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Language as Cognitive Tool Kit: How Language Supports Relational Thought

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The extreme version of the Whorfian hypothesis—that the language we learn determines how we view the world—has been soundly rejected by linguists and psychologists alike. However, more moderate versions of the idea that language may influence thought have garnered recent empirical support. This article defends 1 such view. I propose that language serves as a *cognitive tool kit* that allows us to represent and reason in ways that would be impossible without such a symbol system. I present evidence that learning and using relational language can foster relational reasoning—a core capacity of higher order cognition. In essence, language makes one smarter.

Keywords: language and cognition, relational meaning, relational learning

Relational cognition pervades human mental life. From the use of verbs and prepositions in everyday language to the discovery of new theorems, relational thinking is ubiquitous and indispensable (Gentner, 1983, 2010; Hofstadter & Sander, 2013; Holyoak & Thagard, 1995). Indeed, there is evidence that our analogical ability—the ability to perceive common relations across different situations—far exceeds that of other species (Christie, Gentner, Call, & Haun, 2016; Gentner, 2003; Penn, Holyoak, & Povinelli, 2008). Higher order cognition depends on relational concepts: for example, relations of *causation* and *prevention* in science, *implication* and *contradiction* in logic, and *commutativity* in mathematics. Relational concepts are also ubiquitous in social life. We recognize and reason about *competition* and *cooperation, reciprocation* and *revenge, compromise,* and so on.

How do we come by this stock of relational concepts? One possibility, famously articulated by Fodor (1975), is that all concepts are innate—including, assumedly, *phone booth* and *Twitter*. It is impossible in principle to rule out the idea that every seemingly new thought is just the surfacing of a previously subterranean innate hypothesis. Nevertheless, I favor a more moderate view—that we may begin life with some set of innate concepts but that most of our concepts are learned.

In this article I make a case for the role of language in promoting the acquisition of relational concepts. I first review evidence that acquiring relational concepts is hard. Then I consider likely candidates for how they might be learned and argue for the importance of relational language in this learning. I offer several examples in which there is evidence that language learning plays a role in children's relational learning.

Acquiring Relational Concepts

Learning new relational concepts is challenging. Although children readily learn names for objects and animate beings, they are slow to learn verbs and prepositions (Gentner, 1982; Gentner & Boroditsky, 2001)[1]—and this holds

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[1] Gentner's (1982) claim was that that the early noun advantage results from an inherent semantic pattern: that it is easier to learn the mapping between nouns and individual concrete objects than to learn the mapping between verbs and their referents. Thus, it should hold cross-linguistically. This claim was initially disputed by researchers who argued that the noun advantage fails to hold in Korean (Gopnik & Choi, 1995) and Mandarin (Tardif, 1996), suggesting that it arises from specific characteristics of English, not from general cognitive factors. Subsequent evidence has largely supported the claim of a cross-linguistic early noun advantage (Bornstein et al., 2004; Frank, Braginsky, Yurovsky, & Marchman, 2016; Gentner & Boroditsky, 2001; Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005; Maguire, Hirsh-Pasek, & Golinkoff, 2006; Waxman et al., 2013), even in "verb-friendly" languages such as Korean (Au, Dapretto, & Song, 1994; Kim, McGregor, & Thompson, 2000; Pae, 1993) and Mandarin (Gelman & Tardif, 1998; Tardif, Gelman, & Xu, 1999). However, the degree of noun bias is influenced by linguistic and cultural factors.

even for relational terms that they hear far more frequently than many of the nouns they learn. The same pattern emerges when input is controlled. For example, Childers and Tomasello (2002) taught 2½-year-olds either three new nouns or three new verbs. After several sessions, with exposure equated, the children could produce an average of 1.18 new nouns but only .63 verbs. In a more naturalistic study, Wick Miller played a game involving plastic beads with a 2-year-old child over several months (reported in Ervin-Tripp, 1974). He made up words for the elements of the game and counted how many exposures occurred before the child produced each word. The noun *po* (for beads of a particular kind) was produced at 2 years 2 months, after 67 inputs; the verb *to sib* (for actions of a particular kind) was not used until 8 months later, after 164 inputs (Ervin-Tripp, 1974). Children are also slow to acquire the meanings of relational nouns, suggesting that their difficulty with verbs is at least partly due to their relational meaning and not just their grammatical form. For example, a young child may define *brother* as a boy about 12 years old, or *uncle* as a nice man in a chair (Clark, 1993; Keil & Batterman, 1984).

What kinds of learning processes might support relational learning? Clearly, simple associative processes are not sufficient (Forbus, Liang, & Rabkina, in press; Hummel, 2010; A. B. Markman, 1999). These can tell us that *cow* is strongly associated with *calf* and also with *milk,* but they cannot record the nature of the relation. Using a purely associative process, we would not be able to discern that the relation between *mare* and *colt* is more like that between *cow* and *calf* than that between *cow* and *milk*.

