conceptual distinctions.

Our research hypotheses are guided by the findings of speech perception researchers and the reasoning of Mandler (1998). Mandler points out that the variability in how spatial entities and spatial relations are expressed across languages does not mean that language is teaching the distinctions. It is equally plausible that language capitalizes on different aspects of the physical qualities of spatial relationships that infants have discovered through perceptual processes. Thus, children may come to the task of learning language equipped with all the principal categorical distinctions that the early-developing parts of the lexicon express; not only the distinctions of English but those of Korean and other languages. If that is the case, then prelinguistic children would possess a richer set of conceptual distinctions

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than those expressed by any language, and learning a language would require that they select, from among the conceptual distinctions in their repertoire, those distinctions that the ambient language expresses. As a result of this selection process, adult speakers may show reduced sensitivity to conceptual distinctions that are not marked by their language, just as they show reduced sensitivity to non-native phonological distinctions. Indeed, young infants may show greater sensitivity than their parents to conceptual distinctions that are captured by the terms of some unfamiliar languages but that are not lexicalized in the native language (Hespos & Spelke 2004).

In the first experiment, we tested 5-month-old infants from an English-speaking environment on categorization of a spatial distinction captured in Korean not English. Because the infants are preverbal and their ambient language does not emphasize the category boundary between tight-fitting and loose-fitting relationships, the hypothesis that spatial concepts are constructed predicts that these infants will not be sensitive to the tight/loose distinction. In contrast, if a large set of conceptual categories exists prelinguistically and serves as the basis for language acquisition, then these infants may well demonstrate sensitivity to this categorical distinction.

We used a habituation-dishabituation paradigm.[1] First, infants saw a narrow cylindrical object lowered into a series of loose-fitting, medium-sized containers

1. For readers not familiar with the habituation-dishabituation paradigm, it is an experimental procedure that is commonly used to investigate discrimination abilities in preverbal infants. The technique relies on infants' tendency to look longer at events that they perceive as novel. A typical experiment has two parts: habituation and test trials. The habituation trials are designed to familiarize infants with a particular category or event. For example infants may be presented with an object being lowered inside a container. Typically infants will look for a long time on the first trials but after repeated presentations infants will show a decline in looking time. When infants reveal a 50% decline in looking over 3 trials they are described as 'habituated'. Next infants are presented with an alternating sequence of two new events. One of the events is a novel instance of the event category that was shown previously and the other event is a familiar instance of previous event. The logic of the experimental design is that if infants perceive the event as novel it will recapture their attention and they will look at the display for a long time (e.g., dishabituate). In contrast if infants do not discriminate the display as new they will maintain their short (e.g., habituated) looking time.In our experiments we presented infant with minimally contrastive events. We habituated infants to an event that was at the midpoint between tight- and loose-fitting containment. In the test trials infants were presented with the same events except the containers were either 50% wider or narrower than the container used during the habituation trials. Thus the degree of change was proportionally the same in both test trials. The question was whether infants would generalize habituation equally (like English-speaking adults) or whether infants were sensitive to the semantic category boundary of tight and loose fit (captured in Korean). For more details please refer to the published paper Hespos and Spelke (2004).

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on a series of trials until their looking times declined. Next, the infants were presented with six test trials in which the same cylindrical object was lowered, in alternation, into a wide container (50% wider, hence also a loose fit) and into a narrower container (50% narrower, a tight fit). If infants make a language-independent categorical distinction between tight- and loose-fitting containment events, then they were expected to look significantly longer at the tight-fit trials. Our results confirmed this prediction: Infants looked significantly longer at the tight-fitting test trials.

Because the containers differed in size for the tight- and loose-fitting test events, however, it was possible that the results from the first experiment stemmed from an inherent preference for perceptual aspects of the tight-fitting event. To test this possibility we ran a second experiment that compared the infants' looking times to the same test events after habituation to an event in which a medium-sized object was lowered into the same medium-sized container as the first study: a "tight-fit" event. Whereas the infants in the first experiment were habituated to a loose-fitting relationship, the infants in the second experiment were habituated to a tight-fitting relationship. The infants in the second experiment showed the opposite pattern of behavior, looking longer at the loose-fit test event. Together, these findings provide evidence that infants categorized the containment events as tight- or loose-fitting and mapped the categorical distinction seen during habituation trials onto the events that they saw during test trials.

Infants living in an English-speaking environment therefore are sensitive to the categorical distinction between tight-fitting and loose-fitting containment relationships. When exposed to continuous variation in the size of the contained object relative to its container, infants make a categorical distinction captured by the Korean morphemes *kkita* and *nohta*. We conclude that sensitivity to this distinction develops in the absence of any relevant linguistic experience, prior to and independently of the language the child will learn. More generally, these findings suggest that infants' understanding of spatial entities emerges from a general cognitive distinction.

