The Grammar of Language

Lera Boroditsky's Cross-Cultural Cognition and the Closure Framework: How Linguistic Grammars Constitute Different Cognitive Worlds

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> *Each language is its own cognitive toolkit. The languages we speak don't just enable communication — they actively shape how we perceive time, space, color, agency, and the world.*
> Lera Boroditsky, How Language Shapes Thought, 2010

> *Every finite closure generates remainder. The remainder is not noise. It is the proof that the grammar is finite.*
> CF Dietz, Consciousness, Closure, and the Cosmos, 2026

Abstract

Lera Boroditsky is Professor of Cognitive Science at the University of California, San Diego, and among the world's leading researchers on linguistic relativity: the question of whether and how the languages people speak shape the way they think. Her research demonstrates across cultures, domains, and experimental paradigms that speakers of different languages think differently about time, space, color, causation, and agency, and that these differences are not merely translational but cognitive: different linguistic grammars constitute different facts about experience from the same sensory input. English speakers think about time horizontally; Mandarin speakers think about it vertically. Kuuk Thaayorre speakers in Australia orient time and sequence by cardinal direction, with extraordinary spatial precision as a consequence. Russian speakers distinguish two blues that English speakers treat as one and perceive chromatic differences faster because their language makes those differences grammatically necessary. This paper argues that Boroditsky's findings are the most extensive cross-cultural experimental demonstration available of the closure framework's account of grammar-relative knowledge. The linguistic grammar is a closure regime: it draws distinctions, establishes identity criteria, and maintains lawful relationships among the elements of experience. Different grammars constitute different facts from the same world. What is one color in English is two colors in Russian. What is ahead-of in English is up-from in Mandarin. What is left in English is southwest in Kuuk Thaayorre. The facts differ not because the world differs but because the grammars differ. Boroditsky has spent two decades demonstrating experimentally what Semantic Remainder derives formally: no finite grammar captures everything, every grammar leaves remainder, and the remainder differs for every grammar.

1. The Ant on Your Southwest Leg

Imagine someone telling you there is an ant on your southwest leg. You would need a moment. Perhaps you would glance at a window to establish where the sun is, estimate compass directions, and then determine which leg faces southwest relative to your current orientation. In the community of Pormpuraaw in northern Australia, where speakers of the Kuuk Thaayorre language live, this sentence is unremarkable. Children in Pormpuraaw learn it as naturally as English-speaking children learn left and right. The community does not use relative spatial terms. There is no left or right in Kuuk Thaayorre. There is only the cardinal grid: north, south, east, west, and their compounds.

The consequence is extraordinary. Boroditsky asked Kuuk Thaayorre speakers and English speakers to arrange a sequence of photographs showing a progressively eaten apple in temporal order. English speakers arranged them left to right. Hebrew and Arabic speakers, whose writing runs right to left, arranged them right to left. The Kuuk Thaayorre speakers did neither. They arranged them east to west, regardless of which direction they themselves were facing. To do this, they needed to know at every moment where east was. They always did. When Boroditsky repeated the exercise with adults from other cultures, including academics at leading universities, those adults often could not point north when asked. The five-year-old in Pormpuraaw could.

This is not a minor linguistic curiosity. It is evidence that the grammar of a language, the system of distinctions and relations that speakers must navigate to produce and understand utterances, constitutes the cognitive architecture through which those speakers experience the world. The Kuuk Thaayorre grammar requires absolute spatial orientation. Speakers of it develop absolute spatial cognition as a structural consequence of using the language every day. The English grammar requires relative spatial orientation. Speakers of it develop relative spatial cognition. Neither grammar is wrong. Each constitutes a different world of spatial experience from the same physical environment.

