Avril Kenney
12/4/08

9.56
Final Paper

Language and Thought: Consolidating Information

Introduction

Natural language is an incredible ability allowing humans to express complex and abstract ideas in an efficient and versatile manner. Using language, we can effortlessly convey entirely novel information, with the assurance that the meaning taken from it will be almost exactly the same as the original meaning encoded at the source. A finite number of rules can be applied to a finite number of morphemes to generate an infinite number of sentences capable of representing many of the propositions we can conceive of. These special properties make language an ideal tool not only for communication between people but also for cognition within individuals.

How language is related to other cognitive processes is an open question, one that is the subject of much recent debate. There is a wide spectrum of possibilities and so far none has emerged as obviously correct. One major issue with this area of study is that it is often unclear what is meant by "language." Although individual researchers perhaps know their own definitions, it is difficult to combine all of their findings because each tends to focus on a single aspect of language and treat it as the primary relevant one. This paper will attempt to summarize some of the research on the topic of "language and thought," discuss the overlaps and discrepancies among the different results, and propose directions for future study to help unify the question and work toward a clearer understanding of what language is.

Humans are the only animals with anything even close to what we call language, but unfortunately for the topic under examination here, humans also possess numerous other abilities far beyond any other organisms, making it impossible to find minimal pairs for comparison. No other species that we know of can carry out the convoluted cognitive manipulations that we perform regularly, and so we cannot determine whether their lack of mental capacity is related to their lack of language or only a co-occurrence. In order to investigate human language and human-level thought, cognitive scientists have had to find strategies for looking at differences among people.

Research on the relationship between language and thought can be roughly divided into three categories, each addressing a somewhat different aspect of the problem. First, there is the question of what purpose language serves during the process of conscious reasoning. Second, there is the question of how acquiring linguistic representations for particular concepts influences people's overall thinking about those concepts. Third, there is the question of how grammatical structures from language can enable or promote reasoning that uses parallel but nonlinguistic constructs. Although these are three quite different directions of approaching the topic, they all provide information that will ultimately be important in determining an answer.

Language in Conscious Reasoning

Probably the most familiar arena in which language plays a role, other than communication, is conscious mental processes. Language is a convenient format for encoding thoughts so that their content is straightforward, memorable, and relatively unambiguous. It is so ubiquitous, in fact, that many people take for granted that their thoughts occur in language, with all of their subconscious functions simply packaging their results into the grammar and vocabulary of the person's native language before sending them to consciousness. This is not to say that *all* conscious thought takes place in language – there are obviously some thoughts expressed in terms of other modalities, such as the senses – but those thoughts which have a linguistic form feel subjectively different, and it is difficult to imagine how certain ideas could possibly be expressed by any other means.

Thinking in language undoubtedly does provide some advantage, otherwise we would not do it so automatically and so often. It would be unreasonable to create a linguistic version of every thought solely on the off chance that it would at some point need to be communicated. Converting thoughts into language gives them concrete representations, made up of naturally discretizable pieces to which other elements can be added, deleted, moved, or changed. As Clark (1998) puts it,

> By 'freezing' our own thoughts in the memorable, context-resistant and modality-transcending format of a sentence we thus create a special kind of mental object – an object which is apt for scrutiny from multiple different cognitive angles, which is not doomed to alter or change every time we are exposed to new inputs or information. (p. 178)

Linguistic thoughts are therefore in a way more neutral, more objective, than other forms. Instead of relying on nebulous concepts that have to keep track of many different attributes at once, we introduce this layer of abstraction, using a complete symbolic code to capture each idea and hold it stable. Ideas involving multiple characteristics and complicated relationships can be concisely represented in the pre-made structures of words and grammar, making them simple to store and retrieve, as well as versatile to manipulate.

Because of its serving this function so well, language has been argued by some to be *necessary* for representing some types of ideas. Without language, it could be that people are simply incapable of formulating certain concepts or performing certain types of reasoning. Individuals with aphasia, an acquired selective impairment of language, provide a unique opportunity to test this hypothesis, since they have acquired language normally and been able to use it for whatever initial concept-formation purposes it has in development, but they are now unable to form linguistic structures properly or at all.

