CHAPTER 16

LANGUAGE IN COGNITION

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This chapter reviews some of the ways in which natural language might be implicated in human cognition. After some initial ground clearing, it discusses the views of Whorf and Vygotsky, together with some of their contemporary adherents, before discussing some proposals that have been made for the language-dependence of certain classes of concept (for natural kinds, for mental states, and for numbers). The chapter then discusses the alleged role of language in integrating the outputs of different conceptual modules and in realizing so-called "System 2" cognitive processes.

1. Introduction

Our question in this chapter concerns the degree of involvement—or lack thereof—of natural language in human cognition. In what ways, if any, do human thought processes involve language? To what extent is human thinking dependent upon possession of one or another natural language? The answers that people have returned to these questions range along a spectrum of claims of varying strength, with the variations reflecting changes in the quantifiers and/or the modality with which the claim is made. At one extreme sits the assertion made by some philosophers that it is *conceptually necessary* that *all* thought is dependent upon language. At the other extreme is the claim that all thought is, not only conceptually, but also metaphysically and causally, *in*dependent of natural language. And in between these two poles lie a multitude of possible claims that *most*, *some*, or *specific types* of thought are dependent upon natural language, where the dependence in question can be conceptual, metaphysical (that is, constitutive), or causal.

It is unclear whether anyone has ever really endorsed the thesis of the independence of thought from language in its most extreme form. For even those who, such as Fodor (1975), picture natural language as but an input-output system for central cognitive processes of thinking and reasoning will allow that there are many thoughts (both tokens and types) that we would never have entertained in the absence of language. Everyone allows that the utterances of other people can have a significant impact on the thoughts that occur to us at any given moment. Hence there are some thought *tokens* that we would never have entertained in the absence of language. And everyone allows that the testimony of other people is the source of many of our beliefs as well. Hence there are some thought *types* that we would never have entertained if we had been incapable of comprehending what people say to us. These obvious points are taken for granted by all parties in the debate.

While the strongest thesis that thought (or all propositionally structured forms of thought)[1] is conceptually dependent upon language has been defended by some philosophers (Davidson 1973, 1975; Dummett 1981, 1989; McDowell 1994), this is not a view that we need to take seriously for the purposes of this chapter. At any rate, we do not propose to do so for such views are not given any credence among cognitive scientists. Not only are carefully considered attributions of thought to nonlinguistic creatures rife within cognitive science, but it is taken for granted that for any given type of thought, it will be an open empirical question whether such thoughts might be entertained by a creature that lacks a natural language (with the trivial exception of thoughts that are explicitly *about* natural language, of course).

The discussion that follows will focus on the space between the two extremes. We shall begin (in Sections 2 and 3) with a discussion of some historically influential claims for certain sorts of dependence of thought upon language, made by Whorf (1956) and Vygotsky (1961) respectively, together with some contemporary variants. We shall then in Section 4 discuss some ways in which specific types of concept might be claimed to be language-dependent. Section 5 discusses the role that language might play in unifying and combining the outputs of different central/conceptual "modules" (Hermer-Vazquez, Spelke, and Katsnelson 1999; Carruthers 2002). Finally, Section 6 considers the role that language might play within so-called "dual systems theories" of human reasoning processes (Evans and Over 1996; Frankish 2004; Carruthers 2009a).

2. Of Whorf and Whorfianism

The zeitgeist of the second quarter of the twentieth century was behaviorism. It was widely assumed that all animal behavior could be explained in terms of conditioned responses to stimuli, and that the same forms of explanation could, ultimately, be

[1] Dummett (1981), for example, allows that animals might be capable of what he calls "proto-thoughts," which lack the conceptual-compositional structure of genuine human thoughts.

extended to explain most if not all of human behavior as well (Watson 1924; Skinner 1957). It was against this background that the anthropologist and linguist Benjamin Lee Whorf made his proposals about the ways in which natural language serves to structure and shape human cognition. (Many of Whorf's articles are collected together in Whorf 1956.) And that background no doubt played a significant role in winning such wide acceptance for Whorf's views.

Whorf, like most other anthropologists before and since, was impressed by the immense variety displayed by human cultures; he was likewise, as a linguist, impressed by the variety of grammatical forms and modes of conceptualization displayed by the world's natural languages. Some languages, for example, have no words for "left" and "right," and instead describe spatial relationships exclusively by means of geocentric coordinates such as "north" and "south," and/or object-centered coordinates such as "between the river and the sea." Some languages, such as English, have multiple color terms, whereas some, such as Dani, have just two terms meaning roughly "light" and "dark." And famously, the Eskimos were supposed to have many more words available to them than do other people for describing types of snow.[2] What Whorf proposed is that these differences have significant effects on the cognitive processes of the people in question, leading them to apprehend the world quite differently.

While Whorf's views continue to be popular in some areas of the social sciences and (especially) the humanities under the banner of "the social construction of reality," they fell into disrepute among cognitive scientists through much of the second half of the twentieth century. In part this resulted from the cognitive revolution in psychology and surrounding disciplines that took place in the early years of this period. And in part it resulted from a well-known experimental study demonstrating the *lack* of influence of color vocabulary on color vision, color memory, and color categorization. Let us comment briefly on each.

Within a behaviorist framework it perhaps did not seem so implausible that an important new set of stimuli (the linguistic utterances of other people) and behavioral responses (one's own speech) should have a reorganizing influence on previously existing input-output pairings. Hence it did not seem implausible that acquiring one sort of language rather than another might make a difference in how subjects apprehend the world more generally. But once we take seriously that the mind is real, and really organized into different faculties for perception, inference, and action, it immediately becomes problematic to understand how and why linguistic structures should have any significant reorganizing effects outside of the language faculty itself.

As for color, the story begins with an influential study by Berlin and Kay (1969), who investigated color vocabulary in a wide array of languages. What they found were systematic relationships suggestive of a set of underlying universals that reflect the fixed structure of the visual system. In particular, as languages introduce additional

[2] This last claim has since been discredited. See Martin (1986) and Pullum (1991).

color terms, they always do so in a specific order, suggesting an underlying universal structure of relative color salience. Heider and Olivier (1972) then followed up with an experimental study of color naming and color memory in speakers of English (which has eleven basic color terms) and Dani (which has just two). It turned out, as expected, that English speakers use a far greater variety of color terms when asked to name a set of color chips, but they found no differences between the two groups in their capacity to remember and re-identify a color chip over a thirty-second interval. This seemed to many people to be a decisive refutation of one strand in the Whorfian account of the relationship between language and thought.[3]

Since the early 1990s, however, Whorfianism has been undergoing something of a revival, albeit in a weakened form (Hunt and Agnoli 1991; Lucy 1992a, 1992b; Gumperz and Levinson 1996). What has been argued in this new wave of research is no longer that language has a *structuring* effect on cognition (meaning that the absence of language makes certain sorts of thoughts, or certain sorts of cognitive process, completely unavailable to people). The main claim, rather, is that one or another natural language can make certain sorts of thought and cognitive process more *likely*, and more *accessible* to people.

