Précis of *Universals and variation in language and thought: Concepts, communication, and semantic structure*

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Do speakers of different languages think differently or do we all share a single underlying conceptualization of the world around us? On one hand, if universals of thought exist independent of language, then these universals may reflect basic constraints on cognition. If this is the case, then what are these conceptual universals, where might they come from, and what principles do they follow? On the other hand, if thought varies across languages, this may indicate that the way we talk about the world alters the way we think about it. If so, then under what circumstances, and through what mechanisms does language change human cognition?

This dissertation builds on foundational research on the relation between language and thought to address several remaining gaps in our understanding of the questions above. It engages cross-cutting questions from semantic typology, language evolution, and linguistic relativity to explain universals and variation in language, cognition, and interactions of the two. In particular, the four projects presented here test and characterize (1) specific universals in cognition, (2) general principles in language change, (3) general principles in thought, and (4) mechanisms by which language may influence thought. These projects, corresponding to the chapters of this dissertation, contribute evidence for universals in conceptual structure, an account of the forces that shape both language and cognition, and a challenge to the view that language actively influences cognition during thought.

Introduction

What is the nature of the relation between language and thought? Languages parcel human experience into categories that are picked out by words (e.g. green, up, snow) and features of grammar (plural, feminine, future). These categories vary considerably across languages, providing for two opposing accounts of language and thought.

The *universalist* view holds that people perceive and construct the experienced world similarly, regardless of language. By this account, language acts to partition a universally shared conceptual space into varied but non-arbitrary semantic categories (Berlin & Kay, 1969; Jameson & D'Andrade, 1997; Levinson et al., 2003; Regier et al., 2007). Consistent with this view, there are recurring cross-linguistic tendencies that suggest a universal conceptual repertoire (Levinson et al., 2003; Khetarpal et al., 2009).

The other account, known as the Sapir-Whorf hypothesis, proposes that linguistic systems create categories that shape perception, causing speakers of different languages to conceptualize the world in fundamentally different ways (Whorf, 1956). This *relativist* view is supported, in part, by evidence that variations in language align with systematic differences in thought: speakers of different languages solve mazes in opposite directions (Majid et al., 2004), pre-linguistic infants notice changes that adults overlook (Hespos & Spelke, 2004), and routine distinctions made by speakers of some languages are ignored or impossible for others (Boroditsky & Gaby, 2010). The evidence that certain aspects of language correspond to divergence in basic cognition supports the idea that language plays an influential role in thought.

One proposal posits a reconciliation of these seemingly dissonant views, suggesting that there is a universal conceptual basis for the categorical distinctions that languages make, but that this conceptual foundation may be altered by language (e.g., Kay & Kempton, 1984; Hespos & Spelke, 2004; Regier & Kay, 2009). There is convergent support for this view across several domains (e.g., Hermer-Vazquez et al., 1999; Gilbert et al., 2006; Frank et al., 2008; Gilbert et al., 2008), but many important questions remain unanswered. If speakers of all languages share a common foundation of thought, what cognitive universals constitute this foundation? Are these cognitive universals apparent in the ways that languages parcel human experience into categories? More broadly,

what pressures shape the universals and variation in category meanings, and through what processes do such pressures drive language change? Do these pressures parallel principles of nonlinguistic cognition? In what circumstances do the categories in language influence cognition directly, to what degree, and by what mechanisms?

This dissertation seeks to establish the nature of the emerging reconciliation between universalist and relativist views. The research described here informs all of the questions above, drawing on the tools and perspectives of three distinct but related traditions in the study of language and thought: semantic typology, language evolution, and linguistic relativity. In particular, I focus on spatial cognition as a testbed for this integrative approach. Spatial cognition provides an ideal domain for relating questions of language and thought across multiple perspectives because it is a foundational area of human cognition and a prominent topic in language. A substantial body of previous research in psychology has examined spatial reasoning, memory, and navigation as crucial components of cognition shared across cultures and species (e.g., Tolman & Honzik, 1930; Shepard & Metzler, 1971; Shepard & Cooper, 1982; Pick & Acredolo, 1983; Hermer & Spelke, 1994), yet complementary work in linguistics finds that human languages exhibit a large range of diverse spatial semantics (e.g., Bowerman & Pederson, 1992; Brown & Levinson, 1993; Levinson et al., 2003). Building on this previous work, I investigate the structure and relation of language and thought in the domain of space. Do universals in spatial cognition underlie variation across languages? What principles characterize universals and variation in spatial language and thought? What role does language play in spatial cognition?