Lera Boroditsky has spent two decades mapping the territory this observation opens onto. Time, color, causation, agency, number, gender: in domain after domain, the linguistic grammar shapes the cognitive facts that speakers of that grammar constitute from their sensory experience. The closure framework calls this grammar-relative knowledge: the facts that any cognitive system constitutes depend on the grammar it uses, and the same world presents differently to different grammars. Boroditsky has been demonstrating this experimentally across cultures with a precision and breadth that no other researcher has matched. This paper argues that her findings are the cross-cultural experimental confirmation of what Semantic Remainder derives formally and what the Grammar of Knowing establishes epistemologically.

2. Boroditsky's Four Claims

Boroditsky's research program has four interconnected findings, each demonstrating grammar-relative knowledge in a different domain.

2.1 Language Shapes Spatial Cognition

The Kuuk Thaayorre findings demonstrate that the spatial grammar of a language produces corresponding spatial cognitive capacities. Speakers who must maintain absolute cardinal orientation to use their language develop extraordinary orientation skills as a structural consequence. Speakers who use relative spatial terms develop relative spatial cognition. The same physical space is experienced through different cognitive architectures depending on the grammar.

Boroditsky has shown this pattern across multiple communities and spatial systems. Some languages use body-relative terms like left and right. Some use absolute terms like north and south. Some use object-relative terms like near the tree or past the river. Each system draws different distinctions, constitutes different spatial facts, and produces different spatial cognitive capacities in speakers who use it daily. The spatial world is not given to perception independently of grammar. It is constituted by the grammar within which perception is organized.

2.2 Language Shapes Temporal Cognition

English speakers think of time as horizontal. We say that a meeting has been moved forward, that we are looking back on the past, that a long time stretches ahead. These metaphors are not decorative. Boroditsky demonstrated experimentally that English speakers respond faster to temporal judgments when primed with horizontal spatial arrangements and slower when primed with vertical ones. Mandarin speakers show the opposite: they use vertical temporal metaphors, saying that earlier events are up and later events are down, and respond faster to temporal judgments when primed with vertical spatial arrangements.

These are not trivial response time differences. They reveal that the temporal metaphors embedded in a language become the cognitive architecture through which time is experienced. The grammar constitutes time as a spatial structure: horizontal in English, vertical in Mandarin. The same sequence of events is experienced through different spatial architectures depending on which language's temporal grammar the speaker inhabits. Time is grammar-relative.

The Kuuk Thaayorre speakers carry this further: they arrange time on the cardinal grid, east to west, because that is the spatial system their grammar uses for everything. Their temporal architecture is the same as their spatial architecture because their language draws no distinction between the two. Time and space are constituted together in the Kuuk Thaayorre grammar in a way that English and Mandarin grammars separate. Each grammar constitutes a different temporal world from the same sequence of events.

2.3 Language Shapes Color Perception

Russian has two words for what English calls blue: siniy for darker blues and goluboy for lighter blues. This is not merely a lexical difference that Russian speakers could set aside when thinking about color. Boroditsky and her colleagues demonstrated that Russian speakers show faster discrimination between colors that cross the siniy-goluboy boundary than between colors that fall within one category, even when the objective chromatic distance between the colors is held constant. English speakers, who have no such boundary, show no such discrimination advantage.

The linguistic boundary is a cognitive boundary. The grammar draws a distinction. The distinction constitutes two colors where the English grammar constitutes one. Russian speakers do not merely have a word for the distinction: they have a perceptual fact that English speakers lack. The grammar has constituted a fact about color experience that a different grammar does not constitute from the same sensory input.

This finding matters philosophically because it demonstrates grammar-relative constitution of perceptual facts, not merely of abstract concepts. The blue-goluboy distinction is not a high-level conceptual categorization layered on top of a universal perceptual experience. It is a difference in perceptual processing speed, measurable in milliseconds, that reflects the structural organization of the color domain by the grammar. The world does not come pre-divided into two blues. The grammar divides it.

2.4 Language Shapes Causation and Agency

English is an unusually agentive language. When events occur, English grammar typically assigns an agent: someone or something caused the event. When Dick Cheney accidentally shot his friend during a hunting trip, his natural English response was elaborate: he had to string together agents and causes across multiple clauses to acknowledge the accident without fully owning it. In Spanish, accidents are typically expressed as things that happened to the agent rather than as things the agent did. The vase broke, not John broke the vase. The language distributes agency differently.

