

Revisiting the Syntax–Semantics Interface: Theoretical, Empirical, and Computational Insights

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ABSTRACT: The syntax–semantics interface has become a central focus in linguistics, as it explains how structural configurations shape meaning and how interpretation constrains syntactic possibilities. This review aims to synthesize theoretical, empirical, computational, and cross-linguistic perspectives to provide a comprehensive account of the interface. Findings indicate that generative and minimalist theories emphasize structural roles, while constructionist and distributional models highlight usage and context. Empirical studies reveal challenges for bilingual and heritage speakers, and computational approaches demonstrate the value of hybrid models bridging theory and data. The review contributes to advancing linguistic theory and practice by underscoring the need for integrative models that combine formal rigor, empirical validation, and cross-linguistic inclusivity.

Keywords: Syntax–Semantics Interface, Generative Grammar, Distributional Semantics, Bilingualism, Cross-Linguistic Variation, Computational Linguistics, Language Acquisition.



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INTRODUCTION

In contemporary linguistics, the study of the syntax–semantics interface has emerged as a key domain for understanding how linguistic structures encode meaning and how interpretations constrain syntactic possibilities. This interface is not only theoretical but also essential for explaining language processing, acquisition, and variation across linguistic contexts. The aim of this review is to provide a comprehensive synthesis of theoretical, empirical, computational, and cross-linguistic research on the syntax–semantics interface, with particular attention to underrepresented contexts such as bilingual and heritage speakers.

Over the past decades, multiple frameworks have attempted to explain the interdependence of syntax and semantics. Generative and minimalist approaches foreground the structural role of syntax in guiding meaning, while constructionist and distributional models emphasize the inseparability of form and context. Psycholinguistic and neurolinguistic studies provide empirical

evidence that syntactic complexity and semantic plausibility jointly influence comprehension outcomes. These findings underscore that language processing cannot be adequately explained by syntax or semantics alone.

At the same time, challenges persist. Ambiguity in argument structures, variability in cross-linguistic patterns, and context-dependent interpretations complicate the development of universal models. Bilingual and heritage speakers, in particular, highlight the complexities of mastering syntactic–semantic mappings in environments where linguistic input is uneven or fragmented. Such cases illustrate the need for integrative approaches that combine formal theories with empirical validation.

Recent advances in computational linguistics have further expanded the study of the interface. Distributional semantics and hybrid models such as Glue Semantics bridge theoretical constructs with large-scale data, enabling more precise modeling of ambiguity and variation. However, many frameworks remain limited in their ability to incorporate pragmatic, prosodic, and cognitive factors that shape real-world language use.

Given these developments, the present review seeks to move beyond descriptive summaries of existing models. It critically evaluates their strengths and limitations, highlights areas where theoretical and empirical insights converge or diverge, and identifies directions for future research. By situating the syntax–semantics interface within both structural and sociolinguistic contexts, the review contributes to a deeper understanding of how meaning and form co-evolve in diverse linguistic environments.

METHOD

The methodological framework for this review was designed to provide a comprehensive and systematic analysis of the literature concerning the syntax–semantics interface. Given the breadth of theoretical and empirical contributions in this field, the selection and evaluation of studies required a carefully structured process to ensure the inclusion of relevant, high-quality sources. The approach combined the use of established bibliographic databases, targeted keyword strategies, well-defined inclusion and exclusion criteria, and a thorough screening process to identify and synthesize the most pertinent contributions. This methodology reflects established standards in conducting narrative reviews in linguistics and cognitive science and is intended to maximize both the rigor and relevance of the resulting synthesis.

The first stage of the research involved the identification of databases most suitable for locating scholarly works related to syntax and semantics. Scopus and Web of Science were prioritized due to their comprehensive coverage of peer-reviewed journals, conference proceedings, and scholarly books across multiple disciplines (Boleda, 2020). These databases provided a strong foundation for retrieving high-quality publications that address both theoretical and empirical aspects of the interface. Complementing these resources, Google Scholar was also employed to broaden the scope of retrieval, particularly in capturing grey literature such as dissertations, working papers,

and research reports that may not be indexed in Scopus or Web of Science (Poletiek et al., 2021). The inclusion of Google Scholar was especially valuable in ensuring that emerging or less conventional perspectives were represented, thus minimizing potential publication bias and enhancing the inclusivity of the review corpus.