Perspectives on spatial language and cognition across disciplines

Many questions on the relation between spatial language and thought are grounded in the observation that spatial meanings vary across languages. Hence, the basis for this line of inquiry is found in semantic typology, a subfield of linguistics which seeks to survey and catalog the variety of meanings picked out by categories in language, and the larger systems of meaning that these categories form. Semantic typology presents a unique perspective on structured meaning in language, and a natural starting point for studies of language and thought across many domains of cognition. To the extent that language reflects cognition, the models of semantic structure developed by typologists afford a rich set of hypotheses about analogous conceptual structures (e.g., Croft, 2003; Haspelmath et al., 2005; of particular relevance for this dissertation: Kay & McDaniel, 1978; Talmy, 1983; Levinson et al., 2003). The first project of this dissertation, in Chapter 2, explores this application of semantic typology, translating a model of spatial semantics into a hypothesis on the structure of spatial cognition to evaluate whether universals in spatial cognition underlie the variation in language.

Building broadly on traditions in typology, a recent movement in cognitive science seeks to explain linguistic structure through accounts that emphasize the function of language as a communicative system (e.g., Piantadosi et al., 2011; 2012; Fedzechkina et al., 2012; Gibson et al., 2013). Applied within semantic typology, this approach characterizes patterns in the semantic structure of language as driven by general principles of efficiency from an information theoretic framework (Regier et al., 2007; Baddeley & Attewell, 2009; Kemp & Regier, 2012). One such study demonstrates that these principles of communication can be used to explain universals and variation in spatial category systems across languages (Khetarpal et al., 2013), simultaneously motivating universal tendencies and providing constraints on variation.

While this approach, and those grounded in semantic typology more generally, contribute many observations about the patterns of meaning in language—and corresponding hypotheses about cognition—they leave open questions about how these patterns arise. To evaluate the processes that shape systems of meaning, an account of the relation between language and thought must also be informed by studies of language evolution. Research in this area considers the mechanisms and processes of language change, including direct constraints on language produced by the dynamics of language transmission (e.g., informational bottlenecks as limitations on holistic systems of meaning; Kirby, 2002) and indirect influences imposed by cognitive biases in learning and memory (e.g., Kalish et al., 2007). It provides computational and empirical tools for assessing the selective pressures that shape semantic structure (e.g., Kirby et al., 2008) and identifying implicit cognitive biases (Kalish et al., 2007) through the experimental paradigm of iterated learning. Consequently, simulations of language learning and related techniques can be used to uncover the general principles that contribute to the structure of language and

cognition. This approach informs universal theories by providing empirical grounding for specific universal features and general principles. In this vein, Chapter 3 employs a simulated language learning paradigm to characterize pressures in language transmission that give rise to efficient systems of spatial categories.

Work within semantic typology and language evolution may reveal structure imposed by language, but such structure need not correspond to the architecture of nonlinguistic cognition. To evaluate accounts of cognitive universals, it is necessary to gauge nonlinguistic cognition across languages directly through behavioral experiments. The study in Chapter 4 employs this approach to assess whether an information-theoretic account of structure in linguistic meanings may have its roots in cognition.

Any evaluation of universalist and relativist views of language and thought hinges on the nature of thought, which may be assessed broadly in comparative studies across languages, but also in focused experiments on linguistic relativity. Convergent data across a range of cognitive experiments is necessary to establish the roles of language-specific and universal forces in shaping the concepts and processes we use to represent the world around us. Cognitive and linguistic tasks enable assessments of both the baseline nature of nonlinguistic cognition and cases in which language plays an active, causal role in defining or influencing thought (e.g., Hermer-Vazquez et al., 1999; Frank et al., 2008; Gilbert et al., 2008). Following work in this area, Chapter 5 tests a mechanism through which variation in spatial language may influence spatial cognition, and finds evidence that challenges a classic account of language and thought in the spatial domain.

Answering the broad question of how language and thought relate is the primary project of an entire field within cognitive science, and this central question is composed of a constellation of related inquiries that are often posed and answered by largely separate approaches. While these questions are often treated independently by research programs in semantic typology, language evolution, and linguistic relativity, each of these projects informs and constrains the others. The research in this dissertation synthesizes the major ideas and methodologies of these programs to inform a more cohesive account of the relation between language and thought in the domain of spatial cognition.

The introduction reviews the tradition of examining questions in language and thought on a domain-by-domain basis, and the motivation for doing so in two foundational domains: color and space. The later chapters of this dissertation follow that tradition, building on a broad foundation of basic research in spatial cognition to test the generality of accounts and principles established in the color domain. In particular, they address four open questions on the nature of semantic and conceptual universals, and the role of language in spatial cognition:

Chapter 2	Universals in conceptual structure: Which influences underlie universal tendencies in language—is there a universal conceptual space for spatial relations that speakers respect across languages?
Chapter 3	Universal forces in language change: What processes shape semantic systems in language? Do changes in the semantics of spatial categories follow principles of informative communication?
Chapter 4	Universal principles of cognition: Do cognitive universals follow general principles? In particular, does spatial cognition follow the same principles that govern semantic systems across languages?
Chapter 5	Language in cognition: What causes cognition to vary in line with language? Does language-like spatial reasoning depend on access to language?