Kertesz (1988) analyzed the performance of aphasics on nonverbal tasks, particularly

Raven's colored progressive matrices (RCPM), a test in which subjects are shown a visual pattern and required to choose the missing element from among several options. He reports that global aphasics, who have severely impaired language abilities, do perform worse than control subjects; relative to patients with right-hemisphere damage and no language impairment, their scores are not significantly worse, but their reasoning is qualitatively different. In some milder forms of aphasia, however, performance on RCPM is at a typical level. Across subjects, nonverbal scores were correlated with ability for language comprehension but not production. These results support the fact that people do create linguistic representations when reasoning about complex problems and have difficulty when unable to do so, but they are not evidence that it is necessarily impossible to solve such problems without language.

One hypothesis for the role of language is that it is the only format in which conscious propositional or conceptual thought occurs (Carruthers 2002). Under his view, people without language can still use visuospatial imagery and other nonlinguistic methods for conscious thinking, but they cannot combine information from separate cognitive modules because such concepts have no single mode of presenting themselves. This opinion is challenged by results from Varley (1998), in which a global aphasic subject passed tests that supposedly require propositional reasoning, despite the fact that he was barely able to produce multi-word utterances and performed at chance on grammaticality judgments. However, the two tasks used were tests of theory of mind (unexpected contents) and causality inference, and it is possible that these could be done without propositional thought.

Another area in which language has been thought to be used is processing numbers and symbolic mathematical expressions. This involves manipulation of symbols for concepts with no innately present representation, and it requires the use of recursion, a feature central to natural language. Varley et al. (2005) investigated three severely aphasic men and found that their mathematical abilities were highly dissociated from the corresponding verbal abilities. All three subjects had poor receptive grammar and could not produce much more than nouns and short phrases. These aphasics successfully carried out tasks including arithmetic operations (some requiring understanding of reversibility), analysis of bracket expressions, and recursive generation of numbers. Their performance shows that conscious numerical reasoning can proceed without using the corresponding grammatical constructions.

The difficulty with studies on aphasics is that aphasia results from accidental injury or stroke, not controlled brain lesions, so the nature of impairment can only be determined through administering tests and to a lesser extent through imaging the brain. Although there are patterns of symptoms, they vary widely and do not necessarily result from the same underlying causes in each case. It is still unclear whether aphasics have an intact representational system and have trouble translating it to and from language, whether such a system existed but is damaged, or whether one never existed in the first place and language is the only problem. To avoid this issue, neurotypical subjects can be used but prevented from using language. Researchers can take advantage of the fact that people cannot perform multiple linguistic tasks simultaneously, so if a person is engaged in verbal shadowing, he will not be able to use language in performing another task. This technique has been used to separate out the effects of language on a variety of tasks in which it is believed to be implicated.

False-belief theory of mind reasoning is often considered to be linked with language, perhaps requiring the representation of untrue propositions embedded within sentences. Newton and de Villiers (2007) tested normal adults on a video task of belief reasoning, which did not explicitly have any linguistic components, and compared a verbal-shadowing with a rhythmic-shadowing condition. Subjects in both conditions passed a true-belief task, but subjects who did verbal shadowing performed at chance on a false-belief task, while those doing rhythmic shadowing almost always passed. These results demonstrate that although people can successfully reason about complex events without verbalizing (as shown in the true-belief version), they do not have an automatic way to represent false beliefs nonlinguistically.

A study by Hermer-Vazquez et al. (1999) suggests that language is used for combining information across modalities that do not have an inbuilt method for interacting. The specific example they describe consists of using geometric and nongeometric visuospatial cues to remember a location. When an object is hidden in one corner of a rectangular room, rats and young children can only use geometric information to reorient and locate it after being disoriented, searching with equal probability in either of the two geometrically appropriate corners, despite the presence of other cues such as scents or colors (for example, the object might be "to the left of the blue wall"). Adults normally are able to incorporate this additional information to locate the object, but when they are engaged in verbal shadowing, their behavior is the same as the rats'. Importantly, when the geometric aspect is removed and only color information is present they can again locate the object, indicating that each aspect can be encoded separately but language is used for putting them together. In children, success in the reorientation was compared to several measures of verbal and nonverbal ability and was found to correlate only with production of the words "left" and "right." It is therefore likely that in this task people are encoding perceptual information in language to aid in cross-domain representations. Spelke (2001) proposes that the same phenomenon occurs in numerical reasoning, with language being used to combine features of a precise small-number sense and an approximate large-number sense.

