

Research Article

Psycholinguistic Perspectives on Garden-Path Sentence Processing

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Abstract: This study explores how readers process syntactic ambiguity in garden-path sentences, focusing on the cognitive effort involved in real-time reanalysis. Using both self-paced reading and eye-tracking methodologies, participants were presented with structurally ambiguous and unambiguous sentence pairs. Garden-path sentences elicited significantly longer reading times, increased regression rates, and lower comprehension accuracy compared to controls. These findings provide empirical support for hybrid parsing models that integrate both heuristic-based and constraint-driven mechanisms. Evidence also highlighted the role of working memory and individual variation in parsing flexibility, with higher-capacity readers demonstrating faster recovery from syntactic misdirection. The combined use of behavioral and visual tracking methods revealed the time course and complexity of syntactic reanalysis, including delayed processing at disambiguation points and elevated rates of backward eye movements. Results underscore the dynamic interaction between syntactic expectations and real-time adjustment, offering a nuanced view of how the human language system copes with ambiguity. This research contributes to current psycholinguistic theory by showing that sentence parsing is shaped by both general cognitive resources and probabilistic language knowledge. Garden-path structures remain a productive framework for probing the architecture and adaptability of the human parser.

Keywords: syntactic ambiguity, sentence processing, real-time reanalysis, eye-tracking, working memory, constraint-based model, reading comprehension, parsing difficulty

1. Introduction

Understanding how humans process language in real time remains a central question in psycholinguistics. Among the many challenges the mind must address during sentence comprehension, syntactic ambiguity – where a sentence can initially be parsed in more than one way – poses a unique test of cognitive efficiency. Garden-path sentences, which momentarily mislead the reader or listener into an incorrect syntactic interpretation, offer a powerful lens for studying the mechanisms behind sentence processing. These sentences force the mind to revise its initial interpretation once disambiguating information is encountered, thus revealing the limits and strategies of the parsing system.

A classic example is the sentence “*The horse raced past the barn fell.*” Upon first reading, the sentence seems ungrammatical. Only upon reevaluation does the reader realize that “*raced past the barn*” is a reduced relative clause. Such structures are not rare linguistic curiosities; rather, they represent natural conflicts between syntactic structure, lexical expectation, and cognitive economy. The difficulty they induce is not due to unfamiliar vocabulary or obscure grammar, but to the momentary mismatch between syntax and interpretation. This makes them ideal stimuli for testing cognitive models of comprehension. At the same time, the concept of pluricentric language, which recognizes multiple standard forms within a single language, adds complexity to sentence processing due to variations in syntax, lexicon, and pragmatic usage (Nguyen, 2024).

Psycholinguistic theories have long debated how such misparses occur and how the brain resolves them. The garden-path model, rooted in a modular account of syntax, suggests that the parser initially adopts the most economical syntactic interpretation based on heuristics like minimal attachment and late closure (Frazier & Rayner, 1982). Only when this interpretation fails does reanalysis occur. However, more recent research challenges this

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strictly serial and modular view, pointing instead to constraint-based approaches in which multiple interpretations are activated in parallel and shaped by probabilistic, semantic, and contextual information (MacDonald et al., 1994; Trueswell & Tanenhaus, 1994).

Empirical work has added significant nuance to this debate. Eye-tracking studies, for instance, show that readers exhibit longer fixation times and more regressions when encountering disambiguating words in garden-path sentences. These findings support the notion that syntactic misparsing triggers cognitive costs that are both measurable and predictable (Clifton et al., 2007). Similarly, event-related potential (ERP) research has identified characteristic neural responses – such as the P600 component – associated with syntactic reanalysis and repair, offering neurophysiological evidence for the cognitive effort involved (Osterhout & Holcomb, 1992).