The basic point can be expressed in terms of Slobin's (1987) idea of "thinking for speaking." If your language requires you to describe spatial relationships in terms of compass directions, for example, then you will continually need to pay attention to, and compute, geocentric spatial relations; whereas if descriptions in terms of "left" and "right" are the norm, then geocentric relations will barely need to be noticed. This might be expected to have an impact on the efficiency with which one set of relations is processed relative to the other, and on the ease with which they are remembered (Levinson 1996). Likewise in respect of motion events, if you speak a language, such as English, that employs an extensive and often-used vocabulary for *manner* of motion ("walk," "stride," "saunter," "hop," "skip," "run," "jog," "sprint," etc.), then you will continually need to pay attention to, and encode, such properties. In languages such as Spanish and Greek, in contrast, manner of motion is conveyed in an auxiliary clause ("He went into the room *at a run*"), and it often goes unexpressed altogether. One might then predict that speakers of such languages would be both slower at recognizing, and poorer at remembering, manner of motion (Slobin 1996). This claim has been subjected to careful experimental scrutiny by Papafragou et al. (2002), however, who are unable to discover any such effects.

Levinson's claims for the effects of spatial language on spatial cognition have also been subject to a lively controversy (Levinson 1996, 2003; Li and Gleitman,

[3] Roberson et al. (2000) have more recently undertaken a replication and extension of Heider and Olivier's study, and claim to find a significant influence of language on memory after all. But as Munnich and Landau (2003) point out, the subjects in the Roberson et al. study engaged in overt speech rehearsal of color names during the thirty-second interval before their memory was tested. The task was therefore a verbally mediated one. And that language should have an impact upon verbally mediated tasks is not at all surprising, and lends no support to the Whorfian view that languages have an important effect on *non*linguistic forms of cognition.

2002; Levinson et al. 2002; Li et al. 2005; Papafragou 2007). Let us pull out just one strand from this debate for discussion. Levinson (1996) had tested Tenejapan Mayans—who employ no terms meaning *left* and *right*—on a spatial reversal task. They were confronted with an array of four items on a desk in front of them, and told to remember the spatial ordering of three of the items. They were then rotated through 180 degrees and walked to another table, where they were handed the three items and told to "make them the same." The Mayans turned out to employ geocentric rather than egocentric coordinates when complying with the instruction, just as the hypothesis of "thinking for speaking" would predict.

In the course of their critique, however, Li and Gleitman (2002) point out that the task is plainly ambiguous. The instruction, "make them the same," can mean "lay them out similarly in respect of egocentric space" or "lay them out similarly in respect of geocentric space." (And indeed, Westerners who are given these tasks will notice the ambiguity and ask for clarification.) Li et al. (2005) therefore reasoned that Levinson's results might reflect, not an effect of language upon thought, but rather an effect of language upon language. Since the instruction is ambiguous, subjects are presented with the problem of disambiguating it before they can respond appropriately. And since geocentric descriptions are overwhelmingly more likely in the society to which the Mayans belong, they might naturally assume that the instruction is intended geocentrically, and act accordingly. It does not follow that they would have had any particular difficulty in solving the task in an egocentric fashion if cued accordingly. And for all that the experiment shows, they might routinely deploy egocentric concepts in the course of their daily lives (if not in their daily speech).

To test this, Li et al. (2005) devised a series of unambiguous spatial tasks that admit of only a single correct solution. In one of these, for example, the subjects had to match a card containing two differently sized circles to one of four cards of the same sort, but variously oriented. Once they were familiar with the task, they were allowed to study the card at one table before being rotated 180 degrees and walked to a second table where four cards were laid out for them to match against. But they did this under one of two conditions. In one, the card was covered and carried to the other table while they watched without its orientation relative to Earth being changed. (This is the geocentric condition.) In the other, the card was placed in their hands and covered before they turned around through 180 degrees to face the other table. (This is the egocentric condition.) Contrary to Levinson's predictions, the subjects did just as well or better in the egocentric condition. And when the task demands were significantly increased (as when Li et al. had subjects recall and trace out one particular path through a maze under two conditions similar to those described above), the Mayan subjects actually did significantly *better* in the egocentric condition (80 percent correct versus 35 percent correct; see Papafragou 2007).

Therefore, the claim that different natural languages have differing effects on nonlinguistic cognition is still unproven. While the idea has a certain intuitive plausibility, and while evidence has been presented in its support, it has also been successfully criticized in a number of studies. Whether any sustainable version of weak

Whorfianism will emerge from the ongoing process of testing and debate is open to serious doubt.

3. Vygotsky and Linguistic Scaffolding

At around the same time that Whorf was writing, the Soviet psychologist Lev Vygotsky was developing his ideas on the interrelations between language and thought, both in the course of child development and in mature human cognition. These remained largely unknown in the West until his book *Thought and Language* was first published in translation in 1962 (with portions omitted). This attracted significant attention, and a number of further works were translated through the 1970s and 1980s (Vygotsky 1971, 1978; Wertsch 1981, 1985).

One of Vygostky's ideas concerned the ways in which language deployed by adults can *scaffold* children's development, yielding what he called a "zone of proximal development." He argued that what children can achieve alone and unaided is not a true reflection of their understanding. Rather, we also need to consider what they can do when scaffolded by the instructions and suggestions of a supportive adult. Moreover, such scaffolding not only enables children to achieve with others what they would be incapable of achieving alone, but plays a causal role in enabling children to acquire new skills and abilities. Relatedly, Vygotsky focused on the overt speech of children, arguing that it plays an important role in problem solving, partly by serving to focus their attention, and partly through repetition and rehearsal of adult guidance. And this role does not cease when children stop accompanying their activities with overt monologues, but just disappears inwards. Vygotsky argued that in older children and adults *inner* (subvocal) speech serves many of the same functions.

Many of these ideas have been picked up by later investigators. For example, Diaz and Berk (1992) studied the self-directed verbalizations of young children during problem-solving activities. They found that children tended to verbalize more when the tasks were more difficult, and that children who verbalized more often were more successful in their problem solving. Likewise Clark (1998) draws attention to the many ways in which language is used to support human cognition, ranging from shopping lists and Post-it notes, to the mental rehearsal of remembered instructions and mnemonics, to the performance of complex arithmetic calculations on pieces of paper. And by writing an idea down, for example, you can present yourself with an object of further leisured reflection, leading to criticism and further improvement.