Frank et al. (2008) conducted a study in which people had to match an exact number of objects in tasks of varying difficulty, with the easiest consisting of a one-to-one match of items evenly spaced in a line, and the hardest requiring subjects to watch items being dropped into an opaque container and then reproduce the number. In the difficult ("nuts-in-a-can") task, typical adults would be able to keep track of the objects by counting them, but when they had to perform verbal shadowing, they could only approximate the value. In the easy task, there is no need to ever represent the overall cardinality of the set, so even with shadowing people were almost always correct. The performance of these English-speaking subjects during verbal shadowing was similar to that of people from the Amazonian Pirahã tribe, which does not have words for exact quantities. This suggests that when exact numbers must be remembered, language is the method used for representing them.

These findings all provide convincing evidence that people deprived of language use do not perform certain cognitive processes, but it remains unclear what is the similarity among these particular tasks, or whether there even exists a single unifying theme. It is apparent that creating linguistic representations can be very helpful and is the default mechanism for solving some problems. The question of whether language is the only possible form for any of these concepts is yet to be answered.

Language for Creating and Storing Concepts

A less obvious and more controversial effect of language is in the creation of specific concepts. To a certain extent people view the world in a standard way guided by biology, segmenting it into units of space or time and categorizing things based on properties or relationships. But in fact these processes can be influenced by what is encoded in the language a person learns. Some concepts do not have an innate, universal representation, and there is evidence that representations are actually created and modified by language.

Lucy and Shweder (1979) report some of the findings regarding linguistic effects on color memory and discriminability, a topic receiving much attention in the linguistic relativity debate.

When subjects were required to commit color chips to memory and then to identify them from among multiple options after a short interval of time, they performed better for colors that were easier to encode in their language. A more recent study by Winawer et al. (2007) tested speakers of Russian and of English on color-matching with varying shades of blue, for which Russian uses two separate words and English uses only one. They found that Russian speakers had faster reaction times than English speakers in discriminating between two samples that were instances of different color words, but that this effect disappeared when the subjects were engaged in verbal interference. Linguistic color boundaries are therefore probably not extended to nonlinguistic concepts. However, this does not mean that language terms can never interact with other representations.

In many languages nouns have an attribute called gender, which may or may not correspond to the human categories of male and female, but in any case can be assumed to be generally arbitrary because the same words often have opposite genders in different languages. Boroditsky et al. (2003) describe multiple results indicating that people tend to think of grammatically masculine and feminine concepts as respectively male and female, and they are not always consciously aware of this distinction. A particularly striking result is that speakers of Spanish and German rated pictures of objects as more similar to pictures of people when the genders matched in their language, even though the pictures were unlabeled, the words had opposite genders in the two languages, the testing was in English, and the subjects were engaged in verbal shadowing while making the judgments. The authors of the study suggest that learning grammatical gender makes similar characteristics of a concept more salient, which would be consistent with the fact that people tend to judge things that are alike on one dimension as being alike on independent dimensions. The important observation here is that arbitrary features of linguistic terms are in some manner being incorporated into people's overall conceptual representations.

The influence of language on salience of certain aspects over others can also be seen in categorization of spatial relationships. Prelinguistic infants are known to have a detailed understanding of physical laws and properties, demonstrating that people are innately able to reason about space, but even from a young age children make distinctions based on the language they have learned. Bowerman and Choi (2001) used a preferential-looking paradigm to test 18- to 23-month-old speakers of English and of Korean, which have different divisions in lexicalizing how objects touch or fit together, in their understanding of these words in their native language. Even though most of the children were not yet producing the words, they showed a strong preference to look at depictions of the relationship that corresponded with the sentence they heard spoken, indicating that they have the ability to comprehend the abstract relations encoded by linguistic terms that do not correspond to innate concepts.

Another study by McDonough et al. (2003) tested 9- to 14-month-olds as well as adults, in both English and Korean, with preferential-looking but without linguistic cues. After being habituated to seeing objects fit together in one way, subjects were shown two simultaneous scenes involving novel objects, one with the same type of fit and the other with a different type. English has no lexical distinction between the two, calling them both “in,” whereas Korean distinguishes based on whether the fit is tight or loose. In this task the Korean-speakers and the infants of both languages showed significant differences in looking time between the familiar and the different types of fit, but English-speakers did not. English speakers presumably had become less aware of the difference because it is not relevant in their language.