The process of data collection was guided by carefully selected keywords that reflect the core and peripheral dimensions of the syntax–semantics interface. The primary keywords included "syntax–semantics interface," "formal semantics," "generative grammar," and "logical form" (Poletiek et al., 2021). These terms were selected because they directly correspond to central constructs in linguistic theory and are widely used in scholarly discourse. To capture more specialized areas of inquiry, additional terms such as "argument structure" and "bilingualism" were incorporated into the search queries (Sheinfx et al., 2016). These keywords facilitated the identification of literature addressing specific challenges, such as the representation of argument structures or the manifestation of interface phenomena in bilingual and heritage language speakers. Boolean operators were employed strategically, combining terms with "AND" and "OR" to refine search results and ensure comprehensive retrieval across databases.

Inclusion and exclusion criteria were critical in shaping the corpus of reviewed studies and ensuring both relevance and quality. Only works that explicitly investigated the relationship between syntax and semantics were considered eligible. Articles with a tangential focus on syntax or semantics alone, without meaningful engagement with their interaction, were excluded. To maintain scholarly rigor, only studies published in peer-reviewed journals were included, thereby ensuring that the findings had undergone formal academic scrutiny. Furthermore, emphasis was placed on literature published within the last decade, reflecting the rapid theoretical and methodological advancements in the field. This temporal criterion ensured that the review incorporated the most up-to-date debates and findings, although earlier landmark studies were also considered where their inclusion was necessary for contextualizing contemporary developments.

The methodological approach of the studies under consideration also influenced inclusion decisions. Preference was given to empirical and experimental research that provided data-driven insights into the syntax–semantics interface, whether through psycholinguistic experiments, corpus analysis, or computational modeling. While theoretical works formed an important part of the review, studies that lacked empirical grounding or offered purely speculative accounts without methodological substantiation were deprioritized. This approach reflects the growing emphasis in linguistics on integrating theoretical constructs with empirical validation, thereby reinforcing the robustness of the conclusions drawn from the literature (Poletiek et al., 2021).

The screening and selection process was conducted in multiple stages. Initially, search results were screened at the title and abstract level to quickly eliminate irrelevant studies. Articles that passed this preliminary screening were then subjected to full-text review, during which their methodological rigor, thematic relevance, and theoretical contributions were evaluated in detail. This dual-stage screening ensured that only the most relevant and methodologically sound studies were retained. Throughout the process, the focus remained on identifying research that contributed to an understanding of the systematic interdependence between syntax and semantics,

whether by elucidating theoretical frameworks, providing psycholinguistic evidence, or exploring cross-linguistic and bilingual phenomena.

To enhance the reliability of the selection process, cross-verification was conducted by re-running searches across different databases using identical keyword sets. This step helped to identify potential gaps in retrieval and to ensure that no significant studies were omitted due to database-specific indexing practices. Additionally, bibliographic snowballing was employed by examining the reference lists of key studies, which proved effective in uncovering relevant works that did not appear in the initial keyword searches. This iterative and recursive process allowed for the construction of a comprehensive and representative corpus of literature on the syntax–semantics interface.

The final corpus included a balanced mix of theoretical analyses, empirical experiments, and computational models, reflecting the multidisciplinary nature of research at the syntax–semantics interface. Studies ranged from psycholinguistic investigations of real-time language processing to corpus-based analyses of argument structure and cross-linguistic comparisons of syntactic and semantic patterns. Importantly, works focusing on bilingualism and heritage speakers were deliberately included to expand the scope of the review beyond canonical contexts and to provide a more inclusive account of how interface phenomena manifest across diverse populations (Sheinflux et al., 2016). This breadth of coverage ensured that the review was not limited to mainstream linguistic traditions but instead accounted for the complexity and variability inherent in natural language.