One source of relational knowledge is direct explanation. For young children, parents often use generic language to signal important conceptual information (e.g., "This is a cow. Cows give milk"; Gelman, 2003). But although children clearly learn from this kind of interaction, this kind of teaching cannot be the whole story. Laying aside the demands it would place on the caretaker, young children often lack the relational vocabulary needed to understand an explanation of a concept like *brother,* or of the difference between *give* and *put*. Instead, parents are likely to demonstrate with examples, and that brings us to analogy.

An important avenue to relational concepts is through analogical comparison. Comparing two things invites a structure-mapping process (Gentner, 1983, 2010; Gentner & Markman, 1997) in which common relational patterns within the two analogs are aligned (*structural alignment*) and the entities are placed in correspondence according to the relational alignment.[2] For example, if Mickey loves Minnie and Donald loves Daisy, then the relational alignment of the two "love" relations will dictate that Mickey corresponds to Donald in this analogy—despite their obvious dissimilarity as individual entities. Of importance, achieving a structural alignment tends to heighten the salience of the common relational structure, making it more likely to transfer to other situations (Catrambone & Holyoak, 1989; Gentner & Bowerman, 2009; Gick & Holyoak, 1983; Loewenstein, Thompson, & Gentner, 1999).

Analogical comparison processes are crucial in acquiring new relational concepts (Christie & Gentner, 2010; Doumas & Hummel, 2013). But this raises the question of how such comparisons come about. For young children, spontaneous comparison is mostly limited to pairs that are highly similar overall. This means that spontaneous comparison processes are too limited in scope to account for the amount of relational learning we see even in young children.

This brings us to the role of language. A major way in which language supports acquiring relational language is by inviting comparison. During initial learning, hearing a relational term used for two situations invites children to compare them and derive their common abstraction. Children learn early in development that words name things that are alike in some way (E. M. Markman, 1989; Waxman & Hall, 1993), so when two things receive the same label, children are likely to compare them; and this may reveal a common relational pattern (Gentner & Namy, 1999). Further, once a new concept is formed—whether by comparison or by some other process—applying a label can confer stability to the concept, making it easier to retain and transfer. Lupyan and his colleagues have shown that people learn and extend object categories better when they are named (e.g., Lupyan, Rakison, & McClelland, 2007), and there is evidence that this may apply to relational concepts as well.

For example, Gentner, Anggoro, and Klibanoff (2011) taught 4½-year-old children new relational concepts using pictures. Children were told, "Look, the knife goes with the melon. What goes with the paper in the same way?" Whereas 6-year-olds correctly chose the relational match (scissors, which cut paper, just as a knife cuts melon), younger children tended to choose an associate (a pencil) or an object match (more paper) instead. But when given the knife–melon example and another analogous example ("The axe goes with the tree"), the 4½-year-olds succeeded. Their performance was still higher if they were also given a common relational term ("Look, the knife is the fep for the melon, and the axe is the fep for the tree. Which one is the fep for the paper?"). Even though the children had never heard *fep* before, this new word invited them to compare the two analogs—allowing them to abstract the "cutter" relation and transfer it to the test example.

Language can support, beyond individual word meanings, relational cognition through inviting *structural parallels.* Learning the semantic and syntactic structure of the language can invite corresponding conceptual patterns, which

[2] Structural alignment sometimes fails; for example, children and other novices may simply make object matches instead of aligning the relations. This is especially likely when the learner is not familiar with the common relations.

can have wide ramifications. We turn now to two examples in which this kind of structural parallel can support children's relational learning—one in spatial cognition and one in numerical cognition.

Space

For native speakers, the spatial terms in the language feel so natural that it comes as a shock to discover how much they vary across languages. However, pioneering work by Melissa Bowerman and her colleagues showed that languages differ in how they carve up the spatial world—even for the seemingly basic distinction between containment and support (Bowerman, 1996; Gentner & Bowerman, 2009; see also Feist, 2008).