The idea that linguistic features give people a tendency to think in certain ways is supported by Bloom (1984), who contends that the presence of

> linguistic labels, lexical or grammatical, ... acts to trigger in the mind of the hearer

> or reader the specific cognitive schemas associated with those labels, thereby ... establishing specific direction to further thought processing. (p. 275)

He showed stories involving counterfactual conditionals to speakers of Chinese and of English, in their respective languages, and found that in English the subjects correctly interpreted the counterfactual parts as untrue, while in Chinese they almost always interpreted them as true. Bloom's methods in this experiment were highly disputed, but a later study by Yeh and Gentner (2005) used new stories and found similar results, though less extreme. Their Chinese and English participants responded with equal accuracy for stories in which the truth-value of the statement could be determined based on general knowledge, but Chinese performed worse when the judgments required using contextual information, presumably because of the absence of an explicit grammatical indication. Slobin (1996) reports that even the speech of young children correctly encodes different aspects based on what language they speak, and he suggests that speakers' selective attention to features marked in their language is due to "thinking for speaking," a subjective way of viewing the world that is acquired together with the language.

It is perhaps not as surprising as would be expected that language has some impact on our mentally stored concepts – from a learning perspective, all knowledge could potentially be useful, so it makes sense that concepts should incorporate any new information regardless of the source. The intriguing question highlighted by these results together with the previous section is in what form our underlying mental representations actually exist. None of the examples so far shows whether language can create concepts that could not potentially exist otherwise.

Language as a Scaffold for Reasoning

The most debatable of the claims about language and thought is that acquiring language gives people the skills necessary for other, nonverbal types of reasoning. Since the structure of language provides a format for representing certain relationships, perhaps people can learn about the existence of such relationships through language and then use them in other modalities. Many of the studies relevant to this question are examining reasoning in people with impaired language or lacking the ability to form certain grammatical constructions, and therefore do not completely distinguish between having acquired domain-general concepts versus using language explicitly during thinking. However, they can still provide evidence pointing in one direction or the other, and lead to further investigations of the question.

Specific language impairment (SLI) is a developmental language disorder that is somewhat difficult to characterize but seems to selectively impair language, both production and comprehension. A case study of one boy with SLI, called AZ, is described by van der Lely et al. (1998), who report that his nonverbal intelligence is in the normal range despite severe grammatical difficulties. AZ performed poorly on standardized language tests; he was unable to understand constructions such as reversible passives or pronoun reference, he made errors in forming wh-questions and tensed verbs, and he rarely produced any embedded phrases. In non-grammatical language tasks, involving pragmatic or logical inferences, he performed normally. His nonverbal IQ scores were in fact above the average for his age, some significantly higher. He also performed at or above the level of age-matched controls on a task requiring him to judge the relative sizes of bars displayed on a screen, as well as on measures of complexity and speed of information processing. In all the tests administered, there was no evidence that AZ's grammar deficits had effects on any other cognitive processes, implying that his reasoning abilities did not depend on a complete grammar to develop.

De Villiers and Pyers (1997, 2002) propose that it is necessary to understand the grammar of sentence complements before acquiring the ability to reason about false beliefs. In a longitudinal study, they compared preschoolers' understanding and usage of complements to their performance on false-belief tests. The false-belief scores were significantly predicted by the measures of complements, and not by any other linguistic factors. Additionally, complement scores in one round of testing predicted false-belief scores in the following round, but not vice-versa, suggesting that the grammar does indeed come first and the two are not simply both the result of the same developmental change.

To separate out the effects of biological development from the process of language acquisition, Morgan and Kegl (2006) gave theory of mind tests to deaf signers of Nicaraguan Sign Language (Idioma de Señas de Nicaragua, or ISN) who had acquired the language at varying ages. All of them had normal scores on nonverbal intelligence tests such as Raven's Matrices and were judged to have the fluency levels expected given their age of acquisition and length of exposure. Subjects whose initial exposure to ISN had occurred prior to the age of ten years performed significantly better on a false-belief task than those who had not been exposed to the language until later ages. In an elicited narrative task, both groups mentioned approximately the same number of mental-state concepts, but the late learners produced significantly fewer propositions involving false beliefs. The posited explanation is that theory of mind has a critical period and develops in tandem with language, so people who do not learn language from a young age will have impaired acquisition of complex features like false belief.