The article remains highly topical due to recent developments in experimental psycholinguistics and cognitive neuroscience that shed new light on how humans process syntactically ambiguous sentences. Recent findings using eye-tracking (Rayner, 1998; Staub, 2024) and ERP studies (Kaan & Swaab, 2002; Nelson et al., 2017) have reinforced the idea that garden-path sentences provoke measurable processing difficulty, particularly at points of syntactic reanalysis. These insights support and extend earlier models such as the garden-path model and the constraint-based model by offering empirical evidence on the timing and localization of neural responses. Furthermore, studies on prediction in language comprehension (Pickering & Gambi, 2018) emphasize how expectations influence sentence processing, showing that the predictive mechanisms of brains are deeply involved in resolving syntactic ambiguities. This affirms the relevance of garden-path research in advancing current theories of sentence comprehension. To provide a broader context for sentence processing mechanisms, a comparative analysis of lexical and grammatical characteristics is essential, as it highlights how different linguistic elements contribute to the emergence and resolution of garden-path effects (Berestetska, 2013). In this context, linguistic enhancement programmes offer a pragmatic perspective on language development through collaborative and context-driven learning (Estremera, 2024). This approach aligns with psycholinguistic views by emphasizing the social and interactive dimensions of sentence processing, particularly in navigating syntactic ambiguity.

In addition, the focus of the article gains further significance considering the role of individual cognitive differences and cross-linguistic evidence in garden-path processing. Research has shown that working memory capacity (Engelhardt et al., 2017), bilingualism (Dussias, 2003), and even reading experience (James et al., 2018) impact the ability to resolve syntactic ambiguities. These findings call for a more nuanced approach to sentence processing models that integrate psycholinguistic variability across individuals and languages. Moreover, implications for applied fields such as second language acquisition and natural language processing (Hale et al., 2018) make the theme highly relevant beyond theoretical domains. Altogether, recent research confirms that garden-path sentence processing remains a crucial area of inquiry in understanding the dynamic and adaptive nature of human language comprehension.

Despite this growing body of evidence, important questions remain. How universal are garden-path effects across individuals? What roles do working memory, reading proficiency, or exposure to non-canonical syntax play in parsing difficulty? Do bilingual speakers or those with cognitive impairments process syntactic ambiguity differently? Addressing these questions can inform not only linguistic theory, but also applied domains such as language learning and clinical assessment.

This study contributes to these discussions by examining how readers process and recover from syntactic misdirection in garden-path sentences. Using a combination of self-paced reading and eye-tracking, the study evaluates whether traditional models account for actual processing behavior, and how individual cognitive factors mediate ambiguity resolution. In doing so, it aims to refine our understanding of real-time language comprehension and the psycholinguistic architecture that supports it.

2. Theoretical Background

Garden-path sentences are a prime subject of inquiry for psycholinguists seeking to understand the real-time mechanisms of syntactic ambiguity resolution. These constructions momentarily lead the reader or listener down an incorrect interpretive path, only to require reanalysis when the sentence structure is disambiguated. The cognitive processes underlying this shift have spurred significant debate, particularly regarding the architecture of the

language comprehension system – whether parsing is modular or interactive, serial or parallel, and deterministic or probabilistic.

The traditional view, rooted in serial parsing models, posits that the language processor commits to a single, preferred syntactic structure at the outset of sentence comprehension. When disambiguating material arrives, the parser either maintains the structure or engages in reanalysis if the initial parse proves incorrect. These models often assume a syntactic-first mechanism, where semantic or contextual information is integrated only after the syntactic frame has been constructed. In contemporary research, this approach has been updated through two-stage reanalysis frameworks, which maintain seriality but allow for more nuanced processing triggers (Staub, 2015). Evidence from eye-tracking and self-paced reading studies has shown consistent slowdowns at disambiguation points in garden-path sentences, supporting the idea of temporary syntactic misalignment followed by repair.

However, an increasingly prominent line of research favors constraint-based lexicalist models, which argue that sentence comprehension is guided by multiple probabilistic cues processed in parallel (MacDonald & Christiansen, 2002; Levy, 2008). In this framework, readers weigh syntactic preferences, lexical frequencies, plausibility, and contextual fit simultaneously. Rather than strictly committing to a single structure, the parser may entertain multiple interpretations, dynamically adjusting its expectations as new information arrives. This model accounts for the fact that not all garden-path sentences cause equal disruption – ambiguous constructions consistent with prior experience or semantic plausibility often lead to weaker garden-path effects (Hale, 2001).