Boroditsky's research shows that these grammatical differences in agency assignment produce differences in memory and moral judgment. English speakers remember the agent of an accidental event more readily than Spanish speakers do. They attribute more blame to agents of accidents. They find the same event more intentional-seeming because their grammar frames it as something that an agent did rather than something that happened. The linguistic grammar constitutes different causal facts from the same event. The same accident is an agent's action in English and a thing that happened in Spanish. These are different cognitive worlds.

3. What Boroditsky Needs

Boroditsky's research program is among the most carefully designed and widely replicated in cognitive science. Her cross-cultural experiments control for confounds with experimental precision, isolating the linguistic variable as the driver of cognitive differences. Her findings span perception, memory, reasoning, and moral judgment. They have survived methodological challenges and scrutiny from skeptics of strong linguistic relativity.

The philosophical foundation that the research points toward but does not fully articulate is this: why does grammar constitute cognitive facts rather than merely labeling pre-given ones? The standard challenge to linguistic relativity is that the world comes already structured and language merely provides names for its pre-existing features. Russian has two words for blue because Russians noticed a distinction that English speakers simply lack a word for. The perceptual boundary is there; the word makes it available.

Boroditsky's evidence contests this. The Russian speakers respond faster because the grammatical boundary is a cognitive boundary, not because they simply have a word for a distinction they would make anyway. The Kuuk Thaayorre speakers have better absolute orientation because their grammar requires it, not because they would have developed that skill without the grammatical requirement. The grammar is constitutive, not merely descriptive.

But Boroditsky does not have a philosophical account of why grammars are constitutive rather than merely descriptive: what it is about the relationship between linguistic structures and cognitive processes that makes the grammar produce the fact rather than merely label it. The closure framework provides this account. A linguistic grammar is a closure regime: it draws distinctions, establishes identity criteria, and maintains lawful relationships among the elements of experience. The distinctions it draws are not reports of pre-existing differences in the world. They are constitutive acts: they create cognitive facts from the undifferentiated sensory input that arrives before any grammar has organized it. Different grammars draw different distinctions and therefore constitute different facts. This is not a hypothesis about linguistic relativity. It is a structural consequence of what any finite organized system that draws distinctions must do.

4. Two Concepts That Ground Grammar-Relative Cognition

The closure framework is introduced here at the minimum level needed to ground Boroditsky's findings.

4.1 Linguistic Grammar as Closure Regime

A closure regime is a system that stabilizes some content by drawing distinctions, establishing identity criteria, and maintaining lawful relationships among its elements. It constitutes facts within its scope and generates remainder at its boundary.

A linguistic grammar is a closure regime in this precise sense. It draws distinctions: between blue and goluboy, between left and north, between John broke the vase and the vase broke itself, between time-as-horizontal and time-as-vertical. It establishes identity criteria: the criteria that determine when two experiences count as instances of the same category, whether siniy and goluboy are the same color or different ones, whether now and earlier fall in the same or different temporal quadrant on the cardinal grid. And it maintains lawful relationships among its elements: the relational structure that connects spatial terms to each other, temporal terms to spatial ones, agentive constructions to causal attributions.

These distinctions, identity criteria, and lawful relationships constitute facts. The Russian speaker who has the siniy-goluboy distinction in their grammar has a cognitive fact that the English speaker lacks: these are two blues. Not as a label for a distinction they would make anyway but as a constituted perceptual reality that the grammar has produced. The Kuuk Thaayorre speaker who has the cardinal grid as their spatial grammar has a cognitive fact that the English speaker lacks: this body part is southwest. Not as a calculation performed on demand but as an immediately constituted feature of spatial experience.