These first two experiments demonstrated that preverbal infants in an English-speaking environment were sensitive to a semantic category boundary that exists within the English category of "in". Next we tested what would happen for a Korean category boundary that cross-cuts the English categories of "in" and "on". A new group of 5-month-old infants from an English-speaking environment saw a narrow cylindrical object lowered onto a pedestal, until their looking times declined. Next, they were shown the same test trials as the previous experiment. If the infants were influenced by the on/in categorical boundary, they would show no preference for either test display. However if infants detected the loose-fitting (*nohta*) relationship in habituation trials then they were expected to look signifi-

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cantly longer at the tight-fitting test events. Our results confirmed this prediction: Infants looked significantly longer at the tight-fitting test trials.

Once again, it is possible that the results from Experiment 3 stemmed from an inherent perceptual bias. To test this possibility, a fourth experiment compared infants' looking times to the same test events after habituation to an event in which a ring was placed on a post: a tight-fit-on event. The infants in this experiment showed the opposite pattern of behavior, looking longer at the loose-fit test event. Together, these findings suggest that 5-month-old infants are sensitive to a Korean categorical distinction even when it cross-cuts the boundaries of their ambient language.

In two respects, our findings resemble the findings of studies of phonemic discrimination. In the first experiment, infants saw a continuum of container widths. The container used in habituation trials was 50% narrower than the loose-test container and 50% wider than the tight-test container. We found that infants parse a continuum of spatial variation into categories of spatial relationships between objects, just as prior studies have found that infants parse a continuum of acoustic variation into categories of speech sounds (Werker 1989). Second we found that infants are sensitive not only to the spatial distinctions that are lexicalized in their native language but also to spatial distinctions that are lexicalized in other non-native languages. Similarly, studies of speech perception have found that infants are sensitive to the phonological distinction of non-native languages as well as to the phonological distinctions of their native language (Kuhl, Williams, Lacerda, Stevens, et al. 1992; Werker 1991).

While the evidence thus far suggests that there are conceptual precursors to spatial language, it does not suggest where these conceptual categories come from. One possibility is that the origins of category distinctions come from core knowledge of the mechanical principles that govern objects' behavior. When two objects fit tightly together, such as a ring on a finger or a cylinder in a cylindrical container just wide enough to hold it, then almost any motion of one object will induce an exactly parallel motion in the other object. The constraints of solidity and action on contact ensure that these objects will move together unless one acts specifically to separate them. In contrast, when two objects fit loosely together, such as an apple in a bowl or on a table, the motions of the two objects are only partly constrained by one another. Because the objects are solid, the apple cannot move laterally through the side of the bowl or downward through the surface of the table; because the objects are in contact, motions of the bowl or table will influence the motion of the apple. In neither case, however, will the motions of two loose-fitting objects be strictly parallel. If a bowl containing an apple is suddenly moved, for example, the apple and bowl will undergo both common and relative motions, with the apple both moving with the bowl and rolling against it.

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Because tight- and loose-fitting containment place different constraints on the motions of objects, it is possible that core knowledge of objects and their motions could also lead infants to categorize these spatial relationships differently, into the mechanical categories of support, containment, tight-fit, and loose-fit that are lexicalized in various languages. But do infants in fact reveal such core knowledge in their spatial categorizations? Our next experiments were undertaken to address this question.

In the next experiment, we used a violation-of-expectation paradigm to test 5-month-old infants' expectations about motion in loose-fitting containment relations.[2] First, infants saw a narrow cylindrical object lowered into a wide container. Next, the infants were presented with six test trials that alternated between a move-separately event and a move-together event. In the move-separately event, the cylindrical object was lowered inside the wide container and then the container remained stationary and the object moved back and forth inside the container (consistent). In the move-together event, the cylindrical object was lowered inside the wide container and then both the object and container moved horizontally as a unitary object (inconsistent). If infants expected the loose-fitting container to allow the object to move with some independence, then they were expected to look longer at the move-together events. Our results confirmed this prediction: Infants looked significantly longer at the move-together than at the move-separately events.

In a second violation-of-expectation experiment, we tested infants' expectations for the effects of motion on tight-fitting containment relations. Infants saw the same cylindrical object lowered into a narrow container during the familiarization trials. In the test trials, infants saw the object lowered inside the container and then the object was moved back and forth horizontally. On alternate trials, the object and container moved together (consistent) or separately (inconsistent). If infants detected that a tight-fitting container more strongly constrains the motion of its contained object, then infants were expected to show the opposite looking preference from those in the loose-fitting condition and look longer at the move-separately event compared to the move-together event. The results confirmed this prediction: Infants looked longer at the move-separately test event. Together, the

2. The violation-of-expectation paradigm is a variant of the habituation-dishabituation paradigm described above. The technique is used to investigate infants' expectations about how objects behave and interact. The paradigm relies on infants' tendency to look longer at events that are unexpected or surprising. Infants are presented with two types of events. In the expected event the objects in the event move in a typical manner. In the unexpected event the physical laws are violated revealing a magic or unexpected outcome. If infants detect the violation they look longer at the unexpected event. These experiments often have some preliminary trials to familiarize infants to the objects prior to the test trials.

