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Foundations of Linguistic Theory
Spring 2015
June 13, 2016

Language, Perception, and Thought:
What can Neo-Whorfianism teach us about cognition?

1 Introduction

The connection between language and cognition ultimately lies at the heart of any research into the human linguistic capacity. Investigation of this relationship comes in a variety of guises and ranges widely in scope and complexity across the different branches of modern linguistic theory, but one of the oldest and most pressing questions can be stated quite simply: what, if anything, do the properties of human language tell us about the nature of human cognition? Does language simply encode the structure of our thought (cf Fodor 1976)? That is, do the shared design features of human languages reflect essential facts about how we perceive and categorize experience? Or does the relationship between language and thought proceed in the opposite direction: in the words of Whorf (1956), do we "dissect nature along the lines laid down by our native language"? While strong versions of Whorf's *linguistic relativism* have largely been discredited, due at least in part to concerns about the nature and quality of his evidence,[1] the opposing thesis—that there is a disconnect between linguistic differences[2] and cultural ones—has not been fully embraced either (see, e.g. Lakoff 1987). To a certain degree, this is because neither extreme seems quite right at the intuitive level: morever, since language is one of the few points of access afforded to us for investigating questions about human reasoning and cognition, the idea that linguistic diversity opens up an avenue for probing the structure and limits of thought is a difficult one to simply set aside.

In the last few decades, data from languages that appear to conceptualize certain abstract or perceptual categories in an atypical fashion—from the point of view of an English-speaker—has revived interest in linguistic relativism. Languages that appear to lack terms for exact numerals (Gordon 2004, Pica, et al 2004, Everett 2005, Butterworth, et al 2008) form one epicenter of this debate, alongside languages that reportedly make use primarily of geocentric instead of egocentric coordinate systems for encoding spatial relationships (Haviland 1998, Pederson et al 1998, Levinson 2003).[3] Insofar as these "atypical" languages represent and categorize what seem to be central cognitive systems in ways that diverge strikingly from the systems that operate in the most-studied languages, they promise to provide a fertile ground for investigating the direction of influence between language and cognition. The sides in the modern debate over relativism can be cast broadly into three camps. At one extreme is the strong Neo-Whorfian claim that (native) languages exert influence over the cognitive capacities of their speakers, to the point of restructuring, shaping, and even limiting these capacities (Davidoff et al 1999, Levinson 2003, Gordon 2004, and others). At the other end of the spectrum, there are researchers who maintain that there is no causal relationship to be found between linguistic diversity and patterns of thought: that is, who hold that language "cannot extend the range of nonverbal cognitive abilities"

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1   See, for example, Malotki (1983) on temporal expression in the Hopi language.
2   Differences, that is, at the level of language structure and conceptual encoding, not in the sense of dialectal or register variation.
3   Languages such as Balinese (Levinson 2003) and Guugu Yimithirr (Haviland 1998), among others, seem to systematically prefer vocabulary for cardinal direction (*north, south, uphill downhill,* etc) where speakers of English (and the majority of other "western" languages) would typically make use of speaker-oriented terms such as *left, right, behind*, and so on.

(Fodor 1976), and accordingly also cannot limit them (see also Pinker 1994, Li and Gleitman 2002). Others suggest a more measured view—that the languages we acquire natively exert influence over us not by constraining the way in which we think, but rather by enforcing (or reinforcing) certain habits, preferences, and attentional facts (cf. Deutscher 2010). In this paper, I build on Frank et al's (2008) suggestion that numerical vocabulary represents a "cognitive technology" which the speakers of numerically-rich languages utilize to represent abstractions which are difficult to retain and manipulate prelinguistically. I propose a stronger (and more Vygotskian[4]) view: while the cognitive systems that form the basis of human perception (for instance, time and space in the sense of Kant) can never be fundamentally altered or limited by the conceptual structure of a speaker's native language, human cognition also contains the ability to build more complex systems of reasoning from the basic modules with which we are endowed. These increasingly abstract and complex systems—numerical reasoning, cross-modular reasoning (see section 4), and perhaps even reasoning about the knowledge and actions of others (Clark 1998, Hermer-Vazquez et al 1999, Frank et al 2008, Pyers and Senghas 2009)—can be, and in fact are, "bootstrapped" by language. In areas of higher level reason and abstraction, language (writ large) acts as a tool for recording and tracking abstractions which can then be manipulated in complex ways that are difficult or impossible to approach without use of a placeholder.