Remainder is what each grammar leaves outside its scope. The English grammar constitutes one blue where the Russian grammar constitutes two: the distinction the Russian

grammar draws is remainder for the English grammar. The cardinal grid that the Kuuk Thaayorre grammar constitutes is remainder for the English grammar, which can access it only through deliberate calculation. Every grammar generates remainder at its boundary: the distinctions it does not draw, the identity criteria it does not establish, the relationships it does not maintain, all of which are cognitive facts that speakers of other grammars may have and speakers of this grammar lack.

4.2 Grammar-Relative Facts and the Language Uncertainty Principle

Semantic Remainder, the third paper in the CC-C companion suite, derived the Language Uncertainty Principle as a theorem within the closure framework: no finite linguistic closure can simultaneously minimize definitional and contextual remainder. Every word, sentence, and communicative act is a closure over semantic degrees of freedom with two irreducible dimensions. Maximizing definitional precision leaves contextual nuance as remainder. Maximizing contextual responsiveness leaves definitional precision as remainder. The tradeoff is structural and cannot be eliminated by any linguistic improvement.

Boroditsky's cross-cultural findings demonstrate the grammar-relative side of this theorem empirically. Different grammars minimize different kinds of remainder. Russian minimizes chromatic remainder in the blue domain by drawing the siniy-goluboy distinction. Kuuk Thaayorre minimizes spatial orientation remainder by requiring absolute cardinal reference for all spatial communication. Mandarin minimizes vertical temporal remainder by encoding temporal sequence in vertical metaphors. English minimizes none of these remainders in these domains but minimizes others: English encodes agent causation with unusual precision, minimizing agentive remainder in ways that Spanish does not.

Each grammar is a different tradeoff in the space of possible semantic closures. Each minimizes some remainder and generates other remainder. The 7,000 languages of the world are 7,000 different closures over the space of human experience, each constituting different facts, each generating different remainder. No single grammar constitutes everything. No grammar generates no remainder. The Language Uncertainty Principle holds for every grammar in every language: the tradeoff is structural, not linguistic.

5. Four Claims, One Structure

The vocabulary correspondence between Boroditsky's cognitive science and the closure framework is the most linguistically precise in the series. What Boroditsky calls a linguistic grammar, the closure framework calls a linguistic closure regime. What Boroditsky calls the cognitive differences between speakers of different languages, the framework calls the different facts constituted by different closures from the same sensory input. What Boroditsky calls the perceptual boundary between siniy and goluboy, the framework calls a closure distinction: a cognitive fact constituted by the Russian grammar that the English grammar leaves as remainder. What Boroditsky calls the spatial cognitive skills of Kuuk Thaayorre speakers, the framework calls the organizational capacity that develops when a closure requires certain distinctions to be maintained daily. And what Boroditsky calls the 7,000 cognitive universes created by 7,000

languages, the framework calls 7,000 different closure regimes over the space of human experience, each constituting different facts and generating different remainder.

5.1 The Chromatic Boundary Is a Constituted Fact

The siniy-goluboy boundary is not a pre-existing feature of the electromagnetic spectrum that Russian speakers noticed and English speakers missed. The electromagnetic spectrum is continuous: there is no natural boundary between siniy and goluboy any more than there is a natural boundary between the wavelengths we call red and orange. The Russian grammar draws a distinction within a continuous domain and thereby constitutes a cognitive fact: these are two different colors. That fact is real for Russian speakers in a way that cannot be reduced to the fact that they have two words. The perceptual processing speed difference demonstrates that the distinction is constituted at the level of perceptual organization, not merely labeled at the level of vocabulary.

This is the closure framework's account of how grammars constitute facts from sensory input: the grammar draws a distinction in the domain of experience, and the distinction becomes a constituted cognitive reality rather than a mere label. The distinction is the fact. The fact is grammar-relative: it exists for speakers whose grammar draws it and does not exist for speakers whose grammar does not. The world does not have two blues independently of any grammar. The Russian grammar constitutes two blues. The English grammar constitutes one. Both grammars are organizing the same sensory input and producing different cognitive realities from it.

