The Development of Infants' Spatial Categories

Marianella Casasola

Cornell University

ABSTRACT—*Early theories of how infants develop spatial concepts focused on the perceptual and cognitive abilities that contribute to this ability. More recent research, however, has centered on whether experience with spatial language might also play a role. The present article reviews how infants learn to form spatial categories, outlining the perceptual and cognitive abilities that drive this learning, and examines the role played by spatial language. I argue that infants' spatial concepts initially are the result of nonlinguistic perceptual and cognitive abilities, but that, as infants build a spatial lexicon, spatial language becomes an important tool in the spatial categories infants learn to form.*

KEYWORDS—*infant perception; infant cognition; spatial concepts; spatial categorization*

The ability to recognize the spatial relations in one's environment—such as recognizing one object being placed *in* or *next to* another object—forms the basis of several important abilities, including navigation, map reading, and the acquisition of spatial language. Deciding how to proceed at an intersection depends on the ability to assess the relation between one's current location and one's desired destination. Similarly, correctly using spatial terms requires recognizing the relation between (or among) objects. Understanding the development of infants' spatial concepts not only provides insight into adult spatial cognition but also informs our understanding of related infant abilities, such as discriminating between physically possible and impossible events, parsing action events into simpler units (e.g., how an object moves in space and its direction of motion), and forming abstract categorical representations. However, it is the relation between infants' spatial concepts and their acquisition of language-specific semantic spatial categories that recently has generated interest in how infants learn to form spatial categories. In this article, I review the perceptual and cognitive abilities that underlie the development of infants' spatial categories and briefly posit how spatial language can contribute to the formation of those categories.

Address correspondence to Marianella Casasola, B51 MVR Hall, Cornell University, Ithaca, NY 14853; e-mail: mc272@cornell.edu.

THE CURRENT DEBATE

The identification of cross-linguistic differences in how children organize spatial events for linguistic expression renewed interest in which spatial categories young infants possess universally (Choi & Bowerman, 1991). While English-learning toddlers distinguish between containment (*in*) and support (*on*) events in their labeling of spatial events, Korean-learning toddlers instead distinguish between actions resulting in an interlocking, tight-fit relation (*kkita*), such as a cork placed in a bottle or a Lego block stacked on another Lego, and those resulting in a loose-fit relation, such as blocks placed in a basket (*nehta*) or a teacup resting on its saucer (*nohta*; Choi & Bowerman, 1991; Choi, McDonough, Bowerman, & Mandler, 1999). The differences between Korean and English speakers' semantic (meaning) categories are not unique. Speakers of Finnish, Danish, Spanish, Mixtec, and Tzeltal (to name only a few) all organize spatial relations on different bases for linguistic expression (e.g., Bowerman, 1996).

The diverse ways in which languages organize spatial events into semantic categories and toddlers' early sensitivity to their language-specific patterns (Choi & Bowerman, 1991; Choi et al., 1999) raised questions about the sufficiency of young infants' spatial categories for acquiring language-specific semantic categories. Some researchers argue that infants' perceptual and cognitive abilities alone contribute to the development of their spatial categories and are sufficient for acquiring spatial categories specific to their language (Hespos & Spelke, 2004; Mandler, 1996), whereas others propose that spatial language helps shape spatial categories, particularly those that are language specific (Bowerman, 1996; Bowerman & Choi, 2001; Gentner & Boroditsky, 2001). Interestingly, recent research suggests that both accounts may be accurate, albeit for different spatial categories. As will be shown, infants' perceptual and cognitive abilities are sufficient for forming some, but not all,

spatial categories. As children begin to acquire spatial terms, experience with spatial language aids them in forming broader, more perceptually diverse spatial categories.

EARLY SPATIAL ABILITIES

By 3 months of age, infants make several spatial distinctions, including *above*, *below*, *left*, and *right* (Quinn, 2005). Researchers have used infants' looking time to infer their recognition of spatial events. In these studies, infants are familiarized with one relation (e.g., *above*) and subsequently are presented with the familiarized relation and a novel relation (e.g., *below*). Infants' differential looking to one relation over the other (usually, significantly longer looking at the novel relation than at the familiarized one) is taken as evidence that they can discriminate between the relations.