In addition to directly encoding representations, grammar could also plausibly be used in the construction of parallel concepts; one of these, as described earlier, is exact number, which is similar to language in its use of recursion. Grinstead et al. (1998) provide a convincing argument against this hypothesis, based on the numerical abilities of people who are mostly or completely without language. A subject named Chelsea, who was born deaf and did not begin acquiring language until she was over 30 years old, had virtually no syntactic ability, yet she understood and produced number words in various contexts, and she was able to perform arithmetic at the level of a typical adult. Another deaf subject, named Ildefonso, was taught number symbols without ever learning language, and within a few minutes understood addition and subtraction as well as two-digit numerals. In a group of languageless deaf men, numerical representations were created without having to be introduced by someone who had learned them linguistically. These instances clearly show that language is not a prerequisite for numerical cognition.

The results summarized in this section provide evidence for and against the idea of language as a constructor of reasoning methods. They have compared both specific and general grammatical abilities to different aspects of thinking, with some findings very straightforward and others more difficult to interpret. In order to discover the details of what influence language truly has, future studies will have to single out specific areas to test and carefully control for all other factors.

Discussion

All of the research so far on the topic of language and thought has certainly returned useful data, but overall there seems to be a lack of connection. Of course, it would not be expected that everyone in the field should be working on the exact same experiments, and it is important for the question to be approached from different directions. The problem is that there does not appear to be a single question trying to be answered. Each paper could be claimed to be relevant to the question of "how language influences thought," but without any definitions this phrase has little meaning and provides no guidance as to how we can combine even everything that has already been learned. Though the individual results are undoubtedly interesting in their own right, ultimately we should be trying to reach a complete understanding of something, and this goal would be facilitated by having a clear formulation of what that something is.

Admittedly, the topic under consideration has good reason for being underspecified, for in a way it references what it seeks to evaluate. By asking about language and thought, we assume that the concepts of "language" and "thought" exist distinctly as more than just terms we have created – an assumption whose justification, given the empirical evidence, is not at all certain. When narrower definitions are applied, more definite answers can be reached, but then they are less relatable to anything that uses alternate definitions. It is entirely possible that what is currently viewed as figuring out the relationship between language and thought is really multiple disjoint problems in psychology and cannot be solved as a unit apart from the rest of cognition, but right now we do not even know *whether* that is the case. What we can start by doing is looking for approximately what is included in the term "language."

Biologically, humans possess some sort of language faculty, which gives us the *ability* to learn and use natural language. After a certain critical period at the beginning of one's life, it is impossible to acquire native fluency in a first language, indicating that some part of this mental faculty has become disabled. Language could therefore be defined as the set of capabilities enabled by the language faculty, or specifically everything to which the critical period applies, since that is the aspect that can be observed. In that case, people such as Chelsea demonstrate that language includes syntax but does not include recursion or words. It would be somewhat odd to consider a definition of language that does not include words, but it does bring up the important point that grammar is largely separate, as shown in the case of AZ and other children with SLI. Learning words and arbitrary referential symbols such as numbers is not subject to a critical period, at least not in the way that grammar is, and it can occur independently of learning any syntax.

An unfortunate property of acquisition is that people cannot acquire language without acquiring *a* language. Either a particular language is instantiated during the critical period, or the capacity disappears. Even if grammar is the only part that must be acquired by a preset time, there will always be a lexicon along with it, and it can only be learned from exposure in context, which makes it impossible to distinguish between effects of knowing the grammar and effects of having understood the content of what was said using that grammar. For the hypothesis that only initial acquisition of grammatical constructions is necessary for the creation of other abilities, studies on aphasics could arguably be relevant, but an understanding of exactly what is impaired in aphasia relies on the same unanswered questions.

