Logical Phonology carves a path toward the first truly modular account of I-language

Veno Volenec

University of Zagreb

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INTRODUCTION

- Main claim
  - Due to the recent development of Logical Phonology (Bale & Reiss 2018; Volenec & Reiss 2020; Leduc, Reiss & Volenec 2024; Gorman & Reiss 2025; *inter alia*), the functioning of the *entire* I-language can be formally described in set-theoretic terms
  - This in turn *explicitly* captures the idea that I-language is a cognitive module, an achievement that has eluded us so far
- What motivates this claim?
  - On the one hand, generative linguistics has claimed for a long time that language is a cognitive module, ultimately reducible to a neural module (see next page)
  - On the other hand, if I-language is indeed a module, then by definition its functioning needs to be expressible in terms of the *same type* of cognitive operations.
  - However, to date, no one has managed to demonstrate that this is the case!

INTRODUCTION

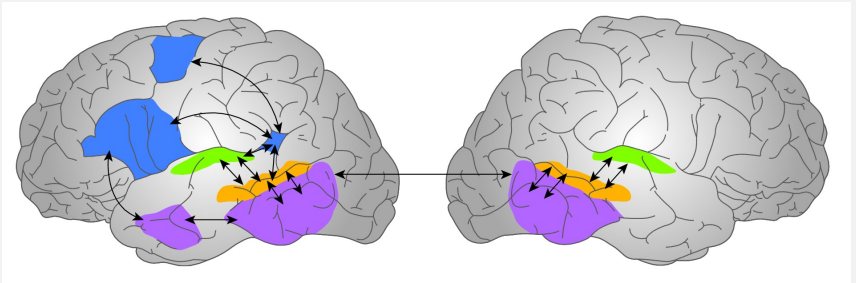
- I-language as a modular 'organ' of the mind/brain
  - "From the biolinguistic perspective, we can think of language as, in essence, an 'organ of the body,' more or less on a par with the visual or digestive or immune systems. Like others, it is a subcomponent of a complex organism that has sufficient internal integrity so that it makes sense to study it in abstraction from its complex interactions with other systems in the life of the organism. In this case it is a cognitive organ, like the systems of planning, interpretation, reflection, and whatever else falls among those aspects of the world loosely 'termed mental,' which reduce somehow to the organic structure of the brain." (Berwick & Chomsky 2016: 56)
  - "Every complex biological system we know is highly **modular** in its internal structure. It should not be a terrible surprise to discover that the human mind is just like other complex biological systems: that it is composed of interacting sub-systems with their specific properties and character, and with specific modes of interaction among the various parts. [...] When we look at a particular system, say language, we also find internal modularity. That is, we find sub-systems with their own quite specific properties interacting in highly determined ways." (Chomsky 1984: 16–17)

INTRODUCTION

- Research question & proposal
  - What formally unites I-language into a single **module**? Its reliance on **set-theoretic operations** applied to **uniquely linguistic representations** (phonological features, syllables, morphemes, etc.)
- Outline of the talk
  - What is modularity?
    - General properties of modules; cognitive & neural modularity; modules, submodules, interfaces; computation vs. transduction
  - Arguments and evidence for the modularity of the mind
    - Cognitive evidence, neurobiological evidence, linguistic evidence
  - How Logical Phonology helps to attain true modularity
    - Set-theoretic operations in syntax, semantics, and morphology; organization of LP
  - Consequences of modularity for Logical Phonology
    - Phonology is a substance-free computational module
    - There must be a phonology-phonetics interface; Cognitive Phonetics
  - Conclusion and further issues

MODULARITY OF THE MIND

- A module of the mind
  - A domain-specific, informationally encapsulated, hardwired cognitive system governed by principles that are not completely shared by any other part of cognition (Allott & Smith 2021)
  - Consists of a finite set of primitive, atomic symbols (basic **representations**) and a finite set of operations that manipulate those symbols (basic **computations**)
  - **Cognitive module** = a characterization of a faculty in terms of abstract computations and representations; 'functional', i.e., what it does and how it does it
  - **Neural module** = a characterization of a faculty in terms of brain structure and activity; 'physical'
    - I-language is a complex neural circuit/network in the large perisylvian region of the dominant hemisphere and a smaller perisylvian region of the non-dominant hemisphere (STG) (Kemmerer 2023; Hickok 2025)