Certain spatial relations are discriminated earlier in development than are others. A number of factors, including the relative complexity and perceptual salience of different relations, have been posited to explain this. Relations that include one object in relation to a single landmark appear easier to discriminate than those that include multiple landmarks, explaining why infants understand the concept of *between* later in development than they do *above*, *below*, *left*, and *right* (Quinn, 2005). Similarly, perceptual features may highlight some relations over others. For example, the objects in a containment relation often change in appearance (i.e., the inserted object or figure becomes partially occluded when placed inside another object, the landmark object). Perceptual changes in either the figure or landmark may direct infants' attention to the spatial relation and consequently aid them in discriminating these relations earlier in development than spatial relations that lack these perceptual changes, such as support or proximity (e.g., *next to*) relations.

Although changes in the appearance of the figure or landmark objects may highlight particular spatial relations over others, infants' recognition of a spatial relation is not dependent on these perceptual cues. When 6-month-old infants were familiarized to a containment event in which a figure became partially occluded when inserted into the landmark object (see Fig. 1A), infants nonetheless recognized the containment relation when viewed from a high (bird's-eye) visual angle, even though the landmark object no longer partially obscured the figure (Casasola, Cohen, & Chiarello, 2003). As can be seen in Figure 1B, infants looked significantly longer at an event with a novel relation (*behind*) but the same amount of occlusion as in the familiarized event than they did at an event that maintained the same containment relation but changed the degree to which the figure became occluded (see Fig. 1B). The results demonstrated that 6-month-old infants respond to containment on the basis of the spatial relation rather than on the changed appearance of the objects.

FROM SPECIFIC TO ABSTRACT

At 6 months, infants begin to form abstract categorical representations of spatial relations, recognizing a spatial relation independent of specific objects. This ability marks an important developmental achievement in spatial cognition. Infants learn to note the equivalence of a spatial relation across different objects and, consequently, can view consistency in the spatial relations in their environment. To test infants' spatial categorization, infants are familiarized to different objects in a single relation (see Fig. 2). They then are tested with two pairs of unfamiliar objects, one in the familiarized relation and one in a novel relation. Infants' longer looking to the novel relation than to the familiarized one is attributed to their ability to recognize the familiarized spatial relation and to form its corresponding abstract spatial category.

Infants' formation of abstract spatial categories follows a specific-to-abstract developmental progression. Initially, infants' recognition of a spatial relation is dependent on familiar objects. They only discriminate between a familiarized and novel relation when relations involve objects seen during familiarization. It is not until later in development that infants gain the ability to recognize a spatial relation when depicted by unfamiliar objects and, thus, form the abstract spatial category. For example, Quinn (2005) noted that 3-month-old infants depended on familiar objects to discriminate between *above* and *below*, whereas 6-month-olds could do so with unfamiliar objects.

Although 6 months is the youngest age at which infants form an abstract spatial category, where infants fall in the specific-to-abstract progression is not linked exclusively to age but rather depends on the spatial relation in question. Six-month-olds form abstract spatial categories of *containment* and *above* versus *below* (Casasola et al., 2003; Quinn, 2005) but depend on familiar objects to recognize the relation *between*. At 10 months, infants form an abstract spatial category of *between* (Quinn, 2005) but do not yet recognize a *support* relation (Casasola, 2005b; Casasola & Cohen, 2002). The specific-to-abstract progression is robust; it is apparent across different methodologies, with both static and dynamic spatial events, and when the spatial relations involve simple shapes or more complex objects. The progression suggests that infants' spatial concepts are tied to familiar objects before they become abstract. Although infants acquire specific abstract spatial categories at different points in development, their formation of these categories nonetheless follows this specific-to-abstract pattern (Casasola & Cohen, 2002; Quinn, 2005).