One of the problems repeatedly hinted at in much of the research described earlier regards what form mental representations take. In aphasics, we cannot tell whether the language impairment is only in production and comprehension (possibly both internal and external) or whether it has an impact on some underlying representational structures. From introspection it appears that we have concepts stored, sometimes in multiple formats, and connections between them. Many of these concepts are represented nonlinguistically, as seen in the examples of languageless deaf people with numbers and of prelinguistic infants with space. The studies in which objects were attributed traits associated with the syntactic gender of their words indicate that mental concepts can have characteristics added to them as a result of language, but maybe these characteristics could be added just as easily from other sources. What is unclear is whether linguistic symbols (that is, words) are the only format in which some concepts exist.

This question can be better seen by looking at the specific example of numbers. There are infinitely many numbers that can be specified verbally, and any one of them would be interpretable even if a person had never heard it before, because he can decode the symbols. Even when numbers have individual words (for example, “eight” as opposed to “one hundred sixty-eight”) they cannot be perfectly matched during verbal shadowing, suggesting that they too have to be decoded into exact numerosities and are not stored directly. Since concepts like “eight” are used frequently, it is reasonable to assume that our mental representations would be exact if they could, so it is probable that we are incapable of creating that type of concept. While we do have a clear understanding of what "eight" means, and we know facts about it, any manipulations requiring the exact number will require a rederivation.

The same idea could apply to all the tasks which people fail during verbal shadowing: if certain concepts must be rebuilt at every occurrence, they cannot be drawn straight from an underlying form, so there has to be some format available for creating a representation to work with in the conscious reasoning process. This could be true of both words and structured sentences, and in fact does not have to be specific to language, it just happens that language is a format capable of converting relevant information into usable symbols. When we have no inbuilt method for storing a particular concept, the linguistic representation functions as a set of pointers to all the components necessary to generate it. This explanation would be consistent with the observation that people notice attributes better that are explicitly presented in their language.

Conclusion

From looking at the present evidence and the above discussion, we can now state a few questions that should be important to future study on language and thought. First, what is the relationship between language and the language faculty, and does the language faculty play a role in reasoning even when no language is acquired during the critical period? Second, what is the relationship between grammar and vocabulary, and how separable are they? Third, are there any cognitive functions performed by natural human language that cannot be performed by any other symbolic system? These questions are perhaps just as unanswerable as the original one of how does language influence thought, but at least they provide slightly more focused directions for research, and any results would be a step toward combining what has been found so far.

Significant progress has been made in figuring out what language does other than communication, and new results are constantly appearing. The many studies reported in this paper are only a small sample of what has been accomplished. Even from the relatively scattered results presented here, we have begun to assemble a more complete picture of the state of the field. Some concepts can be learned without acquiring a language and others appear to be reliant on it. Features labeled in one's language tend to become more salient in the world, in linguistic and sometimes nonlinguistic contexts. Language in the same form as for speaking can be used for conscious thinking and to create abstract symbolic representations that do not correspond to any innate concepts. All of these conclusions, together with new directions for research, predict a promising future for the study of language and thought.

References

Bloom, A. (1984). Caution – the words you use may affect what you say: A response to Au. *Cognition* 17(3), 275-287.

Boroditsky, L., Schmidt, L., Phillips, W. (2003). Sex, Syntax, and Semantics. In D. Gentner and S. Goldin-Meadow (eds.) *Language in Mind: Advances in the study of Language and Cognition*, 61-79.

Boucher, J. (1998). The pre-requisites for language acquisition: evidence from cases of anomalous language development. In P. Carruthers and J. Boucher (eds.) *Language and Thought: Interdisciplinary Themes*. Cambridge University Press, 55-75.

Bowerman, M., Choi, S. (2001). Shaping meanings for language: universal and language-specific in the acquisition of spatial semantic categories. In M. Bowerman and S.C. Levinson (eds.) *Language acquisition and conceptual development*. Cambridge University Press, 475-511.

Carruthers, P. (2002). The cognitive functions of language. *Behavioral and Brain Sciences* 25, 657-726.

Clark, A. (1998). Magic Words: How Language Augments Human Computation. In P. Carruthers and J. Boucher (eds.) *Language and Thought: Interdisciplinary Themes*. Cambridge University Press, 162-183.

de Villiers, J., Pyers, J. (1997). Complementing Cognition: The Relationship between Language and Theory of Mind. In E. Hughes et al. (eds.) *BUCLD 21 Proceedings*, 136-147.

de Villiers, J., Pyers, J. (2002). Complements to cognition: a longitudinal study of the relationship between complex syntax and false-belief-understanding. *Cognitive Development* 17, 1037-1060.