2 Colour and space: support for linguistic relativism?

Proponents of modern linguistic relativism often point to results in the areas of colour perception and (non-verbal) spatial reasoning as demonstrative of the influence that language has on thought. In this section, I examine these arguments, and suggest that the relevant experimental data is, in fact, a reflection of the influence of language on memory and (communication-oriented) post-processing of perception; in particular, the observed effects represent the influence of language on language (or lingustically-driven behavior), rather than the influence of language on cognition or perception *a priori.*

2.1 Colour perception

At least since Gladstone (1858), it has been noted that languages and cultures vary in their linguistic choices with respect to partitioning the spectrum of observable colour. Gladstone's observations concern the range and use of colour terminology in Homer: he points out a striking lack of diversity and (what he described as) consistency in representations of colour. Berlin and Kay's (1969) prominent study of language and colour takes this to be reflective of the fact that increased granularity in linguistic classification of colour follows a specific, predictable pattern of "evolutionary" development (see also Deutscher 2010). On this view, Homer's paucity of colour terms does not represent a gap in his (or the Homeric Greeks') ability to perceive colour (as per Gladstone's original thesis), but rather results only from the fact that Homeric Greek was at an earlier, or coarser-grained, stage of linguistic colour differentiation than is, e.g., modern English. In advancing this theory, Berlin and Kay draw on evidence from the existence of (arguably less technologically advanced) modern cultures whose partitioning of the spectrum contains relatively few divisions; taken together with evidence from the historical record (such as Gladstone's), study of these systems seems to suggest a common historical pattern wherein the existence of any colour terminology assures the existence of terms for black (dark) and white (light), and increasing diversity proceeds from there to the addition of red, then the addition of green and/or yellow, then blue, and so on, in a more or less predictable order.[5]

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4 Vygotsky (1934): "...the relation of thought to word is not a thing but a process, a continual movement back and forth from thought to word and word to thought..."

5 Relevant languages include Bassa (Liberia; Gleason 1955), Bambara (Congo; Zahan 1951), Navajo (Na-Dené; Landar et

The universalist view, however, comes under fire from relativists (in part) on the basis of experimental evidence which suggests that differences in where languages place boundaries within the colour spectrum apparently correspond to differences in speakers' ability to perceive and discriminate between the relevant colours. One such study, from Davidoff, et al (1999), compares colour discrimination in speakers of Berinmo (a language of Papua New Guinea) to colour discrimination in speakers of English. Berinmo, crucially, has a colour boundary—between the terms *nol* and *wor*—in the blue-green range at a wavelength which is contained wholly within English *green*.[6] Davidoff, et al showed Berinmo and English participants a sample of a particular colour, and, after a brief pause, asked them to identify the original shade from a pair of alternatives. Where English speakers were easily able to identify the correct shade from two alternatives on different sides of the *blue-green* boundary, Berinmo speakers struggled with this task just in those cases where both alternatives belonged to the *nol* region of the spectrum. The reverse pattern was also found: English speakers performed poorly when asked to differentiate between shades of green separated by the *nol-wor* boundary, but Berinmo speakers did not. In both cases, the difficulties experienced were found to be subject to distance from the relevant category boundary, rather than absolute differences in wavelength, etc.[7]

These results support a strong version of linguistic relativism insofar as they seem to suggest that the perceptual abilities of speakers of different languages are directly impacted by the colour categories extant in their native languages. In particular, the claim made by Davidoff, et al (as well as by Levinson 2000 and others) is that acquisition of a language which lacks certain colour distinctions present in other languages actually limits a speaker's ability to perceive the distinction in question (although they may be perceptively privileged in another area of the spectrum). If language, on the other hand, cannot influence our cognitive and perceptual capacities, they argue, the results described above should be impossible; speakers of Berinmo and English should not vary on discrimination tasks based on the available terminology in their native languages, but simply on the basis of wavelength, brightness, and so on (see also Bornstein, et al 1976 for data on colour perception in prelinguistic infants). The fact that colour vocabulary can be shown to systematically correspond with perceptual advantages and limitations, then, is taken to show that language is able to restructures perceptual capacities, at least in the domain of colour.

2.2 Spatial reasoning

Similar arguments are made by Levinson and colleagues with respect to the effects that a language's mode of encoding spatial relationships have on spatial reasoning and navigation in its speakers (Levinson and Brown 1993, Pederson, et al 1998, Levinson 2003, Evans and Levinson 2009). Much of this argument centers on apparent differences between speakers of English-like languages—which rely primarily on *relative* or *egocentric* spatial terminology such as *left* and *right* to locate (nearby) objects with respect to the speaker or an extension of the speaker's perspective—and speakers of languages which seem to prefer exclusively *absolute* or *geocentric* coordinate systems, analogous to the cardinal directions *north, south, east,* and *west* (Levinson 1996). The latter class includes the Tseltal language of the Tenejapan Mayans, as well as the Arrernte language Guugu Yimithirr (North Queensland, Australia; Haviland 1998), which uses a set of inflected directional roots that are reported to be in rough correspondence with the English cardinals. Levinson and others note that speakers of such "absolute"

al 1960), and Yélî Dnye (Papua New Guinea; Levinson 2000).