The thesis that language plays such roles in human cognition is not—or should not be—controversial. But in Vygotsky's own work, it goes along with a conception of the mind as being to an important extent socially constructed, developing in plastic ways in interactions with elements of the surrounding culture, guided and supported by adult members of that culture. These stronger views—such as the similar constructionist views of Whorf—are apt to seem implausible when seen from the perspective of contemporary cognitive psychology. But as we shall see in Section 6, a restricted version of them can survive as an account of a certain *level* of thinking and reasoning within the human mind.

4. Language-Dependent Concepts

As we noted in Section 1, everyone allows that some types of thought are dependent upon language, at least to the extent that language is needed for, or is de facto the cause of, their existence. There are two ways in which one might seek to strengthen this claim. One would be to maintain that not only the acquisition of some *thought*-types, but also some types of *concept* (and hence entire classes of thought involving those concepts), are dependent upon language. Another would be to maintain that language is not just *necessary* for the acquisition of certain types of thought and/or concept, but is actually *constitutive of* the thoughts/concepts so acquired. Many different proposals of these two kinds have been made in recent decades. Here we shall briefly survey three of the more interesting ones.

4.1. Language-Learning and Kind-Concepts

No one in cognitive science doubts that prelinguistic children possess a great many concepts for the kinds of thing and substance that they encounter. And there is a copious body of evidence that older (language-using) children *essentialize* natural kinds—believing that each natural kind has an underlying "essence" that determines its nature (Gelman 2003). Children think that an object that possesses the essence of a kind belongs to that kind, even if it is very different in appearance and behavior. And likewise they think that something can fail to belong to a kind, despite sharing the superficial features of members of that kind, by failing to have the right sort of inner constitution or essence.

One suggestion—defended by Xu (2002; Xu, Cote, and Baker 2005)—is that it is the evidence provided by adult naming practices that tells children which of their concepts, from the wider array of kind-concepts that they possess, they should essentialize. This makes a good deal of sense from an evolutionary standpoint, since the naming practices of the adults in a given society can be thought of as representing the accumulated wisdom of the group, especially concerning which patterns of classification of items in the environment can undergird robust inductive inferences from one circumstance to another. Children might then be predisposed, when learning a new noun referring to a natural kind, to assume that its referent has an underlying essence. If they previously lacked any concept for the kind of thing in question, then they form one. But even if they had previously possessed such a concept, what they now do is essentialize it, thereafter assuming that there is an underlying essence to the kind that determines category membership.

4.2. That-Clauses and Theory of Mind

The hypothesis just canvassed concerns a causal role for language in the acquisition of kind concepts. Others have put forward a similar hypothesis concerning the mental-state concepts that lie at the heart of the "theory of mind" or "mindreading" abilities of human beings. More specifically, it has been proposed that it is by engaging in conversation with a partner that children first come to realize that there are different epistemic perspectives on the world besides their own (Harris 1996). And the evidence does suggest that language use boosts the capacity for mindreading, at least (Perner, Ruffman, and Leekham 1994). Moreover, deaf children who are significantly delayed in their acquisition of language show a corresponding delay for mindreading (Peterson and Siegal 1995). However, the existing data are consistent with a view of mental-state concepts as embedded in an innately structured mindreading faculty or module, whose maturation is boosted by the challenges involved in the interpretation of speech, but whose development is not strictly dependent upon language (Siegal and Surian 2006).

Some have put forward the stronger claim that some mental-state concepts (specifically the concept of *false belief* and its cognates) aren't just causally dependent upon language, but are *constituted* by aspects of the latter (Segal 1998; de Villiers and de Villiers 2000, 2003). The idea is that we only come to be able to think about beliefs, as potentially false representational states of a thinker, by virtue of mastering the clausal structure of natural language *that*-clauses. It is by acquiring competence with such sentences as, "John said that it is cold" and, "Mary believes that it is warm" that children acquire mastery of the concept of false belief; and natural language *that*-clauses remain constitutive of such mastery thereafter.

There exists powerful evidence against this strong constitution-thesis, however. For there are cases of severe agrammatic aphasia in which subjects seem to remain normal in their mind-reading performance (Varley 1998; Varley et al. 2001).[4] These patients have undergone extensive left-hemisphere damage, and as a result have significant problems with language. One such patient has matching comprehension and production deficits, suggesting that there is an underlying deficit in linguistic competence. He has lost almost all capacity to comprehend and to use verbs (while retaining some nouns); and he has certainly lost any capacity to formulate or comprehend *that*-clauses. But he is adept at communicating via pantomime, and performed as normal on a battery of false-belief tasks of the sort often administered to children (explained to him via a combination of one-word instruction and pantomime).

[4] Likewise, there exist cases of temporary paroxysmal aphasia in which language comprehension and production is completely shut down, but in which meta-cognitive skills and mind reading seem to remain fully intact. See Lecours and Joanette (1980).

While these data count powerfully against the thesis that natural language *that*-clauses are constitutive of the mind-reading capacities of adults, they are consistent with the claim that *that*-clause comprehension is at least a necessary condition of the *development* of mind-reading in children, as de Villiers and de Villiers (2000, 2003) also claim. Experiments conducted with Cantonese-speaking and German-speaking children count against this developmental claim, however (Perner et al., 2003; Cheung et al., 2004). So, too, does the fact that there exist many sign languages and some spoken Australian Aboriginal languages that contain no *that*-clause construction at all (Mark Baker, personal communication), since no one has suggested that such people are incapable of mind-reading. (In such languages, instead of saying, "John said that it is cold," subjects would use a clausal adjunct, saying, "It is cold, John said [it].") Moreover, the recent finding that infants perform successfully in non-verbal false belief tasks long before they become capable of using *that*-clauses speaks strongly against the proposal (Onishi and Baillargeon 2005; Southgate, Senju, and Csibra 2007; Surian, Caldi, and Sperber 2007; Song et al. 2008; Scott and Baillargeon 2009; Buttelmann, Carpenter, and Tomasello 2009).

4.3. Number Words and Exact Number Concepts

There is now extensive evidence that some numerical concepts are independent of language (Gallistel 1990; Dehaene 1997; Xu and Spelke 2000; Lipton and Spelke 2003). Specifically, both nonhuman animals and pre-verbal infants as young as six months can make judgments of approximate numerosity. They can judge the rough size of a set, and they can recognize that one set is larger or smaller than another, provided that the sizes of the two sets are sufficiently far apart. (What counts as "sufficient" here is partly a product of learning and experience—older children can make finer numerosity discriminations than can young infants—but it also depends upon the size of the sets in question—numerical discrimination becomes harder as the sets become larger.) Moreover, animals can effect simple numerical computations over their approximate numerosity representations (addition, subtraction, multiplication, and division). For example, they can calculate the rate of return from a foraging source (Gallistel 1990), which requires dividing the total quantity obtained from the source by the time spent foraging there.