Languages also differ in their preferred spatial frame of reference for describing location (Levinson, 2003; Levinson & Brown, 1994). Tzeltal is one of many languages that uses a geocentric (or absolute) frame, even in near-space situations for which English (like many European languages) uses an egocentric (or relative) frame[3] (Majid, Bowerman, Kita, Haun, & Levinson, 2004). For example, an English speaker might ask a companion to "please pass me the plate on your right"; a Tzeltal speaker would ask for the plate to the north. (In geocentric languages, locations can be described independently of which way the speaker and listener are facing; whereas *right* and *left* depend on a person's perspective, *north* and *south* do not.) Many studies have suggested that this difference in language affects the way people think about space, even in nonlinguistic tasks such as recreating a sequence of objects or copying a maze (Levinson, 2003; Levinson, Kita, Haun, & Rasch, 2002; but see Li & Gleitman, 2002). One striking example is a study by Haun and Rapold (2009) in which they demonstrated a new dance to 4- to 12-year-old Namibian children (whose language, Hai‖om, uses a geocentric frame) and German children (whose language, like English, preferentially uses an egocentric frame). After the children successfully mastered the dance, which featured, for example, a right-left-right-right (RLRR) sequence of hand motions, the children were rotated 180 degrees and asked to do the dance again. The German children mostly continued dancing in an RLRR pattern (as English speakers would probably do). In contrast, the Namibian children danced in an LRLL pattern. It appears that they had coded the dance as, for example, north-south-north-north. They preserved this pattern when facing the opposite direction, resulting in a reversal of left–right pattern. Thus, although no spatial language was used in the task, each group interpreted the dance according to their language's major pattern.[4] This and other studies have suggested that the habitual use of these terms makes the corresponding relational systems more available for thinking and reasoning, even in nonlinguistic tasks.

Does learning spatial relational language lead to better understanding of the corresponding spatial relations? One study that suggests a positive answer was done by Pruden, Levine, and Huttenlocher (2011). They recorded children's language during natural family interactions when they were between the ages of 14 and 46 months. At 54 months, the children were given nonlinguistic tests of spatial ability (e.g., they were asked to combine two figures and to say which larger figure they would form). Children's spatial skill at 54 months was predicted by the number of different spatial terms they had produced between 14 and 46 months.

Of course, this could simply mean that spatially talented children readily learn spatial language and also perform well on spatial tasks. To directly test whether acquiring and using spatial language can influence children's ability to represent and reason about spatial relations, Loewenstein and Gentner (2005) devised a simple spatial mapping task. Preschool children (3½- and 4-year-olds) saw two identical three-tiered boxes, each containing three cards (see Figure 1). One card (the "winner") had a star on its back. Children watched the experimenter place the winner in the hiding box and then tried to find the winner "in the same place" in the finding box. the winner was always in the same spatial location (top, middle, or bottom) in the two boxes.

The key manipulation was that prior to the task, half the children (the language group) were shown one box and asked to place toy animals "*on, in,* or *under* the box." The other half (the control group) were shown both boxes but received only general language and gesture (e.g., "Can you put this one right here?") rather than receiving specific spatial terms. During the mapping task, no spatial language was used; nevertheless, the language group performed significantly better than did the control group. Although 3-year-olds can comprehend these spatial terms, the concepts are not so well entrenched as to come to mind automatically; so hearing the terms helps them apply these spatial distinctions to delineate the space. By this reasoning, we might expect that older children, for whom these spatial distinctions have become habitual, would no longer need to hear overt language to succeed. That is exactly what was found across studies. These results are consistent with the

[3] Levinson and colleagues noted that three kinds of spatial reference frames are used across languages: *egocentric* or *relative* frame, which are viewpoint-dependent (e.g., The ball is left of the chair [from the speaker's point of view]); *intrinsic,* which makes reference to faceted objects (e.g., The ball is in front of the house); and *geocentric* (*absolute*), which uses some class of cardinal directions (e.g., The ball is north of the chair; Levinson & Brown, 1994; Levinson et al., 2002).

[4] It is, of course, possible that people in such tasks are mentally using their spatial language to construe the spatial situations—effectively converting a nonlinguistic task into a linguistic task (e.g., Dessalegn & Landau, 2013). It seems unlikely that this can explain the breadth of effects. But if people do sometimes spontaneously use internal language to represent external situations, this does not contradict the present claim—that language provides tools for representation and reasoning.

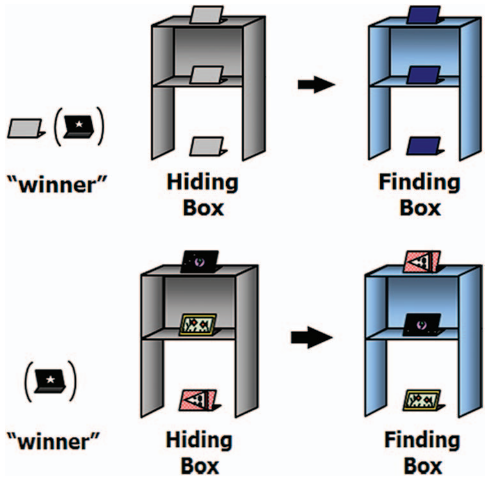

Figure 1. Materials used in the spatial mapping task (Gentner, Ozyürek, Gürcanli, & Goldin-Meadow, 2013; Loewenstein & Gentner, 2005). Children were given six trials and were always shown the correct answer after responding. Half the children received spatial language, and half did not. See the online article for the color version of this figure.

idea that relational language invites corresponding relational representations.