6   Specifically, some of what English-speakers refer to as *green* is captured by *wor* in Berinmo, but Berinmo *nol* covers both English *blue* and some of the range of English *green.*

7   Similar results were reported in 1996 for perceptual discrimination over the blue-green spectrum for speakers of Japanese compared to speakers of English (Uchikawa and Shinoda 1996).

languages appear to maintain constant sensitivity to their spatial orientation; since in a sense this is a precondition for using the spatial grammar of their languages correctly. On the other hand, speakers of relative-coordinate languages seem to find maintaining this degree of sensitivity to direction taxing or impossible. This is the basis on which spatial cognition is claimed to be influenced by the particular frame of reference of a given language.

More concretely, Pederson, et al (1998) compare the spatial reasoning and navigational abilities of Tseltal speakers to those of speakers of Dutch, which uses an English-like relative system (at least over the immediate field). In this study, speakers were presented with toy animals arranged in a row, and then asked to recreate the "same" array from memory under various rotational permutations of the speaker's body. The idea behind this task is that, under 180° rotations, there are two ways of making a display the "same," depending on whether the request is interpreted relatively or absolutely. Pederson, et al found that Tseltal speakers tended strongly to recreate the array of toys in the same absolute arrangement, while Dutch speakers tended to recreate the array identically with respect to their own perspective. Similar results are reported for the same tasks for speakers of Guugu Yimithirr (Levinson 1997), as well as for speakers of an absolute-preferring dialect of Tamil (Dravidian, India) as compared to a relative-preferring dialect of the same language (Pederson 1995), and data from a wider variety of tasks is reported for Tseltal speakers in Levinson, et al (2002). Taken together, these results are used to support the claim that "investigations of their dead-reckoning ability...shows that [speakers of these languages] think the way they speak" (Levinson et al 2002; p.157).

In broad terms, the relativist argument from spatial cognition takes the same form as the argument from colour perception. In particular, if the spatial grammar of a given language constrains the set of coordinate systems which a speaker can use to navigate and reorient nonverbally, then it would seem to be the case that the acquisition of an absolute-preferring or relative-preferring language is able to exert a structuring influence over a central aspect of non-linguistic cognition. However, the evidence from spatial cognition seems to be somewhat less clear-cut than that from colour discrimination, in that it is not clear that there are languages in which relative reckoning systems have no linguistic representation. Haviland (1998) argues—against some of Levinson's claims—that Guugu Yimithirr makes liberal use of both its cardinal roots and a deictic system which can locate objects relative to one another. In addition, although terms for "left" and "right" are not widely used, speakers of Guugu Ymithirr use language associated with parts of their bodies to indicate "facing" orientations, and do distinguish the right from the left hand. Moreover, while it does not seem controversial to grant that speakers of Guugu Yimithirr, Tseltal, and other such languages track their surroundings and orientations as a matter of course with an acuity higher than that of a typical speaker of English, it is not clear that this is an ability which speakers of relative-preferring languages cannot develop. Thus it seems rather difficult to make the case either that speakers of absolute languages are unable to use relative forms of reckoning, let alone that speakers of relative-preferring languages are unable to navigate absolutely. A more likely interpretation of the results from Pederson, et al (1998) and Levinson, et al (2002) seems to be that the spatial grammar of their respective languages privileges certain habits or tendencies in with respect to speakers' spatial reasoning patterns. This may be considered to a certain extent an effect of language on (habits of) thought, but it is far from the strong position that Neo-Whorfian theorists espouse.

2.3 Alternative explanations for the data

In fact, I argue that neither source of evidence demonstrates the reality of linguistic relativism *a la* Levinson and colleagues. Although the experimental results in colour perception and spatial reasoning are real and intriguing, they fail to show the crucial effect that a strong Neo-Whorfian position requires:

that the cognitive effects driven by linguistic representations take hold in cognitive processes that are fully decoupled from on-line language interference. More specifically, insofar as the experiments described above all rely to some extent on a speaker's ability to hold certain information (a colour shade or arrangement of objects) in memory, there is no way to entirely rule out the possibility that the observed effects were driven by participants' tendency to resort to linguistic representations for aid in encoding and retaining the relevant information.