Other researchers have claimed, furthermore, that animals and pre-verbal infants possess a capacity for exact small-number judgment and comparison, for numbers up to three or four (Wynn 1992a, 1992b; Dehaene 1997). For example, infants who see two objects placed behind a screen will be surprised if there is only one object remaining when the screen is lifted, or if there are three objects there instead. These judgments seem, on the face of it, to be numerical ones, since they are independent of the identities and properties of the objects in question. For example, a young infant will *not* be surprised if it first sees a toy clown placed behind the screen, but a toy truck is there instead when the screen is lifted; but it *will* be surprised if when the screen is lifted there are *two* toy trucks there. There is an emerging consensus, however, that these capacities are underlain by an attentional mechanism that opens a fresh *object-file* for each new object introduced (which can be thought of as an arbitrary label, "x," "y," etc.; note that the file itself can be empty of information), rather than requiring any strictly numerical concepts (Simon 1997; Leslie et al. 1998; Leslie, Gallistel, and Gelman 2007). Thus an infant that has seen two clowns placed behind a screen will have two object-files ("x" and "y") open. If two trucks are then observed it can match the "x" to one truck and the "y" to the other (provided that the object-files are empty, or at least contain no information about object category); but if three trucks are observed, then one of them will be left without any associated object-file label, causing the infant to be surprised.

When it comes to exact numerical concepts for numbers larger than four (*five*, *six*, *seven*; *seventeen*; *sixty-four*; *five million*; and so forth), most researchers accept that their acquisition is dependent upon language, specifically on the mastery of count-word lists ("five," "six," "seven," "eight," and so on) together with the procedures for counting. So this is a case where a whole class of concepts appears to be *developmentally* dependent upon language, at least. It remains very much in dispute how the acquisition process is supposed to occur, however. Some have argued that the basic procedure involves mapping the counting list onto the pre-existing approximate numerosity system (Gallistel and Gelman 1992; Wynn 1992a, 1992b). Others have thought that children bootstrap their way to a conception of exact large number by aligning the first few items on their count list with the representations in the object-file system, and then making a sort of inductive leap (Carey 2004; Feingensen, Dehaene, and Spelke 2004). However, Leslie et al. (2007) review these and other proposals and conclude that children require, in addition, an innate concept of the number *one*, together with an innate concept of recursion. (See also Laurence and Margolis 2007.)

There is also some evidence that natural language number-words might be constitutive of our adult possession and deployment of exact number concepts, in addition to being developmentally necessary for their acquisition. For Spelke and Tsivkin (2001) found that bi-lingual subjects trained on new number facts in one language recalled those facts more swiftly and accurately when tested in the language of teaching than when tested in their other language. In contrast, no such effect was found for new approximate number information, nor for new geographical and historical facts. This suggests that the latter are represented and stored independently of natural language, whereas exact number information is stored along with its natural language encoding.

5. Language as Content Combiner

A somewhat different proposal concerning the role of natural language in cognition is that it enables us to combine together the outputs of conceptual "modules," some of which would not otherwise get combined (Hermer and Spelke 1994, 1996;

Carruthers 1998, 2002; Hermer-Vazquez et al. 1999; Shusterman and Spelke 2005). Language is thus said to underpin the flexibility and *conjoinability* of content that is distinctive of human thought processes. (It is manifest to ordinary introspection that any concept that we possess can be conjoined with any other. Indeed, some philosophers have wanted to make this a constraint on concept possession *tout court*, claiming that only creatures capable of doing it can count as genuine concept users. This is the so-called "Generality Constraint" on concept possession—Evans 1982; see Carruthers 2009b, for a critique.) Explaining this proposal will require some background, however, before the evidence adduced in its support can be outlined and evaluated.[5]

Some psychologists—especially those who might describe themselves as "evolutionary"—have argued that in addition to specialized input systems (vision, audition, etc.) the mind contains a large number of specialized conceptual systems for forming new beliefs, for creating new motivations, and for decision making (Barkow et al. 1992; Sperber 1996, 2002; Pinker 1997; Carruthers 2006). Thus, in addition to the approximate numerosity system described in Section 5.3 above, there might be systems for forming beliefs about other people's mental states ("mind-reading"), for making judgments of physical causation ("folk-physics"), for keeping track of who owes what to whom in social exchanges ("cheater-detection"), and so on and so forth. Different theorists differ over the properties that they attribute to these conceptual "modules," and in particular about whether or not they are *encapsulated* (that is, closed off from information held elsewhere in the mind). But the important point for our purposes is that there is general agreement that conceptual modules will have limited connectivity with each other. It will often be the case that two or more modules routinely pass their outputs to a third, "down-stream," module, which may then be capable of combining those outputs into a single thought. But for thoroughgoing modularists there are unlikely to be any systems that are capable of receiving output from *all* conceptual modules—with the notable exception of the language faculty, which has presumably evolved to be capable of receiving, conjoining, and reporting information deriving from *any* conceptual module.

The main difficulty for those wishing to test this proposal lies in our ignorance of the detailed patterning of conceptual-module connectivity. For without knowing which modules connect up with which others independently of language, it is impossible to make predictions about the sorts of combinations of concepts that we should never observe in the absence of language. Fortuitously, however, data unearthed by Cheng (1986) concerning the spatial cognition of rats seemed to provide a plausible way of testing the idea. What Cheng found is that when rats are shown the location of some food hidden in one of the corners of an oblong rectangular space, and are

[5] It is worth noting that the proposal receives some indirect theoretical support from linguistics, where it has been claimed that the language faculty forces us to re-represent all concepts, from whatever source—even singular concepts such as proper names—as predicates. The result is that all atomic sentences can then take the form of existential quantifications over event descriptions that have been built up using conjunctions of the resulting predicates alone. See Pietroski (2005).

then removed from that space and disoriented before being returned, they rely *only* on geometric information when searching for the food. This leads the rats to search with equal frequency in the two geometrically equivalent corners, hence failing to go to the correct corner on 50 percent of occasions. All cues other that geometry are ignored. One of the walls of the container can be strikingly patterned or heavily scented, for example, but the rats ignore this information (even though it would enable them to succeed, and even though they can use it in other contexts for other purposes), and rely only on geometry.[6]

Hermer and Spelke (1994, 1996) had the idea of testing this phenomenon in young children, with identical results. When children are disoriented in a confined[7] rectangular space they, too, rely only on the geometry of the space when searching for the location of a hidden toy that they had been shown previously, even though one of the walls of the room may be bright red while the others are white. Older children and adults, in contrast, can solve these reorientation problems, utilizing both color *and* spatial information to locate the hidden target.