Frank, M.C., Fedorenko, E., Gibson, E. (2008). Language as a cognitive technology: English-speakers match like Pirahã when you don't let them count. *Proceedings of the 30th Annual Meeting of the Cognitive Science Society.*

Grinstead, J., MacSwan, J., Curtiss, S., Gelman, R. (1998). The independence of language and number. Paper presented at the Twenty-Second Boston University Conference on Language Development.

Hauser, M.D., Chomsky, N., Fitch, W.T. (2002). The Faculty of Language: What Is It, Who Has It, and How Did It Evolve? *Science* 298, 1569-1579.

Hermer-Vazquez, L., Spelke, E.S., Katsnelson, A.S. (1999). Sources of Flexibility in Human Cognition: Dual-Task Studies of Space and Language. *Cognitive Psychology* 39, 3-36.

Kertesz, A. (1988). Cognitive Function in Severe Aphasia. In L. Weiskrantz (ed.) *Thought Without Language*. Clarendon Press, 451-463.

Lucy, J. (1992). *Language diversity and thought: A reformulation of the linguistic relativity hypothesis*. Cambridge University Press: Cambridge, England, 208-256.

Lucy, J.A., Shweder, R.A. (1979). Whorf and His Critics: Linguistic and Nonlinguistic Influences on Color Memory. *American Anthropologist*, New Series, 81(3), 581-615.
McDonough, L., Choi, S., Mandler, J.M. (2003). Understanding spatial relations: Flexible infants, lexical adults. *Cognitive Psychology* 46(3), 229-259.
Morgan, G., Kegl, J. (2006). Nicaraguan Sign Language and Theory of Mind: the issue of critical periods and abilities. *Journal of Child Psychology and Psychiatry* 47(8), 811-819.
Newton, A.M, de Villiers, J.G. (2007). Thinking While Talking: Adults Fail Nonverbal False-Belief Reasoning. *Psychological Science* 18(7), 574-579.
Fodor, J. (1980). Fixation of Belief and Concept Acquisition. In J. Piaget, M. Piattelli-Palmarini, N. Chomsky (eds.) *Language and Learning: The Debate Between Jean Piaget and Noam Chomsky*. Routledge, 143-149.
Siegal, M., Varley, R., Want, S.C. (2001). Mind over grammar: reasoning in aphasia and development. *Trends in Cognitive Science* 5(7), 296-301.
Slobin, D. I (1996). From "thought and language" to "thinking for speaking." In J.J. Gumperz and S.C. Levinson (eds.) *Rethinking linguistic relativity: Studies in the social and cultural foundations of language* 17, 70-96.
Spelke, E.S. (2003). What Makes Us Smart? Core Knowledge and Natural Language. In D. Gentner and S. Goldin-Meadow (eds.) *Language in Mind: Advances in the Study of Language and Thought*. MIT Press, 277-311.
Spelke, E.S., Tsivkin, S. (2001). Initial knowledge and conceptual change: space and number. In M. Bowerman and S.C. Levinson (eds.) *Language acquisition and conceptual development*. Cambridge University Press, 70-97.
van der Lely, H.K.J., Rosen, S., McClelland, A. (1998). Evidence for a grammar-specific deficit in children. *Current Biology* 8, 1253-1258.
Varley, R. (1998). Aphasic language, aphasic thought: an investigation of propositional thinking in an a-propositional aphasic. In P. Carruthers and J. Boucher (eds.) *Language and Thought: Interdisciplinary Themes*. Cambridge University Press, 128-145.
Varley, R.A., Klessinger, N.J.C., Romanowski, C.A.J., Siegal, M. (2005). Agrammatic but numerate. *PNAS* 102(9), 3519-3524.
Winawer, J., Witthoft, N., Frank, M.C., Wu, L., Wade, A.R., Boroditsky, L. (2007). Russian blues reveal effects of language on color discrimination. *PNAS* 104(19), 7780-7785.
Yeh, D., Gentner, D. (2005). Reasoning Counterfactually in Chinese: Picking up the Pieces. Proceedings of the Twenty-seventh Annual Meeting of the Cognitive Sciences Society, 2410-2415.