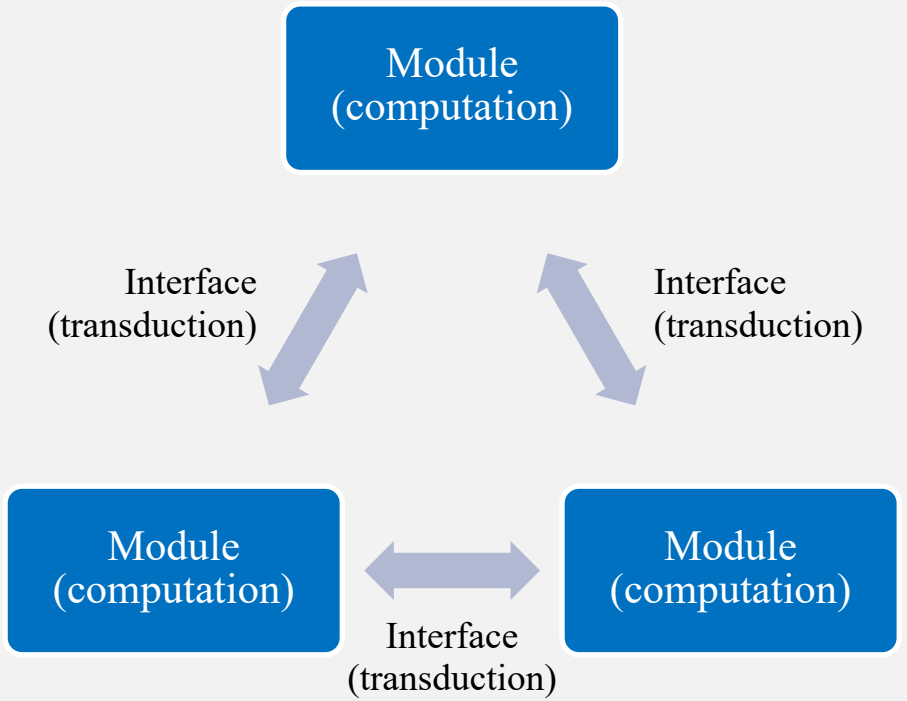


MODULARITY OF THE MIND

- General properties of modules
  (Fodor 1983; Collins 2017; Chomsky 2018; Allott & Smith 2021; Hulst 2024; Robbins & Drayson 2025)
  - **Domain specific**. Every module consists of a unique combination of computations and representations. Each module has a specific way of operating and deals with a specific type of information.
  - **Informationally encapsulated**. A module does not have direct access to any other module. Blind to the workings of other modules, each one operates independently. Modules communicate indirectly, through interfaces. The content of modules is inaccessible to conscious introspection.
  - **Fast and automated**. Since they are encapsulated and therefore need only access a restricted range of information, they operate quickly. They compute in an automatic and obligatory fashion, so they cannot be influenced by conscious command.
  - **Innate**. The general structure of a module is innate, determined biologically, and thus uniform across the species. This is why modules have a fixed developmental schedule. The particular peripheral aspects of modules are determined by experience during the course of the maturation of the organism.
  - **Hardwired**. A cognitive module corresponds to a fixed neural circuit. Modules are therefore subject to selective pathological breakdowns manifested as double dissociations.

MODULARITY OF THE MIND

- **Submodules** = modules within modules; may have a non-trivial hierarchical organization
- **Interfaces** = "intermodular bridges" (Pylyshyn 1984: 147) that allow modules to communicate; they transduce between the types of symbols that are uniquely characteristic of each module
- Modules compute, interfaces transduce
  - **Computation** = manipulation (reordering, regrouping, deletion, addition) of representational elements *within* a module, and *without* a change in the representational vocabulary
  - **Transduction** = conversion of an element in one representational vocabulary into a distinct vocabulary, i.e., a mapping between dissimilar types of representations



EVIDENCE FOR MODULARITY

- Evidence from cognitive science: dissociation between I-language and other cognitive systems
- I-language dissociated from:
  - acoustic processing (Burton et al. 2000; Phillips et al. 2000; Dehaene-Lambertz et al. 2002; Hamilton et al. 2021)
  - attention (Pulvermüller et al. 2008; Blank et al. 2014; Wehbe et al. 2021)
  - visual and spatial cognition (Curtiss and Yamada 1981; Emmorey et al. 1993; Bellugi et al. 2014)
    - prosopagnosia (impaired face recognition), achromatopsia (total color blindness), akinetopsia (motion blindness)
  - 'general intelligence' (Lenneberg 1967; Curtiss 1982, 1988a, 1988b, 1995, 2011; Smith & Tsimpli 1995; Smith et al. 2010)
  - non-linguistic communication (Corina et al. 1992; Willems et al. 2009; Grosvald et al. 2012)
  - arithmetic competence (Grinstead et al. 1997; Brannon 2005; Curtiss 2011)
  - social cognition (Karmiloff-Smith et al. 1995; Smith et al. 2010; Gernsbacher et al. 2016)
  - long-term non-linguistic memory (Scovile & Milner 1957; Kopelman & Morton 2005; Lum et al. 2012)