In summary, the methodology of this review reflects a systematic and rigorous approach to literature selection and evaluation. By drawing on multiple databases, employing precise and contextually relevant keywords, and applying clear inclusion and exclusion criteria, the process ensured that the resulting synthesis is both comprehensive and credible. The emphasis on empirical and experimental studies provided a robust evidentiary foundation, while the deliberate inclusion of underrepresented contexts such as bilingualism and heritage speakers enriched the scope of analysis. This methodological framework positions the review to offer a nuanced and authoritative account of the syntax–semantics interface, one that acknowledges both theoretical complexities and real-world linguistic diversity.

RESULT AND DISCUSSION

The synthesis of the literature on the syntax–semantics interface reveals several major themes that illustrate the depth and complexity of this field of research. These themes encompass theoretical approaches, empirical perspectives, computational and distributional methodologies, and global cross-linguistic comparisons. Taken together, they offer a nuanced account of how syntax and semantics interact, how these interactions are studied empirically, and how they vary across linguistic, cultural, and cognitive contexts.

Theoretical Approaches to Syntax and Semantics

Theoretical models of the syntax–semantics interface continue to play a central role in shaping the field. Generative and minimalist approaches emphasize the primacy of syntactic structure in guiding semantic interpretation, proposing that meaning is derived systematically through formal operations in grammar (Wechsler, 2020). In this tradition, syntax is not merely a mechanism for arranging words but an active determinant of how propositions are interpreted. Empirical evidence suggests that the mapping of syntactic configurations onto semantic roles is neither arbitrary nor redundant but is deeply rooted in the architecture of grammar itself (Boleda, 2020). Morrill (2014), drawing from categorial grammar, underscores this point by demonstrating how type-logical frameworks allow for a precise mapping between forms and meanings, making explicit the logical relationships that underpin linguistic expressions. Such models provide the formal rigor necessary to account for phenomena such as quantifier scope, argument structure, and referential dependencies.

By contrast, constructionist and distributional approaches argue that syntax and semantics cannot be understood in isolation from their usage contexts. Boleda (2020) highlights that meaning often emerges from patterns of use, pointing to the inseparability of form and meaning within communicative environments. Borgonovo et al. (2014) extend this perspective by noting that constructions encode both syntactic and semantic information as holistic units, stored and retrieved as pairings that reflect conventionalized communicative practices. In this framework, the syntax–semantics interface is not a rigid mapping mechanism but a dynamic space where linguistic knowledge interacts with social, cultural, and pragmatic factors. Such perspectives underscore the necessity of integrating formal models with context-sensitive accounts of language use, thereby expanding the analytical scope of interface research.

Empirical Perspectives on Syntax–Semantics Interaction

Empirical research has significantly enriched theoretical debates by testing hypotheses about the syntax–semantics interface in real-time language processing and language acquisition. Experimental studies provide compelling evidence that the acceptability of sentences is influenced by both structural and interpretive factors. For instance, Li et al. (2025) investigated double object constructions among L1 Mandarin speakers learning English as a second language. Their results revealed that difficulties in processing syntactic rules were closely tied to semantic misinterpretations, indicating that failures at one level reverberate through the entire interface. This finding illustrates the interdependence of syntactic and semantic competence and suggests that acquisition trajectories are shaped by the interaction of these domains.

Heritage speakers and bilingual populations provide additional insights into how the syntax–semantics interface operates under conditions of linguistic variability. Jin et al. (2022) reported that heritage speakers often diverge from monolingual norms in their encoding of nominal reference, reflecting the influence of social and cultural contexts on linguistic competence. Their work demonstrates that the interface is sensitive not only to structural factors but also to the sociolinguistic environment in which speakers develop their linguistic abilities. Similarly, Lebkuecher and Malt (2021), studying Japanese–English bilinguals, found that second language experience can disrupt or reshape syntactic and semantic patterns in the first language. These findings emphasize that bilingualism introduces unique challenges at the interface, where

overlapping linguistic systems may create interference, adaptation, or hybridization in processing strategies.