Some evidence that this is indeed the case for colour discrimination tasks comes from Gilbert, et al (2006), which reports on a series of experiments comparing colour perception in the right and left visual fields. Since language and lexical representations are much more strongly associated with the left hemisphere of the brain than with the right, Gilbert. et al predicted that if the perceptual effects were driven by lexical activation of colour terms (rather than a restructuring of the underlying perceptual and/or cognitive processes), they would be in effect more strongly in the right visual field (controlled by the left hemisphere) than in the left. This prediction was borne out: in particular, while reaction and response times were faster in the right visual field for colours with different names and slower and less accurate for colours in the same category, no such effect or systematic difference was found for stimuli presented only in the left visual field. This supports a view on which lexical activation facilitates memory and/or a post-perceptual decision-making process. A second experiment, moreover, showed that taxing participants with an interfering verbal memory task eliminated any statistical difference between performance in the two visual fields. In particular, since the effects of linguistic category vanish when the language capacity is engages by an alternative task, these results suggest that the effects reported by Davidoff, et al and others are due to participants' tendency to record information in a linguistic form in memory, rather than on any restructuring of the underlying cognitive processes brought about by the acquisition of a particular set of linguistic divisions.

The results from spatial reasoning experiments can also be seen to be driven by the overt interference of language. Li and Gleitman (2002) point out that, in the experiments conducted by Pederson, Levinson, and others, participants were given not just a spatial reasoning task to complete but also a simultaneous and related linguistic one. In particular, participants were asked to interpret a request to make the arrangement of toy animals the "same" as the previously-viewed one, and this request was invariably given in the speaker's native language. In addition to any overtly linguistic representations which participants might have relied on for retaining the information about the original arrangement, they were therefore also required to interpret a request containing an ambiguous term. Given the (Gricean) pressure towards cooperativity, Li and Gleitman point out that it is only natural for the participants to interpret this request in the "typical" fashion in which it would be used in their language. That is, while speakers responded to the request to make the arrangement the "same" as if it was unambiguous between an absolute and relative interpretation, this is not a reflection of the fact that that it is essentially unambiguous to them, but rather that they automatically resolve the ambiguity in a manner that the spatial grammar of their native language privileges as (probabilistically) more likely.

This interpretation of the spatial reasoning effects is further supported by a follow-up study from Li, et al (2011), which aims at eliminating ambiguity by modifying the experimental tasks to be goal-oriented. In particular, Li et al proposed that, when participants were presented with a task which required them to use either specifically egocentric or geocentric navigation in order to locate a hidden item, the test of linguistic relativism would be whether absolute language users would perform differentially from relative language users. Relativism would predict, for instance, that Tseltal speakers would be slower and/or less successful on tasks which required exclusively egocentric navigation than on tasks which relied on geocentric encoding. No such effect was demonstrated; moreover, differences in performance between individual Tseltal speakers were not found to correlate systematically with differences in individuals' use, understanding, and competence with the Spanish words for *left* and *right*.

If anything, Li, et al (2011) found that performance on tasks requiring egocentric navigation improved relative to performance on geocentric tasks with increases in task complexity. Not only does this suggest that a speaker-oriented mode of navigation and reckoning is inherent to human spatial reasoning, but moreover that the earlier results were driven by the overt interference of language and lexical interpretation with the spatial reasoning tasks assigned: thus they represent a not altogether surprising (albeit still intriguing) effect of language patterns on language interpretation, rather than an effect of language on underlying cognitive processes.

3 Language as a "cognitive technology" for number

Although I have argued that the evidence from colour perception and spatial reasoning does not demonstrate the influence of language on cognition in a Neo-Whorfian sense, it nevertheless does reveal an interesting connection between language and perceptual systems. In particular, while language is not a necessary or central component of the relevant systems, it seems that it provides a resource or crutch in representing information for storage and/or transmission. This suggests that the successful acquisition of language represents also the acquisition of a tool to be added to our cognitive and/or representational arsenal, and which can then be used in tandem with other (more basic) systems. An idea along these lines—but which goes further in a number of important ways—is made explicit by Frank et al (2008), who argue that explicit linguistic encoding of the "counting" (or natural) numbers represents the development of a "cognitive technology" that bootstraps the construction of increasingly complex systems for numerical representation.