In a further study, the spatial mapping task was made more difficult by introducing a competing object match (see Figure 1b). Prior research has shown that such *cross-mappings,* in which object matches compete with the best relational alignment, are extremely hard for children (Gentner & Toupin, 1986). In this case, children derived greater benefit from hearing the terms *top, middle,* and *bottom* (which convey a connected system of relations) than from hearing *on, in,* and *under,* which lack a unifying higher order structure. Hearing *top, middle,* or *bottom* invited a representation of the monotonic relational structure of the two boxes, and this higher order structure helped the children to achieve a relational mapping. This fits with findings from analogy research showing that people are better able to carry out a relational mapping if given a *systematic* representation: one in which the lower order relations are interconnected by higher order constraining relations (such as the transitive structure in top, middle, and bottom; Clement & Gentner, 1991; Gentner & Toupin, 1986).

A further study tested whether the language advantage would persist over delay. Children performed the spatial mapping task as just described, and again the language group outperformed the control group. Two days later, the children returned to the lab and were shown an altered set of boxes. Both groups—language and control—were simply asked to "play the same game again"; no spatial terms were used except for "Watch, I'm putting it here!" (both groups). Children who had initially received relational language performed significantly better than did those who had not—evidence that language promoted an enduring relational representation (Loewenstein & Gentner, 2005).

Finally, if language instills enduring delineated representations of spatial relations, then we would expect children who lack such input to be at a disadvantage in tasks requiring the representation. Using the same spatial mapping task, Gentner, Ozyürek, Gürcanli, and Goldin-Meadow (2013) gave the spatial mapping task to a group of deaf children in Istanbul. These children were *homesigners*—children whose hearing losses had prevented them from learning a spoken language and who had not been exposed to a sign language. Like other such children they had developed their own gesture systems (*homesigns*) to communicate with others. Critically, although homesigns contain many of the linguistic properties found in early child language (Goldin-Meadow, 2003), the homesigns invented by these deaf children did not contain consistent gestures for conveying spatial relations (Gentner et al., 2013). These homesigners were compared with hearing Turkish children (matched to the homesigners on another spatial task). Both groups were then given the spatial mapping task, without spatial language. The hearing children performed far better on the task than the homesigners did. In fact, the homesigners barely exceeded chance. Gentner et al. (2013) concluded that the deaf children, lacking a stable system of spatial relations, were less likely to represent the arrays in the two boxes in a uniform way and therefore less able to align them and to succeed in the spatial mapping task.

To summarize, young English-speaking children do far better in a spatial mapping task when they are reminded of spatial relational terms that they can use to delineate the space. Once they have done this, they can retain this representation for at least a few days—evidence that the effects of the terms are at the conceptual level. By the time children are 6 years old (whether they speak English or Turkish), these spatial relations are sufficiently fluent that there is no need to remind children of the terms. In contrast, 6-year-old homesigners, who have not acquired this kind of spatial language, perform badly in the mapping task. All this suggests that learning words for spatial relations may benefit our spatial thinking.

Number

The idea of the natural numbers—of a sequence of increasing positive integers—feels so simple and basic that it seems it must be common to all humans. The great English mathematician George Hardy stated this intuition clearly:

> I believe that mathematical reality lies outside us, that our function is to discover or observe it, and that the theorems which we prove, and which we describe grandiloquently as our "creations," are simply our notes of our observations. (quoted in Dehaene, 1997, p. 242)

Yet this is not the case.

The Pirahã are an Amazonian group whose language lacks a full counting system (Everett, 2005). They have three words for numerical quantity: *ho'i, hoı'*, and *aibaagi.* These were initially thought to mean "one," "two," and many," because when asked s how many items they saw (starting with one item and increasing to 10), speakers used *ho'i* for one item, shifted to *hoı'* for two items, and then used *aibaagi* for the rest (Gordon, 2004). However, when speakers were given the same "how many" task starting with 10 objects, then nine, eight, and so on down, they used *aibaagi* for the larger numbers, *hoı'* for around four through six objects, and *ho'i* for roughly one through four objects (Frank, Everett, Fedorenko, & Gibson, 2008). Thus, it appears that these terms mean something like "few," "more," and "even more." In other words, Pirahã appears to lack any terms for true numbers.