The convergence of evidence from bilingual and heritage contexts underscores the importance of examining language processing beyond monolingual norms. It also highlights the diversity of outcomes that arise from differences in linguistic exposure, proficiency, and sociocultural environments. Collectively, empirical research demonstrates that the syntax–semantics interface is not a uniform system but one that reflects the variability of human linguistic experience.

Computational and Distributional Approaches

The rise of computational and distributional methodologies has further transformed research on the syntax–semantics interface. Distributional semantics, which represents word meanings as vectors in high-dimensional spaces, provides a powerful framework for modeling polysemy and compositionality (Boleda, 2020). By capturing usage patterns across large corpora, these models offer a data-driven means of quantifying semantic variation and predicting how syntactic contexts shape meaning. This approach demonstrates that polysemy is not merely a lexical phenomenon but emerges systematically from the interaction of syntactic frames and semantic interpretations.

Formal computational frameworks have also contributed to bridging the gap between theory and empirical data. Asudeh (2022), in his work on Glue Semantics, illustrates how compositional semantics can resolve ambiguities in quantifier scope without requiring multiple syntactic derivations. By integrating logical form with vector-based representations, computational models provide tools for analyzing ambiguity and dependency that are both mathematically rigorous and empirically testable. Similarly, Wechsler (2020) points to the potential of hybrid models that combine formal grammar with distributional representations, enabling a more complete account of the interface. These innovations suggest that computational approaches not only complement but also extend the reach of theoretical linguistics by grounding abstract claims in empirical generalizations derived from large-scale data.

The synergy between computational linguistics and formal theory highlights a broader trend in the field: the movement toward integrative models that can account for both structural precision and contextual variability. Such models are particularly valuable in capturing phenomena like semantic shift, argument structure alternations, and cross-linguistic variation, which resist explanation in purely formal terms.

Global and Cross-Linguistic Perspectives

Cross-linguistic research reveals significant variation in how the syntax–semantics interface is instantiated across languages, offering valuable insights into the universality and diversity of linguistic systems. Szabolcsi (2024) examines quantifier ambiguity across European languages, demonstrating that semantic interpretation often diverges according to language-specific syntactic configurations. These findings challenge universalist assumptions and highlight the need for models that can accommodate typological diversity.

Differences in tense and aspect marking further illustrate the variability of the interface. Woods (2015) contrasts English, which encodes temporal information morphologically, with Mandarin, which relies on aspectual particles. This divergence underscores how the same semantic categories

can be realized through fundamentally different syntactic strategies, with implications for both acquisition and processing. Such cross-linguistic comparisons highlight the multiple pathways through which languages reconcile syntactic structure with semantic interpretation.

Binding phenomena provide another arena in which cross-linguistic variation enriches our understanding of the interface. Zeng and Hua (2019) report that Japanese speakers face challenges in interpreting NP1 NP2 V constructions in Mandarin, a finding that suggests interface difficulties are not confined to individual languages but arise systematically in contexts of second language acquisition. These difficulties reveal how deeply entrenched syntactic conventions interact with semantic expectations, often creating persistent challenges for learners navigating multiple linguistic systems.

Global perspectives thus underscore the dual character of the syntax–semantics interface: while certain challenges, such as processing ambiguity or resolving quantifier scope, appear to be universal, the strategies employed to address them vary widely across linguistic traditions. This variation reflects not only structural differences but also cultural and cognitive factors that shape how languages encode meaning.

Synthesis of Findings

Across theoretical, empirical, computational, and cross-linguistic domains, a consistent theme emerges: the syntax–semantics interface is a dynamic and multifaceted construct that cannot be fully understood through a single methodological lens. Generative and minimalist frameworks underscore the structural foundations of meaning, while constructionist and distributional approaches highlight the importance of context and usage. Empirical studies demonstrate that processing at the interface is shaped by linguistic experience, particularly in bilingual and heritage contexts. Computational models offer formal tools for analyzing ambiguity and polysemy, while cross-linguistic comparisons reveal the diversity of strategies by which languages map structure onto meaning.