5.2 Temporal Architecture Is Grammar-Constituted

The English speaker who thinks of time as horizontal and the Mandarin speaker who thinks of it as vertical are not choosing different metaphors for a pre-existing temporal reality. They are using different grammars that constitute time as having different spatial architectures. The horizontal or vertical orientation of time is not a property of time itself: time has no intrinsic spatial orientation. It is a property of the grammar that constitutes the temporal domain: a closure that draws the temporal-as-spatial distinction in a specific spatial direction.

Boroditsky's priming experiments demonstrate that this temporal architecture is not a superficial metaphor but a structural feature of temporal cognition. The response time differences show that temporal judgments are processed through the spatial architecture that the grammar has established. The Mandarin grammar has constituted time as a vertical domain and Mandarin temporal cognition runs on vertical processing. The English grammar has constituted time as a horizontal domain and English temporal cognition runs on horizontal processing. Different closures, different constituted temporal worlds, different cognitive architectures for navigating time.

5.3 Agency Attribution Is Grammar-Constituted Causation

The English grammar's tendency to assign agents to events and the Spanish grammar's tendency to represent accidents as things that happened rather than things that agents did are different closures over the causal domain. English draws a stronger boundary between intentional and accidental agency, constituting even accidents as agent-caused events. Spanish draws a weaker

agentive boundary, constituting accidents as events in which the agent is a patient rather than a cause.

These grammatical differences constitute different moral worlds. The English speaker who remembers agents of accidents more readily and attributes more blame to them is constituting facts about causation and responsibility that the Spanish grammar constitutes differently. Not because English speakers are more blaming by character but because the grammar they use draws the agentive distinction more sharply, constituting agentive facts that the Spanish grammar leaves as remainder. The moral world is grammar-relative. The closure framework names this grammar-relative constitution of causal and moral facts. Boroditsky demonstrates it with experimental precision.

5.4 The 7,000 Languages Are 7,000 Closures

Boroditsky's most expansive claim is that the world's approximately 7,000 languages create 7,000 cognitive universes: 7,000 different ways of experiencing time, space, color, causation, and the full range of human domains. The closure framework specifies this claim: the 7,000 languages are 7,000 different closure regimes over the space of human experience, each constituting different facts and generating different remainder.

No language constitutes everything. Every language leaves some distinctions unmade, some identity criteria unestablished, some relationships unarticulated. What one language leaves as remainder, another may constitute as fact. The chromatic remainder of English is the chromatic fact of Russian. The spatial remainder of English is the spatial fact of Kuuk Thaayorre. The temporal remainder of English is partly constituted by Mandarin. The causal remainder of English is partly constituted by Spanish. Across the 7,000 closures of the world's languages, different portions of the space of possible human experience are constituted as fact, and different portions are left as remainder.

What no language constitutes is M: the inexhaustible ground that every linguistic closure opens onto without exhausting. The remainder generated by any language is not the sum of the facts that other languages constitute. It is the residue that points beyond all linguistic closure toward what no grammar can fully capture. The 7,000 languages together constitute a rich and varied map of human experience, but the map is never the territory. The territory is M: the inexhaustible world that every grammar approaches and none exhausts.

6. The Connection to Semantic Remainder

The connection between Boroditsky's research and Semantic Remainder deserves specific attention because it is the most direct empirical grounding in the series for a paper in the CC-C companion suite.

Semantic Remainder derived the Language Uncertainty Principle as a theorem: no finite linguistic closure can simultaneously minimize definitional and contextual remainder. The theorem holds because definitional precision and contextual responsiveness are irreducibly distinct dimensions of semantic closure, and no finite closure can minimize both simultaneously. The

theorem was demonstrated across scientific communication, legal language, clinical medicine, and ordinary conversation.