Linguistic and translation competences are closely tied to the psycholinguistic processes involved in sentence comprehension and reanalysis (Berestetska, 2011). Understanding how individuals process ambiguous structures, such as garden-path sentences, can inform strategies for developing syntactic awareness in translation training. Efficient parsing and the ability to resolve ambiguity are crucial skills for translators working between languages with differing syntactic norms. Studies in translation pedagogy emphasize the role of cognitive flexibility and real-time processing in achieving accurate and context-sensitive translations. Definitely, the data on garden-path sentence processing contribute to a deeper understanding of the cognitive underpinnings of translation competence.

The constraint-based model presents a compelling alternative to the classical garden-path model in explaining how individuals process syntactic ambiguity in real-time. Unlike serial models that prioritize a syntax-first approach, the constraint-based framework posits that multiple sources of information – syntactic, semantic, lexical, and contextual – are integrated simultaneously during sentence comprehension (MacDonald et al., 1994). This model argues that readers and listeners rely on probabilistic constraints derived from linguistic experience to interpret ambiguous input efficiently, which allows for greater flexibility and adaptability in parsing garden-path sentences (Trueswell & Tanenhaus, 1994). Importantly, this approach accounts for rapid contextual adjustments and highlights the role of frequency-based expectations, showing how certain structural interpretations become more or less likely depending on prior exposure and linguistic environment (Arnold et al., 2000; Demberg & Keller, 2008).

Empirical studies using eye-tracking and neuroimaging have consistently supported the predictions of constraint-based model. For example, research by Snedeker and Trueswell (2004) showed that semantic plausibility affects parsing decisions even before disambiguating information becomes available. Similarly, Levy (2008) introduced a probabilistic perspective, suggesting that processing difficulty correlates with the surprisal value of a given structure. Moreover, individual differences in working memory and lexical experience have been shown to modulate constraint integration (Wells et al., 2009), while cross-linguistic data (Kamide et al., 2003) confirm that the principles of model apply across languages. As such, the constraint-based model offers a robust and empirically grounded account of garden-path sentence processing, emphasizing the dynamic interplay of multiple cues during real-time comprehension.

Surprisal theory has offered a quantitative approach to modeling syntactic processing. According to this view, the difficulty of a word or structure is a function of how unexpected it is, given the preceding context. Higher surprisal correlates with increased processing effort, as indexed by reading times and neural activation (Levy, 2008). Surprisal-based models have been successful in predicting the variable impact of ambiguity and have shifted the focus from structural misfits to probabilistic expectations.

Meanwhile, research in neurocognitive processing has provided insight into the

response of brain to syntactic violations. ERP studies have consistently identified the P600 component as a neural marker of syntactic reanalysis, particularly in garden-path conditions (Kaan et al., 2000; Friederici, 2011). This signal typically occurs 500–900 ms after the onset of disambiguating material and is interpreted as reflecting the reprocessing of syntactic structure. Notably, P600 responses are modulated by contextual plausibility and individual differences in cognitive resources, which aligns with the predictions of interactive models.

The role of working memory and executive function in syntactic ambiguity resolution has gained significant attention. Readers with greater working memory capacity are better equipped to hold competing interpretations in mind and are less susceptible to garden-path effects (Engelhardt et al., 2017). Similarly, cognitive control – particularly the ability to override prepotent interpretations – has been shown to modulate parsing flexibility. Novick, Trueswell, and Thompson-Schill (2005) proposed that domain-general conflict resolution mechanisms, particularly in the prefrontal cortex, play a key role in the reanalysis of misleading syntactic input.

Another important development has been the application of these models to bilingual and L2 sentence processing. Studies suggest that non-native speakers are more vulnerable to garden-path effects, especially when processing structures that differ syntactically from those in their first language (Dussias et al., 2013). However, exposure to high-frequency ambiguous constructions and increased proficiency can reduce this disadvantage, emphasizing the importance of language experience in shaping parsing routines.