In the relativism debate, a good deal of attention has been paid to languages that lack vocabulary for exact numerals outside of the *subitizing* range (Kaufman, et al 1949). This class includes languages such as Warlpiri (Pama-Nguyan, Australia; Butterworth. et al 2008), which represents the categories "single", "dual" and "more than dual", Mundurukú (Tupi, Brazil; Pica, et al 2004), which has terms at least for the numerals from 1 to 4, but none greater than 5, as well as—infamously—Pirahã (Mura, Brazil; Gordon 2004, Everett 2005), which reportedly lacks *any* verbal representations for exact number (including 1 and 2). Investigations of the numerical abilities of speakers of "noncounting" languages such as these are of particular value to the question of linguistic relativism because patterns of numerical competence among nonverbal individuals (prelinguistic infants and primates, e.g.) are relatively well understood (Wynn 1995, Dehaene 1997, Carey 1998, among numerous others). Consequently, the numerical competence of speakers of Warlpiri, Mundurukú, Pirahã, and other such languages has far-reaching implications for our understanding of the relationship between language and human numerical cognition.

An extensive body of research suggests that humans have at least two "core" (innate) systems involved in the representation and manipulation of quantities. One of these, sometimes referred to as the *analog magnitude* system, allows us to represent approximate magnitudes in set-size comparisons and similar operations. A second system of *parallel individuation* handles exact quantities within the subitizing range (4-5 in adults, 3 in children; Feigenson and Carey 2005) by building models which contain individual representations of distinct objects. Experimental evidence shows convincingly that these core systems are online and active in prelinguistic children, and additionally remain available and accessible for "counting" adults, although they may often be superseded in the latter case by the capacity for precise enumeration that emerges co-temporally with acquisition of what Gallistel and Gelman (1992) call the "counting principle"—that is, comprehension of the add-1 relationship between a number n and its immediate successor $n+1$. It would, therefore, be extremely startling if speakers of non-counting languages did not demonstrate the same basic competences in approximation and small-set tracking

that pre-counting children display; the question for the relativist is thus whether a system for the precise numerical manipulations performed by counting adults develops independently of a linguistic counting principle.

Studies of numerical competence in the Mundurukú (Pica, et al), Pirahã (Gordon, Frank, et al), and Warlpiri (Butterworth, et al) suggest that the answer to this question is negative. Monolingual adult speakers of non-counting languages demonstrated competences comparable to those of counting adults on tasks which involved comprehension and manipulation of approximate quantities, but sharply underperformed with respect to counting adults on tasks involving exact numerical manipulations. Indeed, the performance of non-counting adults on the latter tasks seems to reflect the continued use of systems of approximation, where their counting counterparts switched to more complicated (non-core) systems of representation and abstraction. These results support the conclusion that exact numerical competence (at least over quantities outside of the subitizing range) is built on top of the acquisition and comprehension of a linguistic system of representation for numerical quantities and the discrete differences between them.

On the interpretation where numerical cognition is essentially restructured by the acquisition of a language with a numerical vocabulary, this conclusion seems to be a coup for the Neo-Whorfians. Frank, et al (2008), however, presents a more nuanced interpretation of the performance differences between counters and non-counters. Based on experimental data which aim to replicate and refine Gordon's (2004) study of the Pirahã, Frank, et al propose that non-counting adults do not lack an ability to conceptualize exact numerosity (contra Gordon), just as counting adults do not lose their core competences in magnitude and individual-tracking. Rather, they argue that the mental representation of exact quantity requires some method of encoding or recording, which is absent in languages which do not contain extensive numerical vocabulary.[8]

More precisely, Frank, et al propose that the acquisition of the counting principle does not represent a fundamental change to the structure of numerical cognition in language users, but instead is more akin to the development of a symbolic representation system. Numerical language allows speakers to create "mental representations of exact cardinalities of sets that can be remembered and communicated accurately across time, space, and changes in modality" (p.820). In a sense, then, the comprehension of a lexical item such as *twenty-five* is comparable to the creation of a symbol (e.g. "25"), which in some abstract sense represents the same idea. In particular, use of the term *twenty-five* allows a speaker to store some representation of a set of 25 individuals or objects without needing to keep track of 25 individuated objects in memory—that is, it allows us to store a representation of the relevant set in a way that is easily retrievable and can be handled and manipulated in tandem with other quantities and concepts.