Below, I outline the research projects corresponding to each question and describe my findings.

Chapter 2: Do universals of language reflect a universal conceptual space?

The first line of work explores the relation between universals in language and thought. The major premise of the universalist view is that speakers of all languages share a universal conceptual space, which is partitioned by the categories in language. Previous findings support this account in the domain of color. Specifically, systems of color categories across languages appear to follow a universal semantic hierarchy (Kay & McDaniel, 1978), and these universals in color language correspond closely to universals in color cognition (Boster, 1986).

I evaluate the generality of this finding in the case of spatial relations. Levinson et al. (2003) assessed topological spatial relation names across languages and proposed a hierarchy of spatial notions underlying the

diversity of semantic systems, but did not evaluate their model against nonlinguistic cognition. I test this semantic hierarchy as a model of cognition by asking participants to successively pile sort spatial scenes into increasingly finer categories. The universalist view holds that commonalities in language result from languages partitioning a shared conceptual space. By this account, the semantic universals in Levinson et al.'s hierarchy are caused by cognitive universals, and so will closely match the pile sorts created by speakers of any language. Consistent with this prediction, the pile sorts made by English speakers recapitulate the proposed model of universal semantics. This finding provides support for the proposal that all people share a largely universal conceptual space for topological spatial relations. Additionally, it presents evidence for a specific hierarchy of spatial notions in cognition and in doing so extends Boster's (1986) demonstration in color to the novel domain of spatial relations.

Chapter 3: How do evolutionary pressures shape the universals in language?

The previous chapter provides an explanation of linguistic universals as reflections of a particular, domain-specific hierarchy of spatial notions. Other work has shown that principles of communicative efficiency can explain linguistic universals in a *domain-general* way by appealing to general qualities like similarity and simplicity rather than the specific semantic features of a domain (e.g., Kemp & Regier, 2012; Regier et al., 2015). In particular, Khetarpal et al. (2009, 2013) have shown that spatial systems in language are near-optimally informative by this account. However, in a commentary on this line of work, Levinson (2012) pointed out that although this research explains cross-language semantic variation in communicative terms, it does not tell us "where our categories come from" (p. 989); that is, it does not establish what *process* gives rise to the diverse attested systems of informative categories. Chapter 3 addresses that challenge by demonstrating that cultural transmission produces systems of categories that are both efficient and similar to natural languages.

I present a computational framework for exploring semantic systems through the lens of informative communication, and apply this framework in two studies. The first reanalyzes color naming data from an iterated learning experiment (Xu et al., 2013), in which participants successively learned and transferred novel color categories over several generations, simulating cultural transmission. This analysis tests whether color categories transmitted across generations converge toward informative naming systems. In the second study, I conduct an analogous iterated learning experiment in the domain of spatial relations, and ask the same question of those data. Through these experiments, I show that human simulation of cultural transmission in the lab produces systems of semantic categories that converge toward greater informativeness, in the domains of color and spatial relations. Moreover, as the simulated languages become more informative, they increasingly resemble the semantic structure of natural human languages. These findings suggest that (a) language users are biased toward efficient linguistic systems, and (b) larger-scale cultural transmission over historical time could have produced the diverse yet informative category systems found in the world's languages. More broadly, this result may indicate that nonlinguistic cognition (revealed through learning biases in this task) respects the same general principles of efficiency observed in semantics across languages.

Chapter 4: Do principles of efficiency explain universals in cognition?

This project asks whether the principles that govern efficient semantic systems, as explored in the previous chapter, also characterize nonlinguistic cognition. Inspired by an earlier treatment of color memory (Lantz and Stefflre, 1964), this question adopts a view of thought as self-directed communication. By this account, memory can be seen as a process of transmitting information to oneself over time with the brain as a channel, analogous to transmitting information to others through language. This perspective predicts that categories in cognition would follow the same general principles as those in language.