The ability to form abstract spatial categories necessitates that infants attend more to a spatial relation than to the objects per se. However, the objects in a spatial event often are more salient than the relation between them. Younger infants discriminate changes in objects in *support* relations more easily than the spatial relation itself (Casasola & Cohen, 2002). Attention to "what" over "where" remains apparent even when infants are

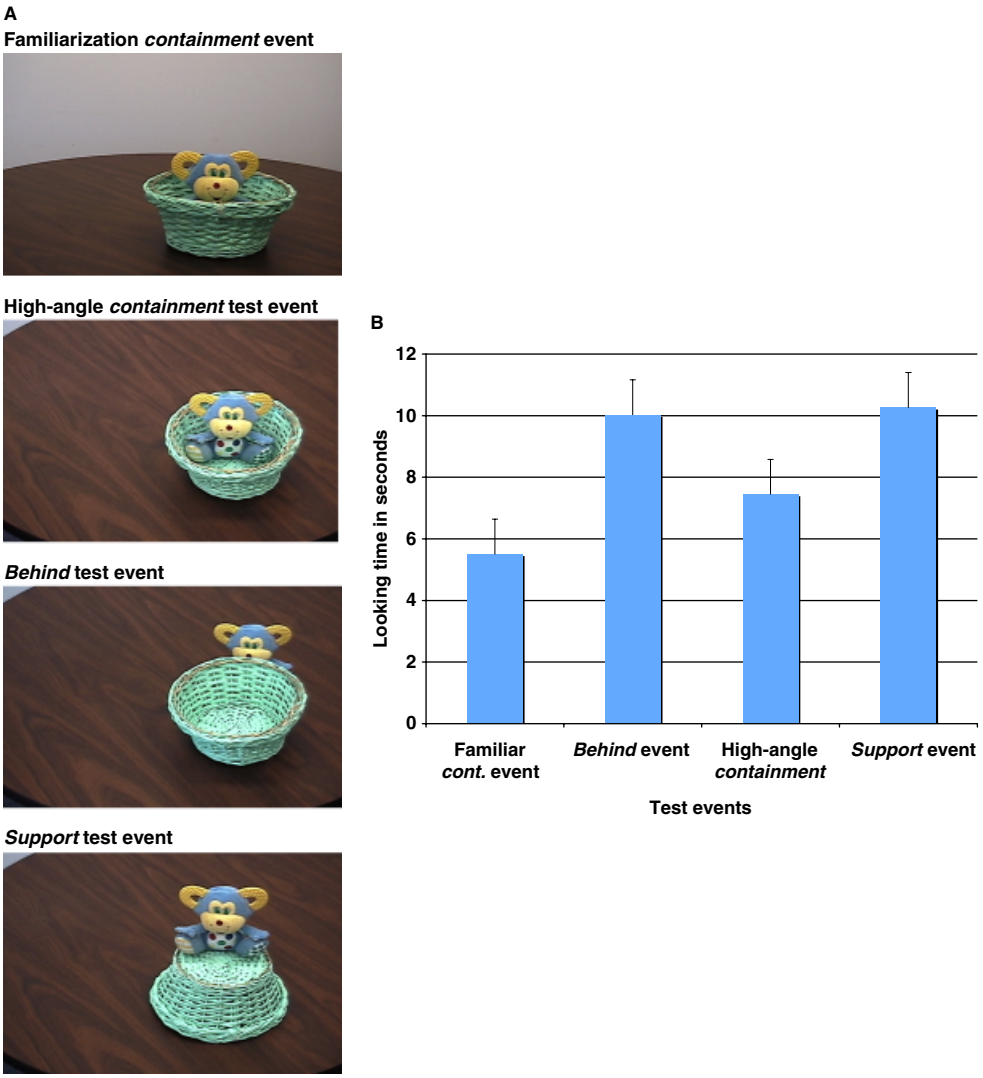

Fig. 1. Final frames of dynamic events used to test 6-month-old infants' discrimination of *containment* from other spatial relations (A; Casasola, Cohen, & Chiarello, 2003) and looking times to each test event (B). Infants were first familiarized to a dynamic containment event (first photo). Following familiarization, they were tested with the same familiarized containment event, as well as a containment event filmed from a high angle so that the figure was no longer partially occluded when inserted (second photo), a *behind* event in which the figure was as occluded as in the familiarization containment event (third photo), and a *support* event (fourth photo). The graph (B) shows that infants looked significantly longer at the test events that presented a novel relation (the behind and support test events) than they did at the familiar containment event. Infants' looking times to the high-angle containment event test event did not differ significantly from their looking time to the familiarized containment event. These results indicate that infants discriminate a containment relation from other events not on the basis of the amount an inserted object becomes occluded but rather on the basis of the change in spatial relation.