4 Reasoning with (and without) language

Assuming that this interpretation of Frank, et al's proposal is on the correct track, it raises a number of interesting questions about the relationship between language, reasoning, and perception. A crucial aspect of the "cognitive technology" view is that numerical language seems to sit on top of the perceptual systems for quantity with which we are innately endowed (Dehaene's "number sense") and add to it in a way that expands the reach of the basic system to a non-perceptual level: in particular, one which involves reasoning over abstract objects which are not directly (visually) representable. This differentiates the influence that language has in numerical cognition from the role that it plays with respect to colour and spatial perception. I have argued that linguistic categories in the latter case

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8   See also the discussion of Nicaraguan Sign Language in section 4.

provide something like a post-perceptual filter which has an effect on memory and communicated aspects of perceptual input, it does not (and cannot) alter the experience or information *as it is received as input*. In the case of numerical cognition, on the other hand, language appears to create new ways of experiencing numerical information, albeit in an abstract domain. The split I am making, then, essentially corresponds to a distinction between experience/instinct and reasoning. That is, while the acquisition of language cannot restructure the nature of input at an experiential/instinctual level, but it may play a vital role in the development of higher-level reasoning systems. Evidence from cross-modular reasoning systems (Hermer-Vazquez, et al 1999) as well as from studies of mental-state language in the development of Nicaraguan Sign Language (NSL) suggest strongly that numerical cognition is not the only reasoning system or ability in which the development and acquisition of language play a "bootstrapping" role.

4.1 Cross-modular reasoning

An influential case study of the role of language in cognitive processing comes from the area of cross-modular reasoning—that is, reasoning which utilizes information from more than one innate perceptual system. Cheng (1986) and Hermer and Spelke (1994, 1996) demonstrate a striking similarity in the capacity (or lack thereof) of children and adult rats to solve problems requiring the synthesis of information from geometric and colour perception. In both sets of studies, the subject witnessed an object being hidden in one of four boxes, each of which occupied one corner of a rectangular room. The subject's task was to relocate the object after being disoriented (within the same space, with vision occluded). While both groups (children and rats) were able to use geometric information (that is, the configuration of long and short walls in the room) reliably to reduce their search space from four to two corners, Cheng and Hermer and Spelke showed that they did not seem able to combine this information with non-geometric input. In conditions where a single wall of the room was a different colour from the other three, children and rats continued to search equally at the two geometrically appropriate corners, rather than use the location of the blue wall to fully determine the position of the hidden object. In a particularly striking result, Hermer and Spelke showed, additionally, that children only begin to behave in an adult-like fashion (that is, correctly synthesizing the two sorts of information) at the age when they begin to comprehend and spontaneously utter linguistic constructions like "left of the blue wall." This suggests that the acquisition of language plays a role in the synthesis of the geometric and non-geometric perceptual information: Hermer and Spelke suggest that the ability to construct an utterance like "left of the blue wall" very literally forms a bridge between the two types of input needed to successfully complete the object-location task.

This conclusion regarding children's acquisition of "flexible" reasoning in reorientation is supported additionally by an influential study of adults whose linguistic circuits were "knocked out"-- that is, fully occupied by an unrelated task. Hermer-Vazquez, et al (1999) demonstrated that adults asked to perform the object-location task while simultaneously repeating verbal (auditory) input—a task intended to prevent them from forming linguistic representations pertaining to the relocation task— performed on par with rats and (pre-sentential) children. In particular, while their use of geometric information was unaffected, adults who were engaged in verbal shadowing were unable to reduce their search space to a single corner, and continued to split their search between the two geometrically appropriate corners. Crucially, the regression in reasoning ability occurred only when the distractor task involved *verbal* shadowing; a control condition involving a (complexity-matched) non-verbal rhythmic shadowing task had no effect on adults' ability to synthesize geometric and colour information in order to fully determine the position of the hidden object.

These results suggest that, just as language forges a path between perceptually-basic "number

sense" and the exact numerical reasoning observed in counting adults, so too does it form a representational conduit across which information from the (apparently) individuated perceptual modules can flow. The results reported in Hermer and Spelke (1994, 1996), and in Hermer-Vazquez, et al (1999) suggest that acquisition of the ability to form sophisticated linguistic structures, which, quite literally, bring geometric and non-geometric information together, simultaneously allows us to reason across perceptual modules. As with the numerical results discussed in section 3, cross-modular reasoning thus represents a case where the influence of language on cognition, instead of recasting linguistic differences between speech communities as cognitive ones (in a traditionally Whorfian sense), instead appears to abstract *away* from low-level taxonomic differences in order to scaffold the development of a higher-level system of reasoning that is fundamentally invariant across languages.