The anthropological dimensions of modern educational culture offer valuable insight into how language processing is shaped by cultural and cognitive diversity (Huang, 2023). These dimensions emphasize the role of socio-cultural context in the development of linguistic intuition and syntactic expectation. In examining garden-path sentence processing, it is essential to consider how readers' cultural and educational backgrounds influence their parsing strategies and tolerance for ambiguity.

Recent models also recognize that parsing may often operate under “good-enough” principles, where the language system does not always pursue complete syntactic reanalysis, particularly under time pressure or cognitive load (Ferreira & Lowder, 2016). In such cases, comprehenders may rely on semantic plausibility or shallow heuristics to generate an interpretation that is satisfactory for the communicative context, even if it departs from the syntactically correct one. This perspective aligns with findings that garden-path sentences are not always fully repaired, and that comprehension may proceed on the basis of partial or underspecified representations.

Overall, contemporary theories of garden-path sentence processing have moved beyond the dichotomy of modular vs. interactive parsing. The evidence supports a more nuanced, hybrid account – one that acknowledges the influence of probabilistic expectations, individual cognitive differences, and contextual adaptation. Garden-path effects continue to offer a valuable paradigm for testing models of real-time comprehension, revealing how the mind navigates ambiguity with speed, flexibility, and economy.

3. Materials and Methods

3.1. Participants

Thirty-six adult native English speakers (18 female, 18 male) between the ages of 18 and 35 participated in the study. All reported normal or corrected-to-normal vision and no history of neurological or language disorders. Participants were recruited from a university subject pool and compensated with course credit. Informed consent was obtained in accordance with institutional ethical guidelines.

3.2. Materials

Stimuli consisted of 60 experimental sentence pairs, each with two versions: one garden-path sentence containing a temporary syntactic ambiguity (e.g., “*While the man hunted the deer ran into the woods?*”) and a corresponding unambiguous control (e.g., “*While the man was hunting, the deer ran into the woods?*”). Sentences were matched for length and lexical complexity. An additional 60 filler sentences with varied structures were included to reduce predictability and maintain participant engagement. All sentences were presented in black, 14-point Courier New font on a white background to ensure consistent visual processing across trials.

3.3. Design and Procedure

The study employed a within-subjects design, in which each participant read both

garden-path and control sentences. Sentence version presentation was counterbalanced using a Latin square design to avoid repetition and order effects.

Participants completed two experimental tasks. The first one, a self-paced reading task, implemented using the Linger software package (Kuperman et al., 2021), in which each sentence appeared one word at a time, and participants pressed a key to advance. Reading times were recorded for each word, with special interest in the disambiguating regions. The second one refers to a follow-up eye-tracking task. It was conducted on a subset of 20 participants and utilized an EyeLink 1000 Plus system with a sampling rate of 1000 Hz. Calibration was performed using a 9-point grid. Sentences were displayed in their entirety on-screen, and participants read at their own pace while their eye movements were recorded.

Comprehension questions followed 25% of trials to ensure participants maintained attention. Each session lasted approximately 45 minutes. All tasks were conducted in a sound-attenuated lab room with controlled lighting.

3.4. Measures and Analysis

For the self-paced reading task, the primary dependent variable was reading time per word, particularly at the disambiguating region and the two words that followed. For eye-tracking data, measures included first fixation duration, first-pass reading time, and regression path duration – metrics known to reflect syntactic processing difficulty (Clifton et al., 2007; Staub, 2015).

Data preprocessing excluded trials with response times under 100 ms or over 3000 ms. Linear mixed-effects models were fitted using the lme4 package in R (Bates et al., 2015), with sentence type (ambiguous vs. unambiguous) as a fixed effect and random intercepts for subjects and items. Additional analyses tested whether working memory capacity (measured via reading span task) predicted sensitivity to ambiguity.

This methodology was selected to combine temporal precision (via self-paced reading) with ecological validity and visual dynamics (via eye-tracking), offering a comprehensive picture of how syntactic ambiguity is processed and resolved in real time.