Peter Gordon (2004) asked whether this lack of number *language* was accompanied by a lack of number *concepts*. He gave the Pirahã a variety of simple numerical tasks (first demonstrating the tasks with a confederate). For example, he placed, say, five batteries in a line and tested whether the Pirahã could place an equal number of batteries on the table orthogonally to the experimenter's line of objects. In another task, he showed participants an array of nuts, then put the nuts into a can and withdrew them one by one, each time asking the participant whether the can still contained nuts or was empty. On these and other simple tasks, the Pirahã were reasonably accurate for three or fewer objects, but they became increasingly inaccurate as the numbers increased from 3 to 10. These basic findings were replicated by Frank et al. (2008), and similar results were found by Pica, Lemer, Izard, and Dehaene (2004) with the Mundurukú, another Amazonian group lacking a full counting system. In all these studies, the degree of inaccuracy increased with the size of the number. This pattern is a signature of the *analog magnitude system*—a system widely shared among birds and mammals—that allows us to quickly recognize, for example, that one pile of sand is bigger than another. This system allows quantity estimation for even very large numbers, but its accuracy is limited by Weber's law: The discriminability between two amounts is a function of their ratio. Thus, the Amazonians were relying on the analog magnitude system, not a system of numbers.

The implication of these findings is that the Pirahã lack a concept of number—a profound difference between them and people raised in Western cultures.[5] The startling conclusion is that, contrary to intuition, the concept of number is not a universal innate endowment. Further, the evidence has suggested that the cardinal numbers come to us via language.[6]

Other evidence that the natural numbers are not so natural comes from children's number learning, which is quite protracted even with help from attentive parents (Carey, 2009; Fuson, 1988; Mix, 2002). A 2-year-old may be able to recite the count list up to 10 but have little understanding of the connection with quantity. If asked to "give me one block," the child can succeed, but if asked to "give me three blocks," the child will respond with a few blocks greater than one. Children gradually bind the small numerals to the corresponding quantities. At first, this binding may be quite specific. For example, Mix (2009) described a child who at 20 months could reliably fetch two treats for the family's two dogs but was unable to transfer this "twoness" to fetch two treats for his two trains. Over time, hearing the same count word applied to different kinds of objects prompts the child to compare the sets and notice their common set size. Thus, language acquisition leads cognitive acquisition in two ways. First, the count list is typically acquired early and scaffolds the child's understanding of the natural numbers themselves (Carey, 2009; Mix, 2002). Second, hearing a given numerical term—say, *three*—applied to different sets fosters comparison and abstraction of the term's meaning.

Summary

The goal of this article is, first, to bring out the importance of language—especially relational language—in augmenting human cognition, not merely by permitting us to transmit information to each other (though that is of course important) but also by providing an internal tool kit that augments our cognitive powers. The second goal is to propose specific processes by which language has its effect—notably analogical comparison and abstraction.

I focused here on two important and pervasive systems of relational cognition: spatial relations and the natural numbers. These two systems have some salient commonalities. They are slow to be acquired; but because they are acquired early, we mostly cannot remember what it was like not to know them. Once acquired, they are in constant use. We effortlessly classify things as *in* or *on* other objects, just as we keep track of how many more plates are needed for the table. Because they are learned so early, and used so often, it can seem as though we have always known them; their fluency and indispensability convinces us that they must be innate. On the other hand, another critical commonality is that acquiring these systems does not force us to see the world in only one way, as extreme versions of the linguistic determinism position might dictate. Learning the cardinal numbers does not require abandoning our innate analog magnitude sys-

[5] The researchers noted that the Pirahã are traditional hunter–gatherers in the forest. For most purposes, one-to-one correspondence—which they clearly can carry out—suffices for their needs (e.g., one flashlight for each member of a hunting party).

[6] Of course, this raises the question of how number language comes about in the first place. I address this briefly in the next section.

tem; we still retain the ability to choose which pile of sand is larger, which tree is taller, and so forth.

A final parallel is that both systems were slow to develop in the history of language. According to Schmandt-Besserat (1996), early systems for keeping track of numbers (around 4000 C in the Middle East) used direct one-to-one tokens: Five sheep were represented by five clay tokens representing sheep, and so on. Even when tokens were used to stand for larger numbers, they were specific to the thing counted; the token for 10 sheep was different from the token for 10 goats. It required another thousand years to arrive at the idea of abstract numbers disassociated from the thing being counted (Schmandt-Besserat, 1996).

Systems of spatial relations are also slow to evolve. Prepositions are also relatively slow to appear in a language; they typically evolve gradually from more concrete terms through a process of grammaticalization. For example, using a sample of 125 African languages, Heine, Claudi, and Hunnemeyer (1991) examined the historical derivation of five spatial relational concepts: *on, under, front, back,* and *in*. They found that *on* was often derived from the term for head, *front* from the term for face, and *back* from the term for back. In these cases, it appears that the human body is the historical source of the spatial term. (It is interesting, however, that for pastoralist groups such as the Maasai of East Africa, the source for some prepositions appears to be animal bodies.) Heine et al. speculated that these abstract spatial relations are the product of gradual metaphorical extensions of more concrete terms.