capable of forming an abstract spatial category. Fourteen-month-olds form an abstract spatial category of *support* if familiarized to two object pairs in a support relation. If familiarized instead to six object pairs in the support relation, infants discriminate when new objects are presented but not when a new spatial relation, such as *containment*, is presented (Casasola, 2005b). Thus, as the number of objects increases, infants attend less to the spatial relation, suggesting that the objects are more salient than the support relation. While the competition between what and where may differ across spatial relations, infants must nonetheless attend more to a spatial relation than to the objects, when forming a spatial category.

HOW SPATIAL COGNITION SHAPES SPATIAL LANGUAGE

Well before they begin to acquire spatial language, young infants have learned to form a number of spatial categories, including

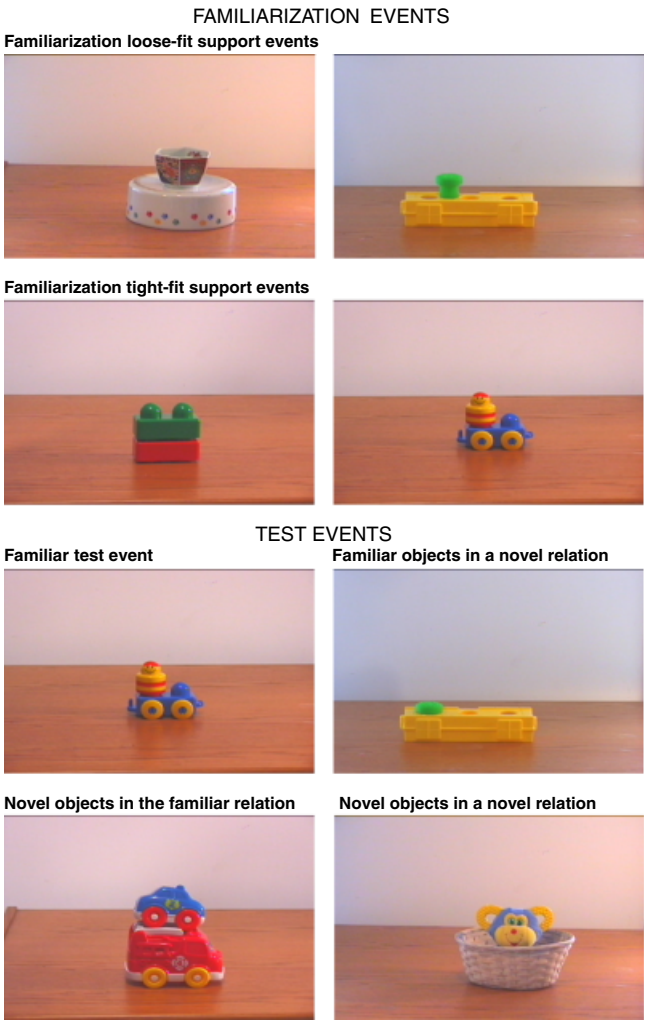

Fig. 2. Final frames of dynamic events used to test infants' understanding of the *support* category. Infants were familiarized to two loose-fit support events and two tight-fit support events (top two rows). Following familiarization, they viewed an event from familiarization, an event with a novel relation with familiar objects, an event with novel objects in the support relation and an event with novel objects in an unfamiliar (containment) relation (bottom two rows). When hearing the spatial word "on" during familiarization, infants looked longer at the events with the novel containment relation than they did at the familiar support relation—both when the objects were familiar and when they were novel—providing evidence that they had formed the abstract spatial category of support (Casasola, 2005a).