4.2 Developing a theory of mind

Of course, there is a crucial difference between the development of cross-modular reasoning and the development of numerical reasoning as discussed. In particular, while Mundurukú, Pirahã, and Warlpiri provide evidence that the development of number language (and hence precise numerical reasoning with numbers outside of the subitizing range) is possible but more or less *optional* for humans, to my knowledge there are no languages that (optionally or otherwise) lack cross-modular constructions such as "left of the blue wall." If cross-modular reasoning and numerical reasoning are indeed examples of the same sort of language-cognition bootstrap relations, why should this be the case? I suspect that these two systems represent something like different developmental stages, at a somewhat evolutionary level. Put another way, while it seems reasonable to suppose that cross-modular reasoning represents a clear advantage (in the evolutionary sense), the ability to manipulate exact numbers arguably only becomes advantageous under certain conditions and/or organizations of society (e.g. individualized rather than collective farming, or animal husbandry vs hunting/gathering). This is, of course, extremely speculative, but some evidence that it may be the right sort of explanation comes from an examination of the emergence of mental-state vocabulary in Nicaraguan Sign Language (NSL), and its apparent correspondence with an emergent theory of mind in NSL-speakers, as represented in their performance on tasks involving others' false beliefs.

NSL is an extremely interesting test case for a number of linguistic questions because there is an extensive (and recent) record of its development (Senghas 1995, Senghas, et al 2005). Until the 1970s, there was little or no centralized instruction for deaf individuals in Nicaragua; this changed with the establishment of a special-education program for the deaf in Managua, which brought created a deaf community for the first time. Individuals in the "first cohort" of this community began to communicate with one another in what is described as a pidgin (*Lenguaje de Signos Nicaragüense;* LSN) put together from their individuated "homesign" systems. With future cohorts of students, the original LSN seems to have evolved into a creole-like language (known as *Idioma de Señas de Nicaragua*; ISN), replete with increasingly complex structures and a more stylized, decreasingly iconic grammar (Senghas and Coppola 2001).

Pyers and Senghas observed in 2001 that first-cohort LSN-speakers appeared to have a relatively impoverished lexicon of mental-state words (i.e. *think, believe, know*) as compared to younger ISN-speakers. It has previously been suggested that the ability to succeed on false-belief tasks—that is, to accurately infer others' states of knowledge when they are distinct from one's own[9]—which emerges

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9   There are a number of variants of the false-belief task: in one of the most common, subjects witness a scene involving two characters and two "hiding places." One character, A, places an object in one of the hiding places, and then leaves the room. While A is absent, the second character, B, moves the object from its original hiding place to the other. A then returns to the room, having witnessed none of this. Subjects are asked where A will look for the object—in its original hiding place, or the other. In order to answer correctly, subjects must recognizes that A has a different set of information

between the ages of 2 and 4 in most developmentally normal children (Wellman, et al 2001), is correlated with the emergence and in particular the comprehension of mental-state language (Perner and Ruffman 2005, Milligan, et al 2007). Pyers and Senghas (2009) used the difference between the two NSL cohorts to probe this question: a first experiment (dated 2001) showed significant correlations between mental-state language and false-belief task success. Moreover, even with the first-cohort (LSN) signers, Pyers and Senghas noted a systematic correlation between spontaneous production levels for mental-state vocabulary and performance on false-belief. The 2001 data is already a significant point in support of the view that the ability to reason at a certain level of abstraction about others' knowledge is dependent on (or at least suggestively co-emergent with) a (linguistic) means of representing the information (de Villiers and Pyers 2002); this is brought into even sharper relief by data collected at a second time point in 2003. At the later time, Pyers and Senghas found that the performance difference between LSN- and ISN-cohort signers had effectively vanished; moreover, this correlated with the disappearance of a distinction in mental-state language use between the two groups.[10]

Crucially, Pyers and Senghas (2009) report that during the time between 2001 and 2003, the ISN-cohort signers had begun to interact significantly more with the first-cohort signers, via the Managua deaf association. In particular, despite the age of the first-cohort signers, it seems that they were only able to develop (or at least accurately self-represent, retain, and reason about) others' knowledge states *following* acquisition of the linguistic structures and vocabulary that represent the relevant information. Perhaps even more significantly, the development of this type of reasoning—which seems, to an English-speaker, as ubiquitous to early childhood development as cross-modular reasoning—was not at all inhibited by occurring outside of a "critical period" window of language acquisition. This strongly supports the view of language as at least in part a scaffold for the development of our higher-level abstract reasoning abilities; it suggests that, while these abilities are necessarily universal (in the sense that all humans fundamentally have the capacity to perform them, irrespective of linguistic differences), they emerge as a result of social factors rather than instinctual ones, such as whether the surrounding community uses the language and reasoning system in question.