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findings from these experiments provide evidence that 5-month-old infants have different expectations for horizontal movement in tight-fit and loose-fit containment. That evidence, in turn, suggests that infants possess physical knowledge about containment that corresponds to the category boundary captured in Korean morphemes of *kkita* and *nohta*. More generally, systems of core knowledge may give rise to a large set of spatial and mechanical concepts: a set far larger than the category distinctions captured by any single language.

These findings raise the question whether the development of spatial concepts and speech perception are similar in a third respect: Over the course of development, do speakers lose sensitivity to the conceptual distinctions that are not captured by the lexical semantics of their native language, just as they lose sensitivity to phonetic distinctions not captured by their native language phonology? As noted above, recent research on this question has yielded conflicting findings (McDonough, Choi, & Mandler 2003; Munnich et al. 2001). However, the events used in these experiments were very different from those used in our studies of infants. To begin to address this question, therefore we presented all the same containment events to two groups of English-speaking adults.

Adults' sensitivity to the distinction between tight-fit and loose-fit was assessed by presenting the same action sequences as the previous experiments and asking adults to rate the similarity of each test action to the habituation actions. The results showed that adults did not react to the difference between tight and loose spatial relationships. One interpretation of these findings is that the method was insensitive. To address this interpretation, sensitivity to the distinction between support and containment was also tested. More specifically, adults were shown the checkered object lowered half-way inside a container and then the test trials consisted of the same object lowered all the way inside a container or placed on top of a pedestal (the container inverted). The results showed a significant difference in that adults judged the containment events as similar and different from the support event. Together, these findings provide evidence that adults are more sensitive to the distinction between support and containment than to the distinction between tight and loose fitting relationships. These findings accord with those of McDonough et al. (2003) and contrast with those of Munnich et al. (2001). More generally, they suggest a further parallel between phonological and semantic development: Whereas adults maintain sensitivity to acoustic and mechanical distinctions that are captured by their native language, they decline in sensitivity to acoustic and mechanical distinctions that are not captured by that language.

How drastic is this decline? In the case of speech perception, it is possible to recover some sensitivity to non-native phonological distinctions through training and through manipulations of attention (MacKain, Best, & Strange 1981; Pisoni, Aslin, Perey, & Hennessey 1982; Tees & Werker 1984). Introspection suggests that conceptual categories may be even easier to recover. Although English-speaking

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readers do not normally categorize mechanical relationships in terms of tightness of fit, those who have read this entire chapter may now be quite likely to do so, at least for a while. Can we get English-speaking adults to make this categorical distinction?

Our first attempt to do this used the simplest and least direct manipulation. The same adults that made the similarity judgments were presented with a second task involving a forced-choice. They had to choose which of the two test events was more similar to the habituation event. We found that adults grouped the events with respect to the tight/loose distinction. These findings suggest that conceptual categories can be recovered quite easily. The findings may help to explain why adults seem to be sensitive to non-native distinctions in some tasks (Munnich et al. 2001) though not other tasks (McDonough et al. 2003). They also suggest a difference between effects of native language on phonological vs. semantic representations. Although the former effects are robust and hard to overcome, the latter effects are subtler and quite easy to overcome, at least in some situations.

The study of natural language semantics, and of natural concepts, are two of the most vexed and difficult topics in cognitive science. One measure of their complexity, and fascination, comes from considering the degree of heat that the Sapir-Whorf hypothesis has generated over the last half-century. Despite vigorous research, contemporary cognitive scientists disagree strongly over the most basic questions about the nature of semantics and concepts and the relations between them. Some psychologists maintain that natural language semantics has simply no effects on natural concepts, and that all attempts to demonstrate the contrary are both conceptually confused and empirically flawed (Li & Gleitman 2002; Pinker 1994). Others maintain that natural language semantics influences everything from perceptual encoding to attention, memory, and reasoning (Boroditsky, Schmidt, & Phillips 2003). Into this fray, we offer two modest suggestions. First, insights into the nature and development of both semantic and conceptual categories can come from studies of core knowledge (Spelke 2000; Hauser & Spelke 2004). These studies, conducted on prelinguistic infants or non-linguistic nonhuman animals, may reveal the ontogenetic and phylogenetic building blocks of all semantic and conceptual development. Second, insights into the relationship between language and concepts, and the effects of linguistic experience on the development of concepts and word meanings, may come from considering the relation between language and auditory perception, and the effects of linguistic experience on the development of speech perception. As Chomsky (1965) has urged, many of the problems in the study of semantics and concepts have analogs in the study of phonology and audition. Because the study of perception and phonology is more advanced than other areas of cognition and language, students of speech perception may light a path for the rest of us to follow.

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