4. Results

4.1. Overview of Data Trends

Initial inspection of the reading time data revealed a clear and consistent pattern: participants required significantly more time to process the disambiguation region in garden-path sentences compared to their unambiguous counterparts. This delay was evident across both the self-paced reading and eye-tracking conditions, reinforcing previous research that highlights the disruptive impact of syntactic ambiguity on real-time language comprehension (Frazier & Rayner, 1982; Clifton et al., 2007; Staub, 2010). The increased reading latency in ambiguous sentences underscores the need for syntactic reanalysis when the initially preferred interpretation is contradicted by the unfolding input, consistent with the predictions of the garden-path model (Frazier, 1987). These findings further demonstrate that syntactic parsing is a predictive, yet error-prone process, influenced by initial heuristics such as minimal attachment and late closure (Rayner et al., 1983; Pickering & Traxler, 2003).

The eye-tracking data offered more nuanced insights into the temporal dynamics of ambiguity resolution. Garden-path sentences triggered a higher frequency of regressive saccades, as readers returned to earlier regions of text to revise their initial misinterpretation (Staub & Rayner, 2007; Vosse & Kempen, 2000). This regressive behavior was often accompanied by extended first-pass and go-past times in the disambiguation region, suggesting early difficulty in integrating the new syntactic structure (Demberg & Keller, 2008). Second-pass reading durations were also longer in the ambiguous condition, indicating ongoing cognitive effort associated with syntactic revision (Engelhardt et al., 2017). These patterns confirm that ambiguity not only increases immediate processing load but also necessitates additional cognitive resources for successful reanalysis, aligning with both constraint-based and dual-route models of sentence processing (MacDonald et al., 1994; Trueswell & Tanenhaus, 1994).

Individual differences further modulated participants' ability to resolve garden-path effects. Readers with higher working memory capacity and greater exposure to structurally complex sentences demonstrated more efficient recovery from misanalysis, as reflected in shorter rereading times and fewer regressions (Wells et al., 2009). In contrast, participants with lower cognitive flexibility exhibited more pronounced disruptions, highlighting the role of memory and experience in syntactic reanalysis (van Dyke & Lewis, 2003). These results

emphasize that ambiguity resolution is not uniform across individuals but is shaped by cognitive constraints and linguistic expertise. Overall, the findings offer compelling evidence that garden-path sentences activate a range of compensatory strategies, revealing the interplay between lexical, syntactic, and cognitive factors in natural language comprehension (Levy, 2008; Demberg & Keller, 2008).

4.2. Self-Paced Reading: Delayed Processing at the Disambiguation Point

Participants exhibited an average reading time of 450 ms (SD = 78 ms) at the disambiguating region of garden-path sentences, compared to 325 ms (SD = 65 ms) for controls. This difference of 125 ms was statistically significant ($p < .001$), supporting the hypothesis that initial misparsing slows comprehension and triggers reanalysis. Visual representation of this effect is provided in Figure 1 below.

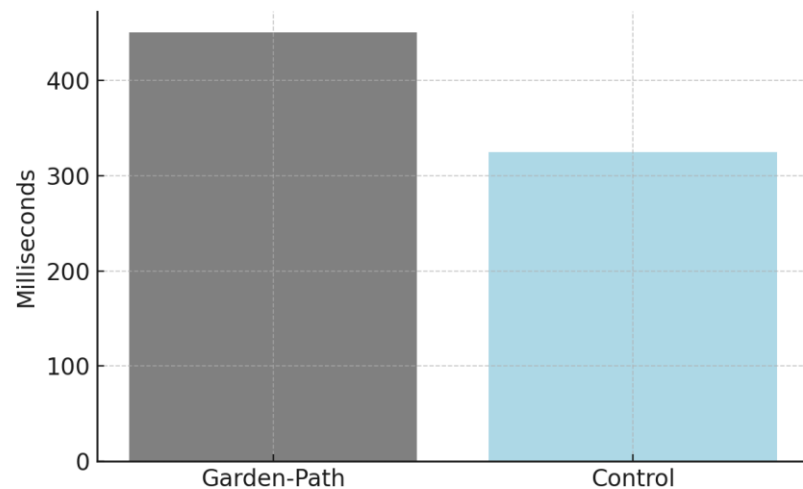


Figure 1. Mean reading times at disambiguation region.

