Cognitive Load and Syntactic Complexity: A Cross-Linguistic Analysis of Sentence Processing

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Abstract

This study investigates the relationship between syntactic complexity and cognitive load during sentence processing across three typologically diverse languages: English, Hindi, and Mandarin. Using eye-tracking and self-paced reading experiments, we demonstrate that increased syntactic embedding correlates with higher cognitive load, but the degree of impact varies by language structure. .

Keywords: syntactic complexity, cognitive load, sentence processing, cross-linguistic, psycholinguistics, eye-tracking

Introduction

Syntactic complexity is a central construct in psycholinguistics, influencing how individuals comprehend and produce language. The cognitive demands imposed by complex syntactic structures—such as center-embedded clauses, nested dependencies, and long-distance dependencies—have been extensively studied in monolingual contexts. However, cross-linguistic comparisons remain underexplored, particularly in languages with divergent typological features.

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English, Hindi, and Mandarin represent three distinct syntactic profiles: English is largely analytic with fixed word order, Hindi is inflectional with relatively free word order, and Mandarin is isolating with topic-prominent structures. These typological differences may influence how syntactic complexity is processed cognitively.

This study aims to fill a gap in the literature by examining how syntactic complexity affects cognitive load across these three languages. We hypothesize that while increased syntactic embedding universally raises cognitive load, the degree and nature of this effect will vary based on language-specific syntactic and morphological features.

Literature Review

The relationship between syntactic complexity and cognitive processing has been theorized through models such as Gibson's (1998) Dependency Locality Theory (DLT), which posits that memory cost increases with the linear distance between dependent elements. Levy (2008) introduced a probabilistic approach, suggesting that processing difficulty arises from unexpected syntactic constructions.

Vasishth et al. (2010) extended DLT to Hindi, showing that postpositional cues mitigate memory load. In Mandarin, studies by Lin and Bever (2006) suggest that topic-prominent structures reduce processing difficulty by allowing early thematic role assignment.

Recent advances in psycholinguistics have emphasized the role of working memory, prediction, and frequency effects in sentence processing (Lewis &Vasishth, 2005; Futrell et al., 2015). However, most comparative studies have focused on Indo-European languages, leaving a gap in understanding how syntactic complexity interacts with cognitive load in non-Western languages.

Cross-linguistic research is essential to test the universality of processing models and to identify language-specific strategies that speakers use to manage syntactic complexity.

Methodology

Participants

Ninety native speakers were recruited: 30 each for English, Hindi, and Mandarin. All participants were university students aged 18–30, with no reported language or cognitive impairments. Participants were monolingual or dominant in their respective languages.

Materials

Stimuli consisted of 60 sentences per language, divided into three complexity levels:

- Simple: Single clause
- Moderate: One embedded clause
- Complex: Center-embedded or nested clauses

Sentences were matched for semantic content and length across languages. Lexical frequency was controlled using language-specific corpora.

Procedure

Participants completed two tasks:

1. Self-paced reading: Sentences were presented word-by-word on a computer screen. Reading time for each word was recorded.
2. Eye-tracking: Using Tobii TX300, fixation duration, regression count, and saccade patterns were measured.

Each participant read all 60 sentences in randomized order. Comprehension questions followed 20% of trials to ensure attention and understanding.

Data Analysis

ANOVA was used to compare reading times and eye-tracking metrics across complexity levels and languages. Post-hoc Tukey tests identified pairwise differences. Effect sizes were calculated using Cohen’s d.

Results

Self-Paced Reading

- English: Reading time increased significantly with complexity ($p < .001$).
- Hindi: Moderate increase; postpositions aided parsing ($p < .05$).
- Mandarin: Least increase; topic-prominent structure facilitated early role assignment ($p < .05$).

Eye-Tracking

- Fixation Duration: Longest in English complex sentences; shortest in Mandarin.
- Regression Count: Highest in English; moderate in Hindi; lowest in Mandarin.
- Saccade Length: Increased with complexity in all languages.

Statistical Summary

- Significant interaction between language and complexity level ($F(2,87) = 6.42$, $p < .01$)
- Post-hoc analysis confirmed English had the steepest increase in cognitive load metrics

Discussion

The findings support the hypothesis that syntactic complexity elevates cognitive load across languages, but the extent varies by typological features. English's rigid word order and reliance on syntactic cues make complex sentences harder to process. Hindi's inflectional morphology and postpositions provide parsing support, reducing cognitive strain. Mandarin's topic-prominent structure allows early thematic role assignment, minimizing processing difficulty.

These results align with DLT and probabilistic models, but also highlight the need for typology-sensitive theories. The implications extend to second language acquisition, where learners may struggle with syntactic constructions unfamiliar to their native grammar. For NLP systems, incorporating typological features could improve parsing and translation accuracy.

Limitations of the study include the relatively small sample size and the use of written stimuli only. Future research should include auditory processing and neuroimaging data to triangulate findings.

Conclusion

Syntactic complexity universally increases cognitive load, but language-specific features mediate this effect. Cross-linguistic psycholinguistic research is essential for developing comprehensive models of sentence processing. Future studies should expand to additional languages, including polysynthetic and ergative systems, and integrate multimodal data sources.

Conflict of Interest: The corresponding author, on behalf of second author, confirms that there are no conflicts of interest to disclose.

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