Boroditsky's cross-cultural findings provide the empirical demonstration of the same principle from a different angle. Different languages minimize different dimensions of semantic remainder. Russian minimizes chromatic definitional remainder in the blue domain by drawing the siniy-goluboy distinction. Kuuk Thaayorre minimizes spatial orientation remainder by making absolute cardinal reference grammatically mandatory. Each choice minimizes some remainder and generates other remainder. The theorem holds across all 7,000 languages: every linguistic closure generates remainder in some dimension because no finite closure eliminates remainder in all dimensions simultaneously. The Language Uncertainty Principle is not a property of any particular language. It is a structural feature of all linguistic closure.

What Boroditsky adds to Semantic Remainder is the cross-cultural experimental demonstration that these different closure strategies produce measurably different cognitive worlds. The remainder generated by one grammar is not a mere absence. It is a positive cognitive fact in other grammars, accessible to speakers of those grammars in ways it is not accessible to speakers of the first. This mutual remainder relationship between grammars is the empirical face of the Language Uncertainty Principle: every grammar buys cognitive precision in some domain by incurring cognitive remainder in others, and the remainder of any grammar is some other grammar's constituted fact.

7. The Grammar of Language

There is an ant on your southwest leg. In Pormpuraaw, this sentence is as unremarkable as there is something on your left arm is in English. The child who hears it knows immediately which leg is meant, because the child's grammar requires knowing where southwest is at every moment, and the child knows. The Harvard academic who hears the same sentence in translation needs to pause, orient, calculate. The same spatial information, the same sensory world, two different cognitive realities constituted by two different grammars.

Lera Boroditsky has spent two decades following this observation across cultures and domains. Time that flows horizontally in English flows vertically in Mandarin and along the cardinal grid in Kuuk Thaayorre. Blue that is one color in English is two colors in Russian, perceptually, measurably, in milliseconds. Accidents that English grammar makes the agent's action are events that Spanish grammar makes things that happened to the agent. The 7,000 languages of the world are 7,000 different closures over the space of human experience, each constituting different cognitive worlds from the same sensory input.

The closure framework names the structure underlying all of these observations. A linguistic grammar is a closure regime: it draws distinctions, establishes identity criteria, and constitutes facts within its scope. Different grammars draw different distinctions and constitute different facts from the same world. What one grammar constitutes as a fact, another leaves as remainder. The remainder of English is the fact of Russian in the blue domain, the fact of Kuuk Thaayorre in the spatial domain, the fact of Mandarin in the temporal domain. No grammar constitutes everything. Every grammar generates remainder that points beyond it toward the inexhaustible world no grammar fully captures.

This is what Semantic Remainder derived formally: no finite linguistic closure can eliminate remainder. This is what the Grammar of Knowing established epistemologically: all knowledge is grammar-relative, all facts are constituted within grammars, and no grammar has access to absolute truth. And this is what Boroditsky has been demonstrating experimentally across cultures for two decades: the grammar constitutes the fact, the fact is grammar-relative, and the world presents differently to every grammar that engages with it. The grammar of language is the grammar of how any finite system of distinctions constitutes a world from what is given to it. Boroditsky mapped it across 7,000 languages. The closure framework names what she was mapping.

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Author's Note

This paper is the eleventh in a series engaging thinkers whose work converges with the closure framework developed in Consciousness, Closure, and the Cosmos. Lera Boroditsky is Professor of Cognitive Science at the University of California, San Diego, Editor in Chief of Frontiers in Cultural Psychology, and one of the world's leading researchers on the relationship between language and cognition. Her cross-cultural experimental work has provided the most extensive empirical demonstration available that linguistic grammars constitute different cognitive worlds from the same sensory input. This paper is the most directly linked in the series to an existing CC-C companion paper: Semantic Remainder derived the Language Uncertainty Principle as a theorem, and Boroditsky's cross-cultural findings provide the experimental demonstration that the principle holds across all human languages and produces measurably different cognitive realities as a consequence. Together, Semantic Remainder and this paper constitute a complete account of linguistic grammar as closure regime: one from formal derivation and one from cross-cultural experimental evidence. The author welcomes engagement from Boroditsky directly and from cognitive scientists, linguists, and philosophers of language who find the convergence between linguistic relativity and the closure framework either illuminating or contestable.