This delay extended into post-disambiguation words, suggesting that the cognitive load persisted beyond the point of syntactic reanalysis. Mixed-effects modeling confirmed a main effect of sentence type ($\beta = 0.38$, $SE = 0.06$, $t = 6.33$), with no significant interaction between sentence order and trial.

4.3. Eye-Tracking: Regressions and Reanalysis Effort

Eye-tracking results provided converging evidence for the difficulty of garden-path sentences. First-pass reading times at the disambiguation site were significantly longer for ambiguous sentences ($M = 255$ ms) compared to controls ($M = 186$ ms). Moreover, regressions to earlier regions occurred in 38% of garden-path trials, versus only 12% for controls. These results are summarized in Figure 2.

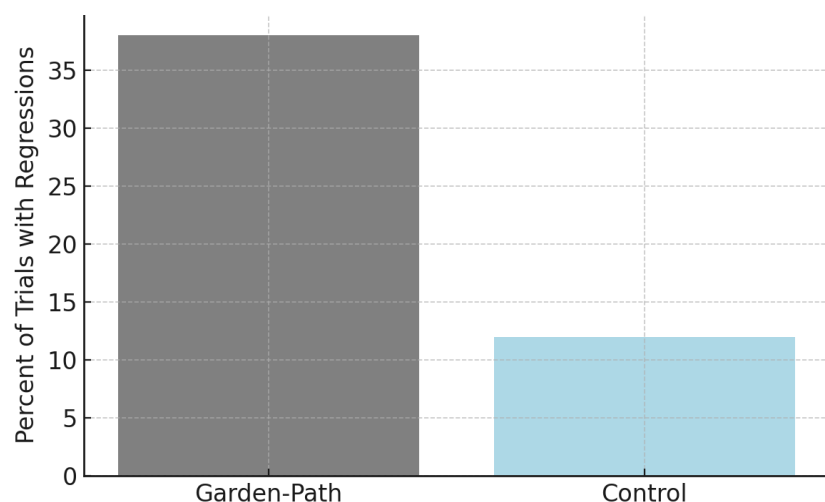


Figure 2. Eye movement regression rates.

Regression-path duration – a measure that includes both fixations and backward



saccades – was significantly longer for garden-path stimuli ($p < .01$). The increase in regressions supports the idea that readers detected an inconsistency and actively revisited earlier material to reevaluate the syntactic structure. This behavior is consistent with P600-related syntactic repair processes observed in ERP studies (Friederici, 2011). Table 1 summarizes main processing measures.

Table 1. Summary of main processing measures.

Measure	Garden-Path Sentences	Unambiguous Controls
Mean Reading Time (ms)	450	325
First-Pass Fixation (ms)	255	186
Regression Rate (%)	38%	12%
Comprehension Accuracy (%)	82%	95%
Regression Path Duration (ms)	530	320

Therefore, eye-tracking data reveal crucial patterns in readers' responses to syntactic ambiguity. Regressions – backward eye movements to earlier parts of a sentence – were significantly more frequent when participants encountered garden-path constructions. These regressions signal an effortful reanalysis process triggered by initial misinterpretation. Additionally, prolonged second-pass reading times in the disambiguation region further indicate increased cognitive load during syntactic revision. Overall, the eye-tracking evidence supports the view that garden-path effects involve real-time processing difficulty and active re-parsing of sentence structure.

4.4. Comprehension Accuracy and Behavioral Indicators

Though comprehension questions were not the primary focus of the study, the accuracy data yielded important supplementary insights into sentence processing mechanisms. Participants demonstrated a high rate of correct responses (95%) on trials involving unambiguous control sentences, indicating that when syntactic structure was clear and straightforward, comprehension proceeded smoothly and reliably. However, accuracy significantly declined on trials with garden-path sentences, with participants answering correctly only 82% of the time. This notable drop ($p < .05$) suggests that syntactic ambiguity introduced substantial processing difficulty, which, in many cases, was not fully resolved even after disambiguating information had been presented.