In sum, I suggest that we are the lucky recipients of powerful linguistic systems that augment our ability to represent and reason about relations. Humans are born with exceptional relational ability, but language lets us carry that ability further. Relational language gives us abstract systems of representation that scaffold our ability to perceive relational analogies and to map relational structure across domains. In the other direction, analogical processes act to create new linguistic meanings. This system of bootstrapping between relational language and relational thought acts to amplify our intelligence both at the individual and at the cultural level.

References

Au, T. K., Dapretto, M., & Song, Y. K. (1994). Input vs. constraints: Early word acquisition in Korean and English. *Journal of Memory and Language, 33,* 567–582. http://dx.doi.org/10.1006/jmla.1994.1027

Bornstein, M. H., Cote, L. R., Maital, S., Painter, K., Park, S.-Y., Pascual, L., . . . Vyt, A. (2004). Cross-linguistic analysis of vocabulary in young children: Spanish, Dutch, French, Hebrew, Italian, Korean, and American English. *Child Development, 75,* 1115–1139. http://dx.doi.org/10.1111/j.1467-8624.2004.00729.x

Bowerman, M. (1996). Learning how to structure space for language: A crosslinguistic perspective. In P. Bloom, M. A. Peterson, L. Nadel, & M. F. Garrett (Eds.), *Language and space* (pp. 385–436). Cambridge, MA: MIT Press.

Carey, S. (2009). *The origin of concepts*. http://dx.doi.org/10.1093/acprof:oso/9780195367638.001.0001

Catrambone, R., & Holyoak, K. J. (1989). Overcoming contextual limitations on problem-solving transfer. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 1147–1156. http://dx.doi.org/10.1037/0278-7393.15.6.1147

Childers, J. B., & Tomasello, M. (2002). Two-year-olds learn novel nouns, verbs, and conventional actions from massed or distributed exposures. *Developmental Psychology, 38,* 967–978. http://dx.doi.org/10.1037/0012-1649.38.6.967

Christie, S., & Gentner, D. (2010). Where hypotheses come from: Learning new relations by structural alignment. *Journal of Cognition and Development, 11,* 356–373. http://dx.doi.org/10.1080/15248371003700015

Christie, S., Gentner, D., Call, J., & Haun, D. B. M. (2016). Sensitivity to relational similarity and object similarity in apes and children. *Current Biology, 26,* 531–535. http://dx.doi.org/10.1016/j.cub.2015.12.054

Clark, E. V. (1993). *The lexicon in acquisition*. http://dx.doi.org/10.1017/CBO9780511554377

Clement, C., & Gentner, D. (1991). Systematicity as a selection constraint in analogical mapping. *Cognitive Science, 15,* 89–132. http://dx.doi.org/10.1207/s15516709cog1501_3

Dehaene, S. (1997). *The number sense: How the mind creates mathematics*. New York, NY: Oxford University Press.

Dessalegn, B., & Landau, B. (2013). Interaction between language and vision: It's momentary, abstract, and it develops. *Cognition, 127,* 331–344. http://dx.doi.org/10.1016/j.cognition.2013.02.003

Doumas, L. A. A., & Hummel, J. E. (2013). Comparison and mapping facilitate relation discovery and predication. *PLoS ONE, 8*(6), e63889. http://dx.doi.org/10.1371/journal.pone.0063889

Ervin-Tripp, S. M. (1974). Some bases for early features of production. In F. Bresson & J. Mehler (Eds.), *Problèmes actuelles en psycholinguistique* [Current problems in psycholinguistics]. Paris, France: Éditions du Centre National de la Recherche Scientifique.

Everett, D. (2005). Cultural constraints on grammar and cognition in Pirahã: Another look at the design features of human language. *Current Anthropology, 46,* 621–646. http://dx.doi.org/10.1086/431525

Feist, M. I. (2008). Space between languages. *Cognitive Science, 32,* 1177–1199. http://dx.doi.org/10.1080/03640210802152335

Fodor, J. A. (1975). *The language of thought*. New York, NY: Crowell.

Forbus, K. D., Liang, C., & Rabkina, I. (under review). Representation and computation in cognitive models.

Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2016). Wordbank: An open repository for developmental vocabulary data. *Journal of Child Language*. Advance online publication. http://dx.doi.org/10.1017/S0305000916000209

Frank, M. C., Everett, D. L., Fedorenko, E., & Gibson, E. (2008). Number as a cognitive technology: Evidence from Pirahã language and cognition. *Cognition, 108,* 819–824. http://dx.doi.org/10.1016/j.cognition.2008.04.007

Fuson, K. C. (1988). *Children's counting and concepts of number*. http://dx.doi.org/10.1007/978-1-4612-3754-9

Gelman, S. A. (2003). *The essential child: Origins of essentialism in everyday thought*. http://dx.doi.org/10.1093/acprof:oso/9780195154061.001.0001

Gelman, S. A., & Tardif, T. (1998). Acquisition of nouns and verbs in Mandarin and English. In E. Clark (Ed.) *Proceedings of the 29th Annual Stanford Child Language Research Forum*. Stanford, CA: CSLI.

Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. In S. A. Kuczaj (Ed.), *Language development: Vol. 2. Language, thought and culture* (pp. 301–334). Hillsdale, NJ: Erlbaum.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7,* 155–170. http://dx.doi.org/10.1207/s15516709cog0702_3

Gentner, D. (2003). Why we're so smart. In D. Gentner & S. Goldin-Meadow (Eds.), *Language in mind: Advances in the study of language and thought* (pp. 195–235). Cambridge, MA: MIT Press.

Gentner, D. (2010). Bootstrapping the mind: Analogical processes and symbol systems. *Cognitive Science, 34,* 752–775. http://dx.doi.org/10.1111/j.1551-6709.2010.01114.x

Gentner, D., Anggoro, F. K., & Klibanoff, R. S. (2011). Structure mapping and relational language support children's learning of relational categories. *Child Development, 82,* 1173–1188. http://dx.doi.org/10.1111/j.1467-8624.2011.01599.x

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). http://dx.doi.org/10.1017/CBO9780511620669.010

Gentner, D., & Bowerman, M. (2009). Why some spatial semantic categories are harder to learn than others: The typological prevalence hypothesis. In J. Guo, E. Lieven, S. Ervin-Tripp, N. Budwig, S. Özçaliskan, & K. Nakamura (Eds.), *Crosslinguistic approaches to the psychology of language: Research in the tradition of Dan Isaac Slobin* (pp. 465–480). New York, NY: Erlbaum.

Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist, 52,* 45–56. http://dx.doi.org/10.1037/0003-066X.52.1.45

Gentner, D., & Namy, L. L. (1999). Comparison in the development of categories. *Cognitive Development, 14,* 487–513. http://dx.doi.org/10.1016/S0885-2014(99)00016-7

Gentner, D., Ozyürek, A., Gürcanli, O., & Goldin-Meadow, S. (2013). Spatial language facilitates spatial cognition: Evidence from children who lack language input. *Cognition, 127,* 318–330. http://dx.doi.org/10.1016/j.cognition.2013.01.003

Gentner, D., & Toupin, C. (1986). Systematicity and surface similarity in the development of analogy. *Cognitive Science, 10,* 277–300. http://dx.doi.org/10.1207/s15516709cog1003_2

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. *Cognitive Psychology, 15,* 1–38. http://dx.doi.org/10.1016/0010-0285(83)90002-6

Gleitman, L. R., Cassidy, K., Nappa, R., Papafragou, A., & Trueswell, J. C. (2005). Hard words. *Language Learning and Development, 1,* 23–64. http://dx.doi.org/10.1207/s15473341lld0101_4

Goldin-Meadow, S. (2003). Thought before language: Do we think ergative? In D. Gentner & S. Goldin-Meadow (Eds.), *Language in mind: Advances in the study of language and thought* (pp. 493–522). Cambridge, MA: MIT Press.

Gopnik, A., & Choi, S. (1995). Names, relational words, and cognitive development in English and Korean Speakers: Nouns are not always learned before verbs. In M. Tomasello & W. E. Merriman (Eds.), *Beyond names for things: Young children's acquisition of verbs* (pp. 63–80). Hillsdale, NJ: Erlbaum.

Gordon, P. (2004, October 15). Numerical cognition without words: Evidence from Amazonia. *Science, 306,* 496–499. http://dx.doi.org/10.1126/science.1094492

Haun, D. B., & Rapold, C. J. (2009). Variation in memory for body movements across cultures. *Current Biology, 19*(23), R1068–R1069. http://dx.doi.org/10.1016/j.cub.2009.10.041

Heine, B., Claudi, U., & Hunnemeyer, F. (1991). *Grammaticalization: A conceptual framework*. Chicago, IL: University of Chicago Press.

Hofstadter, D., & Sander, E. (2013). *Surfaces and essences: Analogies as the fuel and fire of thinking*. New York, NY: Basic Books.

Holyoak, K. J., & Thagard, P. R. (1995). *Mental leaps: Analogy in creative thought*. Cambridge, MA: MIT Press.