4.3 "Optionality" in abstract reasoning

With respect to numerical cognition, the same late-stage development option seems likely to hold for non-counters as well. Somewhat speculatively, the lack of exact numerical manipulation and cognition may be a reflection of the fact that these forms of reasoning have not been made salient (or necessary or useful) by the communities in which non-counters live (cf. Everett 2005). Nevertheless, if and when these skills become useful, it seems likely that they will emerge among non-counters, either through development number language within the substrate language, or via a parallel or adopted method of representation. Evidence for this possibility comes again from NSL speakers, who are embedded in a fully numerate, monetized culture, but whose original (LSN) system lacked exact numerals. Flaherty and Senghas (2011) used a set of the same numerical reasoning tasks as those applied in experiments with the Mundurukú and Pirahã (see especially Gordon 2004) to examine the numerical cognitive abilities of NSL (LSN and ISN) speakers with varying levels of linguistic and/or symbolic numeracy. They found that ISN signers (who do have extensive and exact numerical vocabulary in their sign language) performed like adult Spanish-speaking counters, while performance in first-cohort (LSN) signers was directly correlated not to age, but to mastery either of the ISN number signs or of written Spanish numerals. In either case, a representational system seems to have been essential to the

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than B (or the subject themselves), and use this to predict her behavior.

10 See also Newton and de Villiers (2007) study of false-belief reasoning un adult under the linguistic-inference paradigm of Hermer-Vazquez, et al (1999).

development of exact numerical reasoning, but the evidence suggests that this, like false-belief reasoning, is a more or less inherent human cognitive capacity, although it can remain latent in the absence of external catalysts.   Both with respect to numerical cognition and false-belief reasoning, language and linguistic representation appear to represent a crucial step in the development of the system.   These data, then, support the distinction I am arguing for between *post hoc* linguistic classificatory/categorization of perceptual information, which has given rise to the (false) semblance of cognitive differences between speakers of different languages, and the development of higher-level reasoning, which seems more like Fodor's (1976) "mentalese" in its universality, albeit being necessarily influenced and dependent on linguistic (or semi-linguistic) representations.

5 Conclusions and future directions: w(h)ither Whorf?

There is, perhaps, a lingering Whorfian flavour to the proposal I have made, insofar as certain types of linguistic differences (e.g. the presence or absence of numerical language) are predicted to correlate with differences in the development (and therefore use) of certain systems of reasoning. Ultimately, however, this view of the relationship between language and cognition diverges profoundly from linguistic relativism in its canonical sense. I do not believe that the predicted variation represents irreconcilable or untranslatable cognitive diversity, but rather that it is epiphenomenal on particular paths of language development, which may stem from historical and sociocultural context. My central thesis is that, as humans, we seem to have (at least) two distinct types of cognitive ability: those which inhere in our perceptual apparatus, as it were, and those which we develop and teach ourselves. From the point of view I am advancing, however, it seems clear that both types of ability ultimately rest on the same foundations and basic endowment.

More specifically, the role of language as a "cognitive technology" (*a la* Frank et al 2008) raises the idea that the influence that language has on cognition is something essentially insulated from the (surface-level) linguistic diversity that has traditionally given rise to theories about linguistic relativism. There is certainly evidence that language bears a special relationship to memory; however, where it represents something like a "storage shortcut" for information that comes directly from perceptual systems, it acts as a building block in the acquisition of more abstract reasoning capabilities.   Put another way, while the pre-linguistic interpretations of perceptual information are fundamentally the same regardless of the perceiver's native language, this language may exert a prominent but *post hoc* influence, specifically on the manner in which the perceiver records the information for (potential future) communication. This can cause the appearance of sharp divergences in perceptual capacities between speakers of different languages, but is only an effect (albeit a powerful and fascinating one) of arbitrary choices with respect to classification systems (for colour and local space, for instance). On the other hand, language exerts a defining influence on the systems of abstract reasoning discussed here— exact numerical manipulation, cross-modular synthesis, theory of mind—in that it forms an essential condition for the elaboration and refinement of these systems. The systems developed by and with language, however, are fundamentally invariant across all languages—moreover, they are systems which cannot be regarded as untranslatable, given an adequate representational system (cf Flaherty and Senghas 2011) in the sense of Quine (1960).

Taking this a step farther, it appears to not so much be the case that language influences cognition as that it in some way *is,* or at least represents, our abstract reasoning systems. Thus, despite the anti-Whorfian nature of the claims I have advanced, the idea of language as essential cognitive technology suggests that studies in the "relativist" line can provide valuable and important insight into the structure of human cognitive capacities. By examining differences in cognitive task performance which correlates

with the presence or absence of certain types of systems, categories, or constructions across languages—that is, in languages which differ in the presence or absence of some "design feature"—we may be able to determine which aspects of cognition are simply parts of the essential architecture of human perception and experience, and which are co-emergent with language and represent, in some sense, the mysterious "life of the mind"—the apparently uniquely human capacity to introspect, discover, and create new tools and systems for reasoning, computation, and problem-solving.

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