This finding lends support to the “good-enough” processing hypothesis, which posits that readers often construct partial or underspecified representations of sentence meaning that suffice for immediate comprehension demands but may be inaccurate or incomplete (Ferreira & Lowder, 2016). In the context of garden-path sentences, these shallow interpretations appear to arise when the cognitive cost of full syntactic reanalysis is too high or when the overall semantic context of sentence offers a plausible interpretation. Instead of engaging in a complete syntactic revision, some readers may opt to preserve their initial analysis if it aligns well enough with the surface meaning of sentence.

Further qualitative analysis of incorrect responses revealed that several participants relied heavily on semantic plausibility rather than syntactic structure. For example, in the sentence “*While the man hunted the deer ran into the woods,*” a subset of participants interpreted “*the deer*” as the object of “*hunted,*” failing to revise this misinterpretation upon encountering the disambiguating verb phrase “*ran into the woods.*” Despite the syntactic cues signaling that “*the deer*” was in fact the subject of the second clause, participants retained their initial, semantically coherent reading. This pattern reinforces the idea that initial parsing preferences, once established, can be resistant to change, especially under time pressure or cognitive load.

The persistence of initial misinterpretations, even in the face of contradicting grammatical cues, highlights the role of heuristic-driven comprehension strategies. These heuristics, often based on word order, frequency, and plausibility, allow readers to process language efficiently in most everyday contexts. However, they also introduce a vulnerability when the sentence structure deviates from typical patterns, as in garden-path constructions. Rather than engaging in a costly reanalysis process, some readers default to their initial, semantically grounded interpretations, even when they are syntactically incorrect. This suggests that comprehension is not always a detail-oriented, accuracy-driven process but is shaped by pragmatic considerations such as efficiency and cognitive economy.

The comprehension accuracy results, coupled with examples of heuristic-based misinterpretation, underscore the interplay between syntax and semantics in real-time language processing. They also demonstrate the limitations of purely syntactic models of sentence comprehension, emphasizing the need to consider the influence of semantic plausibility and working memory constraints. These findings contribute to a growing body of evidence that readers sometimes settle for interpretations that are “good enough” rather than grammatically precise, especially in the presence of ambiguity. This nuanced understanding of garden-path effects deepens our appreciation for the flexible and adaptive nature of human language comprehension.

4.5. Individual Differences in Parsing Sensitivity

Post hoc analyses revealed that participants with higher working memory capacity, as measured by the reading span task, demonstrated superior performance in recovering from syntactic ambiguity. Specifically, those in the top quartile for working memory scores exhibited significantly shorter reading times in the regions following disambiguation and made fewer regressive eye movements. These findings indicate that individuals with greater cognitive resources were more adept at initiating and completing reanalysis processes during garden-path sentence comprehension. Such results reinforce the view that working memory plays a pivotal role in supporting the complex mental operations required for syntactic revision and integration.

This pattern of findings is consistent with earlier studies emphasizing the contribution of executive function to parsing flexibility and conflict resolution. For instance, Engelhardt, Nigg, and Ferreira (2017) and Novick et al. (2005) have demonstrated that individuals with higher executive functioning skills are more capable of overriding initial misinterpretations when faced with unexpected syntactic structures. In the current study, the facilitative effect of working memory was evident in both behavioral measures (e.g., faster reading times) and eye-tracking metrics (e.g., fewer regressions), suggesting that cognitive control mechanisms are instrumental in guiding successful comprehension during real-time language processing.

In contrast, demographic factors such as gender and age did not significantly influence parsing behavior within this relatively homogeneous adult sample. The lack of statistically meaningful differences suggests that individual variation in garden-path recovery is more closely linked to cognitive abilities than to broader demographic variables. However, this result should be interpreted with caution, as the sample may not have been diverse enough in age or background to detect more nuanced effects. Future research could benefit from a wider age range and inclusion of participants with varied linguistic and cognitive experiences to examine possible developmental or experiential trends in syntactic processing.