Hummel, J. E. (2010). Symbolic versus associative learning. *Cognitive Science, 34,* 958–965. http://dx.doi.org/10.1111/j.1551-6709.2010.01096.x

Keil, F. C., & Batterman, N. (1984). A characteristic-to-defining shift in the development of word meaning. *Journal of Verbal Learning and Verbal Behavior, 23,* 221–236. http://dx.doi.org/10.1016/S0022-5371(84)90148-8

Kim, M., McGregor, K. K., & Thompson, C. K. (2000). Early lexical development in English- and Korean-speaking children: Language-general and language-specific patterns. *Journal of Child Language, 27,* 225–254. http://dx.doi.org/10.1017/S0305000900004104

Levinson, S. C. (2003). *Space in language and cognition: Explorations in cognitive diversity*. http://dx.doi.org/10.1017/CBO9780511613609

Levinson, S. C., & Brown, P. (1994). Immanuel Kant among the Tenejapans: Anthropology as empirical philosophy. *Ethos, 22,* 3–41. http://dx.doi.org/10.1525/eth.1994.22.1.02a00010

Levinson, S. C., Kita, S., Haun, D. B. M., & Rasch, B. H. (2002). Returning the tables: Language affects spatial reasoning. *Cognition, 84,* 155–188. http://dx.doi.org/10.1016/S0010-0277(02)00045-8

Li, P., & Gleitman, L. (2002). Turning the tables: Language and spatial reasoning. *Cognition, 83,* 265–294. http://dx.doi.org/10.1016/S0010-0277(02)00009-4

Loewenstein, J., & Gentner, D. (2005). Relational language and the development of relational mapping. *Cognitive Psychology, 50,* 315–353. http://dx.doi.org/10.1016/j.cogpsych.2004.09.004

Loewenstein, J., Thompson, L., & Gentner, D. (1999). Analogical encoding facilitates knowledge transfer in negotiation. *Psychonomic Bulletin & Review, 6,* 586–597. http://dx.doi.org/10.3758/BF03212967

Lupyan, G., Rakison, D. H., & McClelland, J. L. (2007). Language is not just for talking: Redundant labels facilitate learning of novel categories. *Psychological Science, 18,* 1077–1083. http://dx.doi.org/10.1111/j.1467-9280.2007.02028.x

Maguire, M. J., Hirsh-Pasek, K., & Golinkoff, R. M. (2006). A unified theory of verb learning: Putting verbs in context. In K. Hirsh-Pasek and R. M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 364–391). New York, NY: Oxford University Press.

Majid, A., Bowerman, M., Kita, S., Haun, D. B. M., & Levinson, S. C. (2004). Can language restructure cognition? The case for space. *Trends in Cognitive Sciences, 8,* 108–114. http://dx.doi.org/10.1016/j.tics.2004.01.003

Markman, A. B. (1999). *Knowledge representation*. Mahwah, NJ: Erlbaum.

Markman, E. M. (1989). *Categorization and naming in children: Problems of induction*. Cambridge, MA: MIT Press.

Mix, K. S. (2002). The construction of number concepts. *Cognitive Development, 17,* 1345–1363. http://dx.doi.org/10.1016/S0885-2014(02)00123-5

Mix, K. S. (2009). How Spencer made number: First uses of the number words. *Journal of Experimental Child Psychology, 102,* 427–444. http://dx.doi.org/10.1016/j.jecp.2008.11.003

Pae, S. (1993). *Early vocabulary in Korean: Are nouns easier to learn than verbs?* Unpublished doctoral dissertation, University of Kansas, Lawrence.

Penn, D. C., Holyoak, K. J., & Povinelli, D. J. (2008). Darwin's mistake: Explaining the discontinuity between human and nonhuman minds. *Behavioral and Brain Sciences, 31,* 109–130. http://dx.doi.org/10.1017/S0140525X08003543

Pica, P., Lemer, C., Izard, V., & Dehaene, S. (2004, October 15). Exact and approximate arithmetic in an Amazonian indigene group. *Science, 306,* 499–503. http://dx.doi.org/10.1126/science.1102085

Pruden, S. M., Levine, S. C., & Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter? *Developmental Science, 14,* 1417–1430. http://dx.doi.org/10.1111/j.1467-7687.2011.01088.x

Schmandt-Besserat, D. (1996). *How writing came about*. Austin, Texas: University of Texas Press.

Tardif, T. (1996). Nouns are not always learned before verbs: Evidence from Mandarin speakers' early vocabularies. *Developmental Psychology, 32,* 492–504. http://dx.doi.org/10.1037/0012-1649.32.3.492

Tardif, T., Gelman, S. A., & Xu, F. (1999). Putting the "noun bias" in context: A comparison of English and Mandarin. *Child Development, 70,* 620–635. http://dx.doi.org/10.1111/1467-8624.00045

Waxman, S., Fu, X., Arunachalam, S., Leddon, E., Geraghty, K., & Song, H. J. (2013). Are nouns learned before verbs? Infants provide insight into a long-standing debate. *Child Development Perspectives, 7,* 155–159. http://dx.doi.org/10.1111/cdep.12032

Waxman, S. R., & Hall, D. G. (1993). The development of a linkage between count nouns and object categories: Evidence from fifteen- to twenty-one-month-old infants. *Child Development, 64,* 1224–1241. http://dx.doi.org/10.2307/1131336

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