those not encoded in their language. Both English- and Korean-learning infants form an abstract spatial category of tight-fit containment events (e.g., placing pegs tightly into holes) as distinct from loose-fit containment events (e.g., placing pencils in a cup) even though only Korean contains distinct words for such relations (McDonough, Choi, & Mandler, 2003). Similarly, English-learning 5-month-olds generalize a tight-fit support relation to a tight-fit containment relation (Hespos & Spelke, 2004). Thus, experience with spatial language is not needed for forming particular spatial categories, demonstrating how certain spatial concepts are formed independently of language.

Infants' cognitive abilities also provide flexibility in organizing spatial events into spatial categories. When McDonough et al. (2003) familiarized infants with only one type of containment relation (e.g., tight-fit), infants formed a narrow category of containment (e.g., one that included tight-fit but not loose-fit containment). When Casasola and Cohen (2002) familiarized infants to both tight-fit and loose-fit containment events (events consistent with the English semantic category of *in*), infants formed a broader category of containment, one that included both tight-fit and loose-fit containment but that excluded other relations, such as support. Thus, infants can group spatial relations on different bases as may be needed for language-specific semantic categories, providing a critical foundation for the acquisition of spatial language.

HOW SPATIAL LANGUAGE SHAPES SPATIAL CATEGORIES

Infants nonetheless do not form abstract categorical representations of all spatial relations. English-learning 18-month-olds, for example, provided no evidence that they can form a spatial category of support that included tight-fit and loose-fit support (see Fig. 2) nor a spatial category of tight fit that included both tight-fit containment and tight-fit support (Casasola & Cohen, 2002). Because the events in these spatial categories are often quite distinct (consider a cup placed on a table versus a ring placed on a pole), infants may not recognize the common relation across the diverse examples. That is, infants do not seem to recognize the relational similarity between a loose-fit support event (e.g., a cup placed on a table) and a tight-fit support event (e.g., a ring placed on a pole), perhaps because these events involve very different types of support relations. Indeed, when variability is reduced by either presenting only one type of support relation or when presenting a single example of tight fit with perceptually similar objects, infants generalize these relations to novel examples, demonstrating that they can form these spatial categories (Casasola, 2005a; Hespos & Spelke, 2004). When a spatial category consists of perceptually variable exemplars, spatial language scaffolds infants' spatial categorization. When 18-month-old infants were presented with a spatial term during familiarization (e.g., "on"), they formed the abstract category of support (one that included tight-fit and loose-fit support, but not containment); in contrast, infants who viewed the events in silence or heard general language phrases ("Look! See what happens?") did not (Casasola, 2005a; Casasola & Bhagwat, 2007). Hearing the same spatial term in reference to different instances of the *support* spatial category highlighted the relational commonality of support across tight-fit and loose-fit support and consequently facilitated infants' ability to form the abstract spatial category. Thus, as infants acquire spatial terms, spatial language begins to aid them in forming more perceptually diverse spatial categories.

CONCLUSIONS AND FUTURE DIRECTIONS

In forming spatial categories, infants recruit whatever perceptual and cognitive tools are available, tools that vary across development and that eventually include spatial language. Infants spatial categorization thus cannot be accounted for with a one-size-fits-all explanation. Spatial categories vary as to whether they are solely the result of their nonlinguistic perceptual and cognitive abilities or are the result of experience with spatial language. Infants' formation of spatial categories also varies across task demands and specific stimuli, highlighting how infants' spatial categories do not suddenly appear on-line but rather slowly emerge and continue to develop.