What Hermer and Spelke then did was to examine whether or not there is something about the children's language abilities that predicts success. And indeed, they found that the *only* predictor of success (but a highly reliable one) is productive use of the terms "left" and "right." Since color vocabulary is acquired much earlier, their suggestion is that it is only with the acquisition of appropriate spatial vocabulary that children first become capable of combining object-property information with geometric information. And in a later study, Shusterman and Spelke (2005) established that the relationship is causal and not just correlational, since *training* children in the use of "left" and "right" has a marked impact on their success in the disorientation tasks thereafter.

Even more dramatically, Hermer-Vazquez et al. (1999) extended these results in experiments with adults. It turns out that if adults are required to "shadow" speech during the experiment (continuously repeating back words that they hear through headphones), then their performance collapses to that of the younger children and rats—they, too, search equally often in the two geometrically equivalent corners. (In contrast, adult performance is unaffected by the requirement to shadow a complex rhythm, which places them under equivalent cognitive load.)

Although these results are striking, and although they show that language is certainly doing *something* in cognition, they don't demonstrate that language is enabling the combination of the outputs from different conceptual modules

[6] One fact that might explain this puzzling phenomenon is that symmetrical spaces are very rarely found in nature. On the contrary, the geometries of spaces "in the wild" are almost always unique. Hence an evolved disposition to default to geometric information when disoriented might have proven both reliable and efficient.

[7] Why the size of the space should matter is puzzling, but Spelke (personal communication) has obtained evidence that in a larger space, the children treat the red wall as a sort of directional beacon, like a distant tree or a line of hills, and that this takes priority over their default-to-the-geometry heuristic.

(namely, one concerned with geometry and one concerned with object properties). This is because "left" and "right" aren't geometric terms. And although the sentence, "It is left of the red wall" combines *spatial* information with color information, it doesn't combine *geometric* information with color information. (This is the sort of sentence that adults say, on introspective grounds, that they repeat to themselves when solving the tasks successfully.) Moreover, even the terms "left" and "right" aren't strictly necessary to enable subjects to solve the tasks. Simply drawing young children's attention to the red wall will actually work just as well. ("Look, I'm placing the doll near the *red* wall.") For if the child first orients towards the red wall, then the geometry of the visible space (long wall on the left, short wall on the right, say) can be used to select the correct corner thereafter.

The best explanation of the role of language in these experiments is as follows. Adults and older children formulate a sentence like, "It is left of the red wall" and see that it encodes all of the information that they need to solve the task. They therefore rehearse that sentence to themselves (if they aren't shadowing speech) while undertaking the task. When they reach the search phase, they then treat the rehearsed sentence somewhat like an instruction for action ("Go to the corner that is left of the red wall"), the following of which enables them to by-pass or pre-empt what would otherwise have been their default inclination to look only at the geometry of the space. Younger children who lack the word "left," on the other hand, might try out for themselves the sentence, "It is *near* the red wall." But since this manifestly doesn't encode all of the information that they need—it doesn't tell them *which side* of the red wall to go to—they don't bother to rehearse it. But in fact (unknown to them), had they done so—or had they just rehearsed, "Go to red"—they would actually have succeeded, since once oriented towards red their geometric knowledge would have kicked in to take them to the correct corner.

On this account, it turns out that the role of language in cognition isn't to unify the outputs of some otherwise unconnected modules (or it isn't in this instance, at least—the wider question remains open). Rather, language is playing a quasi-exe utive function, serving to manipulate the subject's attention and on-line goals. This is the sort of role that we will explore more systematically in Section 6.

6. Dual Systems Theory and Language

Most researchers who study human reasoning, and the fallacies and biases to which it is often subject, have converged on some or other version of a *dual systems* account (Evans and Over 1996; Evans 2008; Sloman 1996, 2002; Stanovich 1999, 2009; Kahneman 2002). Most now agree that System 1 is really a *collection* of different systems that are fast and unconscious, operating in parallel with one another. (For a modularist, these can be identified with the set of conceptual modules.) The principles according to which these systems function are, to a significant extent, universal to the human species, and they are not easily altered (e.g., by verbal instruction). Moreover those principles are, for the most part, heuristic in nature ("quick and dirty"), rather than deductively or inductively valid. It is also generally thought that most of the mechanisms constituting System 1 are evolutionarily ancient and shared with other species of animal.

System 2, in contrast, is slow, serial, and conscious. The principles according to which it operates are variable (both across cultures and between individuals within a culture), and can involve the application of valid norms of reasoning (although System 2, too, can involve the use of heuristics). These System 2 principles are malleable and can be influenced by verbal instruction, and they often involve normative beliefs (that is, beliefs about how one *should* reason). Moreover, System 2 is generally thought to be uniquely human, and some researchers, at least, emphasize the role that representations of natural language sentences (in so-called "inner speech") play in the operations of System 2 (Evans and Over 1996; Evans 2008).

Many writers are not fully explicit about how System 1 and System 2 relate to one another. But the general picture seems to be that they exist *alongside* each other, competing for control of the person's behavior. This is puzzling, however, for one wants to know what evolutionary pressures could have produced such wholesale cognitive change—in effect, creating a whole new system for forming beliefs and goals, and for decision making, alongside of a set of systems that already existed for those very purposes. Why would evolution not have tweaked, or extended, or added to the already-existing System 1 architecture, rather than starting over again afresh with System 2? Frankish (2004, 2008), in contrast, develops an account of System 2 processes as *realized in* those of System 1. So what we have are two *levels* or *layers* of cognitive processes, with one dependent upon the operations of the other, rather than being wholly distinct. This has the advantage that evolution need not have added anything much to the System 1 architecture for System 2 to come into existence. Rather, those System 1 systems needed to be orchestrated and utilized in new ways.

Carruthers (2006, 2009a) deepens and extends this picture, arguing that System 2 begins with the custom of mental rehearsal of action schemata (which is probably already present among some of the other great apes). This utilizes back-projecting pathways from motor cortex to the various perceptual systems, which evolved in the first instance for the swift on-line fine-tuning of action (Wolpert and Ghahramani 2000; Wolpert and Flanagan 2001; Wolpert, Doya, and Kawato 2003). But with overt action suppressed, these pathways can be used to generate visual and other images of the action in question. These images are then "globally broadcast" (Baars 1988, 2002) to the full suite of System 1 modules for forming predictions and new motivations. Inferences are drawn, and the broadcast image can be elaborated accordingly. Moreover, the agent's emotional systems react to the results as they would to the real thing (albeit more weakly, perhaps). These emotional reactions are monitored by the subject and—depending on their strength and valence—the subject's motivation to perform the original rehearsed action is then adjusted up or down accordingly (Damasio 1994, 2003).