EVIDENCE FOR MODULARITY

- Evidence from neurobiology
- Segregation of neural circuitry (with possible ‘reuse’, cf. Anderson 2010); virtually uncontested
  - Modules correspond to fixed, typically localized and hierarchical, networks of neurons; neurons within a module are more interconnected than neurons between modules (i.e., interfaces)
  - Aphasias (Broca’s, Wernicke’s, conduction, etc.) are highly segregated and localized
- Advantages of a modular brain
  - Saves more energy because it sends electrochemical impulses over shorter distances (Gazzaniga et al. 2025)
  - More efficient because tasks can be solved in parallel by different parts of the brain (Bassett et al. 2015)
  - Facilitates learning and adaptation (incl. evolution) because each circuit can change independently from the rest of the brain (Meunier et al. 2010)
  - Augments brain’s resilience because parts of the brain can be disabled without the entire brain being disabled (Taleb 2014)

EVIDENCE FOR MODULARITY

- Evidence from linguistics (Volenec & Reiss 2025)
  - Logical Phonology deals with features such as [HIGH], [VOICED], [NASAL], etc.
  - [HIGH] correlates with the frequency of the first formant (F1)
  - The human auditory system (putative domain *general* mechanism) can discriminate between at least 1300 levels on a single frequency scale (Fastl & Zwicker 2013), so we would expect to have 1300 contrastive vowel heights; but there are at most five contrastive levels, and languages usually manifest only two or three (Gussenhoven & Jacobs 2017: 81); there are *never* more levels than that
  - The *observed* phonetic variability of vowels in terms of F1 is so vast (Hillenbrand et al. 1995: 3104) that we actually *could* have hundreds of vowel height levels; but we always have only a few contrastive levels
  - Features are domain specific units furnished by Universal Grammar (Reiss & Volenec 2022)
  - More broadly: phonology has a handful of discrete categories, despite the fine-grained perceptual sensitivity of the auditory system
  - I-language categories such as features, syllables, morphemes, negative polarity items, unaccusativity, case, etc. serve no role in any other cognitive domain; they are specific to the domain I-language

FORMALIZING THE MODULARITY OF I-LANGUAGE

- What unites I-language into a single module is reliance on set-theoretic operations applied to uniquely linguistic representations (features, syllables, morphemes, words, etc.)
- Syntax
  - "The structures of core I-language are generated by the simplest combinatorial operation, binary set-formation, MERGE"; "the core operation of I-language, also freely available from the *third factor toolkit*, is simple set-formation" (Chomsky 2024: 19, 21)
- Semantics
  - Sentence meaning follows from the syntactic structure, built by MERGE, and the meaning of individual lexical items in that structure (Pietroski 2018)
- Morphology
  - Distributed Morphology captures word-building with MERGE-style set-formation (possibly with some restrictions): "if the computational system is a combinatorial module where units are merged, then it should give an account of both syntax, which combines words, and morphology, which combines morphemes; [...] so words are actually built in syntax" (Fábregas & Scalise 2025: 4)