Together, these findings provide a comprehensive picture of the syntax–semantics interface as both universal and particular: universal in its centrality to language competence and communication, but particular in the ways it is realized across languages, speakers, and contexts. The evidence affirms that the study of this interface is indispensable for advancing linguistic theory, understanding language acquisition, and developing computational tools that reflect the complexity of natural language.

The findings of this review highlight both the strengths and the limitations of formal theories in capturing the complexities of the syntax–semantics interface. Traditional formal models, including generative and minimalist frameworks, have long posited that syntactic structures provide the scaffolding upon which semantic interpretation is built (Wechsler, 2020; Morrill, 2014). However, emerging empirical evidence points to a more intricate and dynamic interaction than initially envisioned. Poletiek et al. (2021), for instance, demonstrate that language learning processes are influenced by hierarchical and layered interactions between syntax and semantics, suggesting that linear models of the interface are insufficient to capture the reality of linguistic processing. This observation directly challenges traditional formalist accounts that prioritize simplicity and linearity, thereby pushing the field toward models that can accommodate layered complexity.

At the same time, there is evidence that supports the general principle of inseparability between syntax and semantics, a perspective central to minimalist thought. Sheinfx et al. (2016) provide compelling evidence that argument structure representation depends fundamentally on the integration of syntactic and semantic information. Such findings reinforce the claim that an independent treatment of syntax and semantics fails to account for how meaning is derived in natural language. Gotham (2018) further articulates this view, arguing that the separation of form and meaning cannot fully explain how compositionality operates in practice. Similarly, Bjorkman (2022) illustrates how cross-linguistic variation in tense interpretation poses challenges to formal theories that attempt to model temporality as a universal function. These tensions reveal that while formal models offer valuable explanatory power, they require continuous refinement to account for variability and context-dependent interpretation.

Beyond theoretical considerations, systemic factors also play a crucial role in shaping the syntax–semantics interface. Pragmatic influences, for example, directly affect how syntactic structures are interpreted. Giannakidou and Etcheberry (2018) argue that pragmatic mechanisms, including focus and presupposition, work in close collaboration with syntax to guide interpretation. Prosody further complicates this picture, as intonational contours often determine the pragmatic force of utterances, thereby reshaping the semantic interpretation of syntactic structures. These findings underscore that linguistic competence cannot be explained solely within the boundaries of syntax and semantics but must also incorporate pragmatic dimensions of language use.

Cognitive factors introduce yet another layer of complexity. Al-Thubaiti (2018) demonstrates that individual cognitive tendencies influence how speakers integrate syntactic and semantic information, with some learners relying more heavily on syntactic cues while others privilege semantic plausibility. Such differences highlight the role of cognitive processing biases in determining the accessibility and efficiency of the interface. These findings are particularly relevant for bilingual and heritage speakers, as studies by Jin et al. (2022) and Lebkuecher and Malt (2021) show that exposure to multiple linguistic systems can reshape cognitive strategies for navigating the interface. The inclusion of systemic factors thus enriches our understanding of the interface, suggesting that its functioning is conditioned not only by structural properties but also by pragmatic context, prosodic realization, and cognitive predispositions.

The integration of theoretical models with empirical findings and systemic perspectives paves the way for several recommendations aimed at advancing research on the syntax–semantics interface. One important direction is the development of hybrid models that combine the formal precision of generative grammar with the empirical richness of psycholinguistic data. Gotham (2018) points to the potential of Glue Semantics, which provides a framework for aligning syntactic derivations with semantic interpretations in a manner that accommodates ambiguity and contextual variation. This integrative approach addresses the shortcomings of purely formal or purely distributional models by ensuring that structural analysis is grounded in interpretive outcomes.