To evaluate this view of thought, I follow an earlier study by Khetarpal et al. (2010), which assessed language and cognition in speakers of English and Dutch via pile sorting of spatial stimuli, and identified small language-specific tendencies and robust universals in pile sorting. First, to provide a stronger test of these universalist findings, I reproduce the previous study in two new languages, Chichewa and Máíhiki, which lend greater linguistic and cultural diversity to the study population. I find that speakers of all four languages, despite large

differences in the granularity of their linguistic spatial systems, make pile sorts with similarly fine granularity. Next, I test whether this universal tendency reflects a drive for efficiency in cognition, analogous to that found in language. I present an account of spatial cognition in which conceptual categories maximize the trade-off between informativeness (making for fine-grained and intuitively organized spatial categories) and simplicity (limiting the number of categories). Consistent with this view, I find that pile sorts made by speakers of Chichewa and Máíhɨki match this universal account more closely than they match the semantics of their native languages. These findings suggest that spatial cognition reflects universal pressures for efficient categorization, and demonstrate behavioral tendencies across languages that result from these pressures.

Chapter 5: Does language play an active role in thought?

The first three chapters characterize universal tendencies in semantic systems, simulated language evolution, and nonlinguistic cognition. They suggest a universalist account in each case, by which cognition is shared across languages, and this shared representation projects commonalities onto the structure of semantic systems, simulated language change, and nonlinguistic categorization. In all of these cases, the universal tendencies in category structure reflect unseen universals in cognition. Accounts of linguistic relativity emphasize the converse scenario, in which variation in language causes variation in cognition. The ideal candidate case study for testing such an account would be a domain with (a) clear variation in linguistic categories, (b) clear variation in cognition, and (c) a strong correspondence between variation in (a) and (b). The subdomain of topological relations considered in other chapters clearly varies across language and cognition, but cognition (at least in pile sorting tasks) exhibits strong universal tendencies and does not show great correspondence with varying features in language. Spatial frames of reference, however, do meet the criteria for an ideal candidate domain. The preferred spatial frame of reference (FoR) in both language and nonlinguistic tasks varies across cultures (e.g., Brown & Levinson, 1993; Pederson, 1995; Levinson, 1996; Pederson et al., 1998; Levinson, 2003), and the preferred linguistic FoR is the best predictor of nonlinguistic FoR in a broad set of demographic factors (Majid et al., 2004), presenting an ideal case for tests of linguistic relativity.

Studying spatial FoR also affords an opportunity to test Kay and Kempton's (1984) two-tiered account of cognition, by which language provides a complementary but removable overlay on a universal foundation. Previous work established that nonhuman primates and toddlers have a preferred FoR that they systematically default to, suggesting a universal primate bias in FoR (Haun et al., 2006). However, adult English speakers in nonlinguistic tasks use an FoR that differs from that of young children and other primates, but aligns with the English language (Li & Gleitman, 2002). Under the two-tiered account, English-speaking adults retain the universal primate bias beneath a divergent overlay of language, but will recover this universal when language is disrupted.

Chapter 5 addresses a high-profile debate over the role of language in spatial FoR, testing Kay and Kempton's (1984) two-tiered account of cognition through verbal interference. I find no evidence that interfering with language produces a shift toward the predicted pre-linguistic mode of thought. I conclude that although language often shapes cognition through online use, this does not appear to be true in the influential case of spatial frames of reference. This finding raises the stakes of the debate around spatial FoR. Either language has no causal effect on cognitive FoR and previous research has widely misattributed alignment between language and thought to a causal role of language, or language learning fundamentally restructures spatial cognition in a way that is difficult to reverse.

Conclusion

Collectively, the studies of this dissertation are designed to compare structures of meaning in words and concepts in order to identify universals, variation, and specific constraints on language and cognition. Much remains to be determined about the nature of both language-specific and universal forces in cognition, and their interaction. However, in recent years, the oscillation between universalist and relativist accounts of cognition has become less dramatic and the debate has instead gained interesting complexity and nuance. The work presented here represents

additional steps in moving this debate toward an equilibrium, in which fascinating questions receive grounded and broadly informed answers.

The universals observed in this dissertation are characterized by accounts that emphasize broad functional considerations in explaining the structure of language and thought. These findings underscore the importance of pressures external to the mind (from communication), constraints from basic cognitive processes (biases and limitations in learning and memory), and general principles of efficiency (simplicity and informativeness) in shaping both language and cognition across cultures.

The findings of this dissertation in the domain of space, taken together with parallels in color, number, and other domains, reinforce an emerging consensus on the relation of language and thought, by which all people share a universal conceptual foundation that may be altered by language. The research here further elaborates this account, suggesting that universals and variation in both language and thought may derive to some extent from general principles of efficiency. At the same time, it challenges the generality of a classic (Kay & Kempton, 1984) formulation of this view, motivating future research. In both complementing and challenging an emerging consensus on language and thought, this dissertation informs our view of language, a defining feature of human cognition, and contributes to a more complete understanding of the nature of thought.

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