On this account, some other species of animal already possess the beginnings of System 2 (although it is perhaps rarely used). But in the course of human evolution, the addition of a number of other System 1 systems—for language production and comprehension, for mindreading and higher-order thinking, and for normative reasoning and motivation—together with a disposition to engage in *creative* activation and rehearsal of action schemata (Carruthers 2007) led to a transformation in the character of System 2. Action schemata for *speech* could now be rehearsed with overt action suppressed, issuing (normally) in auditory (sometimes articulatory or visual) imagery of the sentence in question. The resulting image gets globally broadcast, and is received as input by the language comprehension system inter alia, which sets to work and attaches a conceptual content to it. The result is also received as input by the mindreading faculty, which might then issue in thoughts *about* the rehearsed sentence or thought, setting off a train of higher-order thinking and reasoning. Normative beliefs about what one *should* think or how one *should* reason might also be evoked, leading the subject to have beliefs about what he or she ought to think/say next. Since such beliefs come with built-in motivation, the result might be the formulation and rehearsal of another sentence of the appropriate sort. And since speech actions, like other actions, can be generated and rehearsed creatively, sometimes the contents entertained within System 2 will be radically new, not resulting directly from any thoughts that are entertained at the System 1 level.

On this account, it is because System 2 consists in *cycles* of operation of System 1 that it is comparatively slow, it is because (roughly speaking) only one action can be rehearsed at a time that it is serial, and it is because the resulting images are globally broadcast that System 2 (or rather, this aspect of its operations) is conscious. Moreover, because System 2 is action-based, it can be influenced in any of the ways that actions in general can be. Hence someone can *tell* you how you should tackle some problem, and you can comply, responding just as you would to any other bit of action-advice. For example, your logic teacher might tell you, "In order to evaluate a conditional, you need to look for a case where the antecedent is true and the consequent is false." When confronted by a Wason selection task, you might then ask yourself, "How do I tell whether a conditional is true or false?," evoking a memory of this advice and leading you to turn over both the "P" and the "not-Q" cards.

Likewise you can *imitate* the public reasoning processes of others, such as might be displayed in a philosophy lecture or in a scientific lab meeting, extracting abstract schemata for the sorts of sequences of moves that one should go through when confronted by certain types of problem, and then replicating them. And of course any normative beliefs that you form about the ways in which one should reason (perhaps from a course in logic, or a course in scientific method) can influence System 2, just as they might influence any other type of behavior. Moreover, individuals can vary along any of the above dimensions (e.g., in their normative beliefs), as well as in their dispositions to engage in mental rehearsal in the first place (which we call "being reflective").

On this account, then, natural language plays an important constitutive role in distinctively human (System 2) thought processes. This is not to say that *only* language plays such a role, however. On the contrary, other sorts of action can be rehearsed, leading to global broadcasts and transformations of visual and other forms of imagery, which can in turn issue in decision making. Indeed, one of the dimensions along which individual people differ from one another concerns the extent to which they are verbal or visual thinkers. But everyone uses language in their thinking some of the time, and many people use it a very great deal (Hurlburt 1990). And without language, not only are there many token thoughts that we would never entertain, but a large swathe of our cognitive lives, and our subsequent public behavior, would be very different indeed.

7. Conclusion

Partly in reaction to the more extreme views of Whorf and Vygotsky, most cognitive scientists have been inclined to play down the importance of language in human cognition outside of certain limited domains (such as exact number concepts, perhaps). And they are surely correct that a great many cognitive processes are independent of language, many of them shared with other animals. But if the account sketched in Section 6 is even remotely along the right lines, then representations of natural language sentences have an important role to play in certain aspects of distinctively human thinking and reasoning.

REFERENCES

Baars, B. (1988). *A Cognitive Theory of Consciousness*. Cambridge: Cambridge University Press.

———. (2002). The conscious access hypothesis: Origins and recent evidence. *Trends in Cognitive Science* 6: 47–52.

Barkow, J., Cosmides, L., and Tooby, J. (eds.) (1992). *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*. Oxford: Oxford University Press.

Berlin, B. and Kay, P. (1969). *Basic Color Terms: Their Universality and Evolution*. Berkeley: University of California Press.

Buttelmann, D., Carpenter, M., and Tomasello, M. (2009). Eighteen-month-old infants show false belief understanding in an active helping paradigm. *Cognition* 112: 337–42.

Carey, S. (2004). Bootstrapping and the origin of concepts. *Daedalus* 113 (Winter 2004): 59–68.

Carruthers, P. (1998). Thinking in Language?: Evolution and a Modularist Possibility. In P. Carruthers and J. Boucher (eds.), *Language and Thought*, Cambridge: Cambridge University Press.

———. (2002). The cognitive functions of language. & Author's response: Modularity, language, and the flexibility of thought. *Behavioral and Brain Sciences* 25: 657–719.

———. (2006). *The Architecture of the Mind: Massive Modularity and the Flexibility of Thought*. Oxford: Oxford University Press.

———. (2007). The Creative-Action Theory of Creativity. In P. Carruthers, S. Laurence, and S. Stich (eds.), *The Innate Mind: Volume 3: Foundations and the Future*. Oxford: Oxford University Press.

———. (2009a). An Architecture for Dual Reasoning. In J. Evans and K. Frankish (eds.), *In Two Minds: Dual Processes and Beyond*. Oxford: Oxford University Press.

———. (2009b). Invertebrate Concepts Confront the Generality Constraint (and Win). In R. Lurz (ed.), *The Philosophy of Animal Minds: New Essays on Animal Thought and Consciousness*. Cambridge: Cambridge University Press.

Cheung, H., Hsuan-Chih, C., Creed, N., Ng, L., Ping-Wang, S., and Mo, L. (2004). Relative roles of general and complementation language in theory-of-mind-development: evidence from Cantonese and English. *Child Development* 75: 1155–70.

Cheng, K. (1986). A purely geometric module in the rat's spatial representation. *Cognition* 23: 149–78.

Clark, A. (1998). Magic words: How language augments human computation. In P. Carruthers and J. Boucher (eds.), *Language and Thought*. Cambridge: Cambridge University Press.

Damasio, A. (1994). *Descartes' Error: Emotion, Reason and the Human Brain*. London: Papermac.