Few studies have examined how the effect of language on infants' spatial categories varies with their acquisition of spatial language, yet this topic is central to understanding how spatial language begins to influence spatial categorization. Recent research has shown a link between infants' production of spatial words and a decreased sensitivity to spatial relations not described in their language (Choi, 2006), as well as the facilitative effect of a novel word on their spatial categorization (Casasola & Bhagwat, 2007). Research that focuses on the processes that guide infants' spatial categorization across development and that considers how these processes may change as infants build a spatial lexicon will provide much-needed insight into how infants learn to form spatial categories.

Recommended Reading

Casasola, M. (2005a). (See References). Discusses the role of language in infant spatial categorization in more detail than in the present article.

Choi, S. (2006). (See References). Provides more detail on cross-linguistic differences in semantic spatial categories and outlines findings of how infants' sensitivity to spatial relations changes as they acquire spatial language.

Mandler, J.M. (1996). (See References). Provides a review of how infants' preverbal concepts shape the acquisition of spatial language.

Quinn, P.C. (2005). (See References). Provides a comprehensive review of how young infants learn to form spatial categories.

Acknowledgments—Preparation of this article was supported by National Science Foundation Grant PECASE BCS-0349183.

REFERENCES

Bowerman, M. (1996). Learning how to structure space for language: A cross-linguistic perspective. In P. Bloom, M.A. Peterson, L. Nadel, & M.F. Garrett (Eds.), *Language and Space*. Cambridge, MA: MIT Press.

Bowerman, M., & Choi, S. (2001). Shaping meanings for language: Universal and language-specific in the acquisition of spatial semantic categories. In M. Bowerman & S. Levinson (Eds.), *Language acquisition and conceptual development*. Cambridge, UK: Cambridge University Press.

Casasola, M. (2005a). Can language do the driving? The effect of linguistic input on infants' categorization of support spatial relations. *Developmental Psychology*, *41*, 183–192.

Casasola, M. (2005b). When less is more: How infants learn to form an abstract categorical representation of support. *Child Development*, *76*, 279–290.

Casasola, M., & Bhagwat, J. (2007). Does a novel word facilitate 18-month-olds' categorization of a spatial relation? *Child Development*, *78*, 1818–1829.

Casasola, M., & Cohen, L.B. (2002). Infant categorization of containment, support, and tight-fit spatial relationships. *Developmental Science*, *5*, 247–264.

Casasola, M., Cohen, L.B., & Chiarello, E. (2003). Six-month-old infants' categorization of containment spatial relations. *Child Development*, *74*, 1–15.

Choi, S. (2006). Influence of language-specific input on spatial cognition: Categories of containment. *First Language*, *26*, 207–232.

Choi, S., & Bowerman, M. (1991). Learning to express motion events in English and Korean: The influence of language-specific lexicalization patterns. *Cognition*, *41*, 83–121.

Choi, S., McDonough, L., Bowerman, M., & Mandler, J.M. (1999). Early sensitivity to language-specific spatial categories in English and Korean. *Cognitive Development*, *14*, 241–268.

Gentner, D., & Boroditsky, L. (2001). Individuation, relativity, and early word learning. In M. Bowerman & S. Levinson (Eds.), *Language acquisition and conceptual development* (pp. 215–256). Cambridge, UK: Cambridge University Press.

Hespos, S.J., & Spelke, E.S. (2004). Conceptual precursors to language. *Nature*, *430*, 453–456.

Mandler, J.M. (1996). Preverbal representation and language. In P. Bloom, M.A. Peterson, L. Nadel, & M.F. Garrett (Eds.), *Language and Space* (pp. 365–384). Cambridge, MA: MIT Press.

McDonough, L., Choi, S., & Mandler, J.M. (2003). Understanding spatial relations: Flexible infants, lexical adults. *Cognitive Psychology*, *46*, 229–259.

Quinn, P.C. (2005). Developmental constraints on the representation of spatial relation information: Evidence from preverbal infants. In L.A. Carlson & E. van der Zee (Eds.), *Functional features in language and space: Insights from perception, categorization, and development*. New York: Oxford University Press.