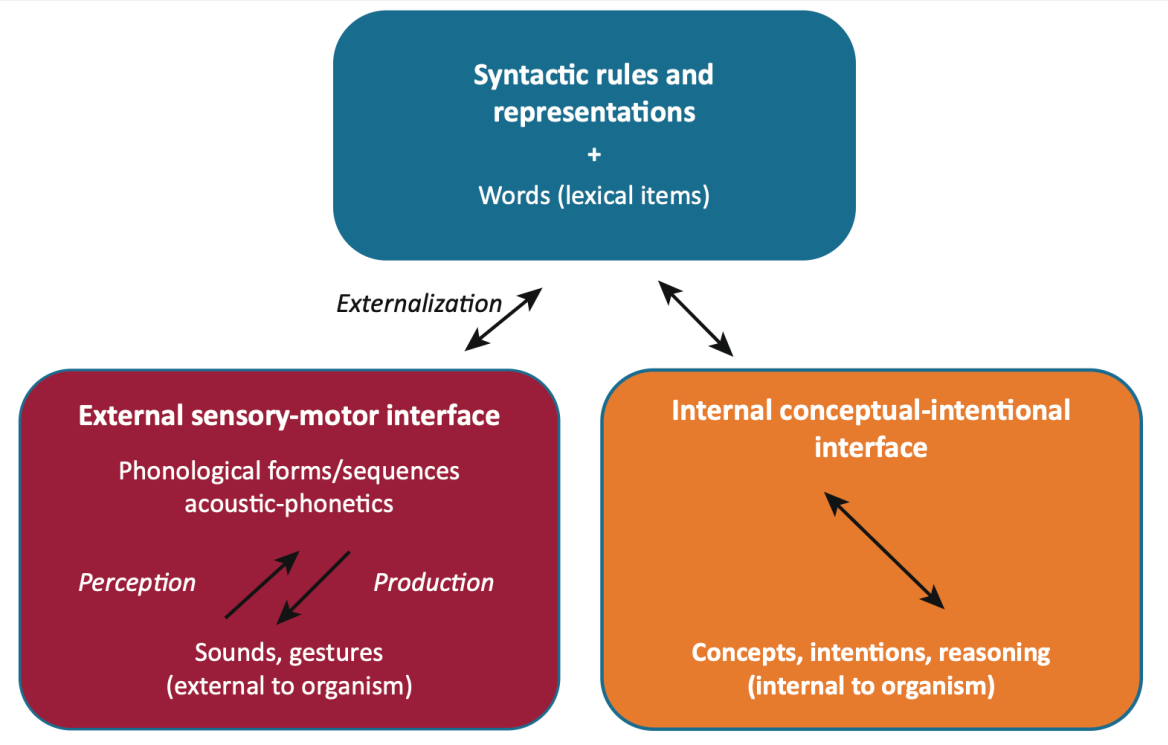
FORMALIZING THE MODULARITY OF I-LANGUAGE

- Logical Phonology
  - Sees the phonological module of I-language as a complex function connecting the underlying representation to the surface representation; computations are set-theoretic operations
  - Some proposed set-theoretic phonological operations
    (Bale & Reiss 2018; Volenec & Reiss 2020; Reiss 2021; Leduc et al. 2024; Gorman & Reiss 2025; *inter alia*)
    - Unification: If A and B are sets, then A ⊔ B results in the smallest set that contains all the members of A and all the members of B (Consistency: A ⊔ B cannot yield a set/segment that contains features of opposite values; it fails in that case, giving an unchanged output)
    - Subtraction: if A and B are sets, then A\B results in the set that contains all and only the members of A that are not members of B
    - Generalized intersection: the GI of a set of sets is the set of members that are in every set to which this operation applies
  - Representations are sets of elements: segments are sets of features; syllables are sets of sets of features; feet are sets of sets of sets of features...

IMPLICATIONS OF MODULARITY FOR PHONOLOGY

- Logical Phonology is a substance-free computational module of I-language
  - Due to informational encapsulation, phonology cannot be influenced by sensorimotor information, i.e., phonetic substance
  - To claim that it contains substance (e.g., formant values) is as incoherent as claiming that vision contains formant values or that the auditory system contains colors
- Logical Phonology communicates with the sensorimotor system via an interface
  - SRs built from features are not directly legible to the sensorimotor system, so transduction is required (just like sound waves are illegible to the brain, so the ear's interfaces need to transduce them into action potentials)
  - Cognitive Phonetics (Volenec & Reiss 2017; 2026, forthcoming): a theory of the phonology-phonetics interface; proposes two simple procedures that transduce between SRs and substance (not a module, but an interface; does not compute, it transduces)

IMPLICATIONS OF MODULARITY FOR PHONOLOGY



Berwick, Friederici, Chomsky, Bolhuis (2012: 3)

Morphosyntax
(computational **module**)

Morphosyntax-phonology **interface**

Logical Phonology
(computational **module**)

Phonology-phonetics
interface
(Cognitive Phonetics)

Sensorimotor system

Morphosyntax-semantics
interface

Conceptual-intentional system

CONCLUSION

- What **unites** I-language into a single **module** is its reliance on set-theoretic operations to build larger structures from primitive representational elements, and to manipulate (add, delete, reorder, regroup) the elements of those structures
- What **divides** I-language into **submodules** are:
  - the unique representational primitives of each submodule; e.g., phonology deals with phonological features, which are absent from all the other submodules
  - the particular properties of set-theoretic operations; e.g., syntactic MERGE is binary and recursive, which does not seem to hold true for phonological unification
- Further issues
  - What exactly are the modules of the mind? What are the (sub)modules of I-language? How to unify cognitive and neural descriptions of modular faculties?
  - What are the computations and representations of Logical Phonology? Which submodules does LP interface with and what is the nature of those interfaces?

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