———. (2003). *Looking for Spinoza: Joy, Sorrow, and the Feeling Brain*. New York: Harcourt.

Davidson, D. (1973). Radical interpretation. *Dialectica* 27: 313–28.

———. (1975). Thought and Talk. In S. Guttenplan (ed.), *Mind and Language*. Oxford: Oxford University Press.

Dehaene, S. (1997). *The Number Sense*. Oxford: Oxford University Press.

De Villiers, J., and de Villiers, P. (2000). Linguistic Determinism and the Understanding of False Beliefs. In P. Mitchell and K. Riggs (eds.), *Children's Reasoning and the Mind*. New York: Psychology Press.

———. (2003). Language for Thought: Coming to Understand False Beliefs. In D. Gentner and S. Goldin-Meadow (eds.), *Language in Mind*. Cambridge, MA: MIT Press.

Diaz, R., and Berk, L. (eds.) (1992). *Private Speech: From Social Interaction to Self-Regulation*. Hillsdale, NJ: Erlbaum.

Dummett, M. (1981). *The Interpretation of Frege's Philosophy.* London: Duckworth.

———. (1989). Language and Communication. In A. George (ed.), *Reflections on Chomsky*. Oxford: Blackwell.

Evans, G. (1982). *The Varieties of Reference*. Oxford: Oxford University Press.

Evans, J., and Over, D. (1996). *Rationality and Reasoning*. New York: Psychology Press.

Evans, J. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology* 59: 255–78.

Feigenson, L., Dehaene, S., and Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences* 8: 307–14.

Fodor, J. (1975). *The Language of Thought*. Brighton, UK: Harvester Press.

Frankish, K. (2004). *Mind and Supermind*. Cambridge: Cambridge University Press.

———. (2008). Systems or levels? Dual-process theories and the personal-subpersonal distinction. In J. Evans and K. Frankish (eds.), *In Two Minds: Dual Processes and Beyond*. Oxford: Oxford University Press.

Gallistel, R. (1990). *The Organization of Learning*. Cambridge, MA: MIT Press.

Gallistel, R., and Gelman, R. (1992). Preverbal and verbal counting and computation. *Cognition* 44: 43–74.

Gelman, S. (2003). *The Essential Child: Origins of Essentialism in Everyday Thought*. Oxford: Oxford University Press.

Gumperz, J., and Levinson, S. (eds.). (1996). *Rethinking Linguistic Relativity*. Cambridge: Cambridge University Press.

Harris, P. (1996). Desires, Beliefs, and Language. In P. Carruthers and P. Smith (eds.), *Theories of Theories of Mind*. Cambridge: Cambridge University Press.

Heider, E., and Olivier, D. (1972). The structure of the color space in naming and memory for two languages. *Cognitive Psychology* 3: 337–54.

Hermer, L., and Spelke, E. (1994). A geometric process for spatial reorientation in young children. *Nature* 370: 57–59.

———. (1996). Modularity and development: The case of spatial reorientation. *Cognition* 61: 195–232.

Hermer-Vazquez, L., Spelke, E., and Katsnelson, A. (1999). Sources of flexibility in human cognition: Dual-task studies of space and language. *Cognitive Psychology* 39: 3–36.

Hunt, E., and Agnoli, F. (1991). The Whorfian hypothesis: A cognitive psychology perspective. *Psychological Review* 98: 377–89.

Hurlburt, R. (1990). *Sampling Normal and Schizophrenic Inner Experience*. New York: Plenum Press.

Kahneman, D. (2002). Maps of bounded rationality: A perspective on intuitive judgment and choice. Nobel laureate acceptance speech. Available at: http://nobelprize.org/economics/laureates/2002/kahneman-lecture.html

Laurence, S., and Margolis, E. (2007). Linguistic determinism and the innate basis of number. In P. Carruthers, S. Laurence, and S. Stich (eds.), *The Innate Mind: Volume 3: Foundations and the Future*. Oxford: Oxford University Press.

Lecours, A., and Joanette, Y. (1980). Linguistic and other aspects of paroxysmal aphasia. *Brain and Language* 10: 1–23.

Levinson, S. (1996). Frames of Reference and Molyneux's Question: Cross-Linguistic Evidence. In P. Bloom, M. Peterson, L. Nadel, and M. Garrett (eds.), *Language and Space*. Cambridge, MA: MIT Press.

Levinson, S. (2003). *Space in Language and Cognition: Explorations in Cognitive Diversity*. Cambridge: Cambridge University Press.

Levinson, S., Kita, S., Haun, D., and Rasch, B. (2002). Returning the tables: Language effects and spatial reasoning. *Cognition* 84: 155–88.

Leslie, A., Gallistel, C., and Gelman, R. (2007). Where Do the Integers Come From? In P. Carruthers, S. Laurence, and S. Stich (eds.), *The Innate Mind: Volume 3: Foundations and the Future*. Oxford: Oxford University Press.

Leslie, A., Xu, F., Tremoulet, P., and Scholl, B. (1998). Indexing and the object concept: Feveloping "what" and "where" systems. *Trends in Cognitive Sciences* 2: 10–18.

Li, P., and Gleitman, L. (2002). Turning the tables: Language and spatial reasoning. *Cognition* 83: 265–94.

Li, P., Abarbanell, L., and Papafragou, A. (2005). Spatial reasoning skills in Tenejapan Mayans. In *Proceedings from the 27th Annual Meeting of the Cognitive Science Society.* Hillsdale, NJ: Erlbaum.

Lipton, J., and Spelke, E. (2003). Origins of number sense: Large number discrimination in human infants. *Psychological Science* 14: 396–401.

Lucy, J. (1992a). *Grammatical Categories and Cognition: A Case Study of the Linguistic Relativity Hypothesis*. Cambridge: Cambridge University Press.

———. (1992b). *Language Diversity and Thought: A Reformulation of the Linguistic Relativity Hypothesis*. Cambridge: Cambridge University Press.

Malt, B., Sloman, S., and Gennari, S. (2003). Speaking versus Thinking About Objects and Actions. In D. Gentner and S. Goldin-Meadow (eds.), *Language in Mind*. Cambridge, MA: MIT Press.

Martin, L. (1986). Eskimo words for snow: A case study in the genesis and decay of an anthropological example. *American Anthropologist* 88: 418–23.

McDowell, J. (1994). *Mind and World.* Cambridge, MA: MIT Press.

Munnich, E., and Landau, B. (2003). The effects of spatial language on spatial representation: Setting Some Boundaries. In D. Gentner and S. Goldin-Meadow (eds.), *Language in Mind*. Cambridge, MA: MIT Press.