Another promising avenue is the expansion of cross-linguistic research. As Szabolcsi (2024) and Woods (2015) demonstrate, languages differ significantly in how they encode quantification, tense, and aspect, and these differences bear directly on the syntax–semantics interface. Comparative work such as that of Bouveret (2021), who analyzed Romance languages, underscores the value of examining diverse linguistic systems to uncover patterns that might remain invisible in single-

language studies. Such research contributes to a more comprehensive understanding of both universality and variation in interface phenomena, challenging theories to account for structural diversity without sacrificing explanatory coherence.

Equally critical is the role of experimental research in refining theoretical accounts. Studies by Dudschig et al. (2021), which investigated negation and polarity processing, illustrate how controlled experiments can uncover the cognitive mechanisms that mediate the interface. These insights are vital for testing hypotheses about the interdependence of syntax and semantics under conditions of real-time processing. Similarly, psycholinguistic studies such as those conducted by Poletiek et al. (2021) provide robust evidence that theoretical claims must align with the realities of language use. The continued incorporation of experimental methodologies into the study of the interface will thus enhance both the explanatory scope and the empirical grounding of theoretical models.

Despite these promising directions, current research remains constrained by several limitations. One persistent challenge lies in adequately modeling ambiguity, particularly when multiple interpretations of a single structure coexist. While Glue Semantics and categorial grammar offer partial solutions (Asudeh, 2022; Morrill, 2014), they often fall short of capturing the full range of variation observed across languages and contexts. Furthermore, much of the existing literature continues to focus disproportionately on major Indo-European languages, leaving the syntax–semantics interface in understudied linguistic systems underexplored. This limitation restricts the generalizability of findings and perpetuates a narrow view of interface phenomena. Cross-linguistic studies involving less commonly studied languages are therefore essential for expanding the empirical basis of the field.

Another limitation concerns the integration of pragmatic and prosodic factors into theoretical models. While research by Giannakidou and Etcheberria (2018) underscores the importance of pragmatics, formal accounts often struggle to systematically incorporate such influences. Similarly, prosodic factors remain underrepresented in interface modeling, despite evidence of their significant role in shaping meaning. Addressing these gaps requires the development of models that move beyond strictly syntactic and semantic boundaries to embrace a more holistic view of language as a multimodal and context-sensitive system.

Finally, the interplay between cognitive variability and linguistic competence represents an underexplored area of inquiry. Research by Al-Thubaiti (2018) suggests that individual differences in cognitive processing may significantly mediate interface outcomes, but further investigation is needed to determine how such differences interact with linguistic exposure, proficiency, and context. Studies that integrate cognitive science with linguistic theory, particularly in bilingual and heritage speaker populations, hold the potential to shed light on the adaptability and resilience of the interface under diverse conditions.

CONCLUSION

This review has synthesized theoretical, empirical, computational, and cross-linguistic perspectives on the syntax–semantics interface, underscoring its central role in linguistic theory and practice. The findings demonstrate that while generative and minimalist frameworks highlight the structural

underpinnings of meaning, constructionist and distributional approaches emphasize the inseparability of form and context. Empirical studies reveal that language learners, bilinguals, and heritage speakers navigate unique challenges at the interface, illustrating the variability introduced by linguistic experience and sociocultural context. Computational models have proven effective in bridging theory and data, offering new ways to account for ambiguity, polysemy, and compositionality. Cross-linguistic comparisons further reveal both universal principles and significant variation, challenging overly rigid models of language.

The urgency of continued research lies in the persistent challenges of modeling ambiguity, incorporating pragmatic and prosodic factors, and expanding analysis to less-studied languages. Policies and academic practices that prioritize inclusivity in linguistic research, particularly by integrating bilingual and heritage contexts, are essential. Future research should embrace hybrid models that integrate formal precision with empirical and experimental validation, alongside expanded cross-linguistic studies. By doing so, the field can move toward a more comprehensive account of the interface, one that not only advances theoretical understanding but also enhances practical applications in language acquisition, pedagogy, and computational linguistics. Addressing these issues is critical for strengthening the explanatory power of linguistic theory and for ensuring that the syntax–semantics interface is understood as both a universal and context-sensitive phenomenon.

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