Onishi, K. and Baillargeon, R. (2005). Do 15-month-olds understand false beliefs? *Science* 5719: 255–58.

Papafragou, A. (2007). Space and the Language-Cognition Interface. In P. Carruthers, S. Laurence, and S. Stich (eds.), *The Innate Mind: Volume 3: Foundations and the Future*. Oxford: Oxford University Press.

Papafragou, A., Massey, C., and Gleitman, L. (2002). Shake, rattle, "n" roll: The representation of motion in language and cognition. *Cognition* 84: 189–219.

Perner, J., Ruffman, T., and Leekham, S. (1994). Theory of mind is contagious: You catch it from your sibs. *Child Development* 65: 1228–38.

Perner, J., Sprung, M., Zauner, P., and Haider, H. (2003). *Want that* is understood well before *say that, think that,* and false belief: A test of de Villier's linguistic determinism on German-speaking children. *Child Development* 74: 179–88.

Peterson, C., and Siegal, M. (1995). Deafness, conversation, and theory of mind. *Journal of Child Psychology and Psychiatry* 36: 459–74.

Pietroski, P. (2005). *Events and Semantic Architecture*. Oxford: Oxford University Press.

Pinker, S. (1997). *How the Mind Works*. London: Penguin Press.

Pullum, G. (1991). *The Great Eskimo Vocabulary Hoax and Other Irreverent Essays on the Study of Language*. Chicago: University of Chicago Press.

Roberson, D., Davies,I., and Davidoff, J. (2000). Color categories are not universal: Replications and new evidence from a Stone-Age culture. *Journal of Experimental Psychology: General* 129: 369–98.

Scott, R. and Baillargeon, R. (2009). Which penguin is this? Attributing false beliefs about object identity at 18 months. *Child Development* 80: 1172–96.

Segal, G. (1998). Representing Representations. In P. Carruthers and J. Boucher (eds.), *Language and Thought*. Cambridge: Cambridge University Press.

Siegal, M., and Surian, L. (2006). Modularity in language and theory of mind: What is the evidence? In P. Carruthers, S. Laurence, and S. Stich (eds.), *The Innate Mind: Volume 2: Culture and Cognition*. Oxford: Oxford University Press.

Simon, T. (1997). Reconceptualizing the origins of number knowledge: A non-numerical account. *Cognitive Development* 12: 349–72.

Shusterman, A., and Spelke, E. (2005). Investigations in the Development of Spatial Reasoning: Core Knowledge and Adult Competence. In P. Carruthers, S. Laurence, and S. Stich (eds.), *The Innate Mind: Structure and Contents*. Oxford: Oxford University Press.

Skinner, B. (1957). *Verbal Behavior*. East Norwalk, CT: Appleton-Century-Crofts.

Slobin, D. (1987). Thinking for speaking. *Proceedings of the Berkeley Linguistics Society* 13: 435–45.

———. (1996). From "Thought and Language" to "Thinking for Speaking." In J. Gumperz and S. Levinson (eds.), *Rethinking Linguistic Relativity*. Cambridge: Cambridge University Press.

Sloman, S. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin* 119: 3–22.

———. (2002). Two Systems of Reasoning. In T. Gilovich, D. Griffin, and D. Kahneman (eds.), *Heuristics and Biases: The Psychology of Intuitive Judgment*. Cambridge: Cambridge University Press.

Song, H., Onishi, K., Baillargeon, R., and Fisher, C. (2008). Can an actor's false belief be corrected by an appropriate communication? Psychological reasoning in 18.5-month-old infants. *Cognition* 109: 295–315.

Southgate, V., Senju, A., and Csibra, G. (2007). Action anticipation through attribution of false belief by 2-year-olds. *Psychological Science* 18: 587–92.
Spelke, E., and Tsivkin, S. (2001). Language and number: A bilingual training study. *Cognition* 78: 45–88.
Sperber, D. (1996). *Explaining Culture: A Naturalistic Approach*. Oxford: Blackwell.
———. (2002). In Defense of Massive Modularity. In I. Dupoux (ed.), *Language, Brain and Cognitive Development*. Cambridge, MA: MIT Press.
Stanovich, K. (1999). *Who is Rational? Studies of Individual Differences in Reasoning*. Hillsdale, NJ: Erlbaum.
Stanovich, K. (2009). *What Intelligence Tests Miss: The Psychology of Rational Thought*. New Haven, CT: Yale University Press.
Surian, L., Caldi, S., and Sperber, D. (2007). Attribution of beliefs by 13-month old infants. *Psychological Science* 18: 580–86.
Varley, R. (1998). Aphasic Language, Aphasic Thought. In P. Carruthers and J. Boucher (eds.), *Language and Thought*. Cambridge: Cambridge University Press.
Varley, R., Siegal, M., and Want, S. (2001). Severe impairment in grammar does not preclude theory of mind. *Neurocase* 7: 489–93.
Vygotsky, L. (1961). *Thought and Language*. Cambridge, MA: MIT Press. (First published in Russian in 1934; republished and translated, with portions that were omitted from the first English translation restored, in 1986 by MIT Press.)
———. (1971). *The Psychology of Art*. Cambridge, MA: MIT Press.
———. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.
Watson, J. (1924). *Behaviorism*. New York: Norton.
Wertsch, J. (ed.) (1981). *The Concept of Activity in Soviet Psychology*. Armonk, NY: Sharpe.
———. (ed.) (1985). *Culture, Communication, and Cognition*. Cambridge: Cambridge University Press.
Whorf, B. (1956). *Language, Thought, and Reality.* London: Wiley.
Wolpert, D., and Flanagan, R. (2001). Motor prediction. *Current Biology* 11: 729–32.
Wolpert, D., and Ghahramani, Z. (2000). Computational principles of movement neuroscience. *Nature Neuroscience* 3: 1212–17.
Wolpert, D., Doya, K., and Kawato, M. (2003). A unifying computational framework for motor control and social interaction. *Philosophical Transactions of the Royal Society of London*, B 358.
Wynn, K. (1992a). Children's acquisition of the number words and the counting system. *Cognitive Psychology* 24: 220–51.
———.(1992b). Evidence against empiricist accounts of the origins of numerical knowledge. *Mind and Language* 7: 315–32.
Xu, F. (2002). The role of language in acquiring object kind concepts in infancy. *Cognition* 85: 223–50.
Xu, F., Cote, M., and Baker, A. (2005). Labeling guides object individuation in 12 month old infants. *Psychological Science* 16: 372–77.
Xu, F., and Spelke, E. (2000). Large number discrimination in 6-month-old infants. *Cognition* 74: B1–B11.