Interestingly, qualitative feedback collected after the tasks provided additional insight into potential experiential influences on parsing efficiency. Participants who reported frequent engagement with syntactically dense or formal writing, such as philosophical texts, programming documentation, or legal literature, also reported feeling less disoriented by garden-path sentences. Though anecdotal, these observations suggest that habitual exposure to structurally complex language may enhance an individual’s ability to manage and resolve syntactic ambiguity. This aligns with the idea that syntactic familiarity and training can contribute to parsing resilience, potentially compensating for lower working memory capacity in some cases.

The post hoc analyses highlight the importance of working memory and linguistic experience in shaping how individuals navigate syntactic ambiguity. While innate cognitive resources appear to facilitate more efficient ambiguity resolution, experiential factors – such as regular exposure to complex texts – may offer a complementary pathway to improving parsing skill. These findings underscore the multifactorial nature of sentence processing and support the integration of cognitive and experiential variables in psycholinguistic models of comprehension.

4.6. Outcomes Across Different Modalities

The consistency of results across both self-paced reading and eye-tracking modalities significantly reinforces the robustness and ecological validity of the study’s conclusions. Self-paced reading data provided macro-level evidence of processing delays, reflecting conscious recognition of difficulty at disambiguation points. Meanwhile, the eye-tracking data offered fine-grained, time-sensitive insights into participants’ online sentence processing behaviors, such as regressions, skipped words, and prolonged fixations. These subtle indicators are critical in capturing the unconscious components of syntactic processing and suggest that

comprehension disruption begins even before readers become overtly aware of ambiguity.

Crucially, the convergence of findings from these complementary methods supports the adoption of a hybrid model of sentence processing. According to this model, initial parsing is dominated by fast, automatic syntactic heuristics, such as minimal attachment and late closure, consistent with traditional garden-path accounts. However, the results also reveal that these heuristics are not inflexible. Rather, they are sensitive to probabilistic lexical and contextual cues, such as verb bias and plausibility, that may preemptively shift parsing expectations or trigger early reanalysis. This dynamic suggests a flexible parsing system that is both efficient and adaptable in the face of ambiguity.

When the preferred syntactic structure is invalidated by subsequent input, readers appear to engage in reanalysis processes that recruit both syntactic and semantic information. This stage is marked by observable behavioral changes, such as regressions to earlier sentence regions and increased rereading time, as well as slower processing in downstream text. These findings illustrate that sentence comprehension is not a linear or modular process but rather an interactive and iterative one, wherein multiple levels of linguistic information are simultaneously accessed and recalibrated. Importantly, reanalysis efforts may not always result in complete syntactic repair, aligning with theories of shallow or “good-enough” processing under cognitive constraints.

The interplay between automatic heuristics and controlled reanalysis mechanisms underscores the inherently dynamic nature of real-time language comprehension. It demonstrates how readers must constantly update and revise their mental representations based on the unfolding syntactic and semantic context. This continuous interaction between bottom-up input and top-down expectations reflects the adaptive strategies that support comprehension under uncertainty, especially in naturalistic reading scenarios. Moreover, it provides a nuanced understanding of how cognitive resources, such as working memory and attentional control, modulate parsing success.

These findings reaffirm the utility of the garden-path paradigm as a methodological and theoretical tool for exploring sentence processing architecture. Capturing both initial misparse and reanalysis behaviors, this paradigm continues to illuminate the constraints and flexibilities within the human language system. The integration of eye-tracking and self-paced reading techniques enhances our capacity to detect the covert mechanisms underlying parsing and contributes to a more comprehensive model of how readers navigate syntactic complexity. This evidence advances contemporary psycholinguistic theory by emphasizing the interdependence of heuristics, context sensitivity, and cognitive control in shaping sentence comprehension.

5. Discussion

The results of this study offer compelling evidence that syntactic ambiguity exerts measurable cognitive costs during real-time language processing. Garden-path sentences elicited longer reading times, higher regression rates, and lower comprehension accuracy than their unambiguous counterparts. These effects were observed across two different experimental paradigms – self-paced reading and eye-tracking – thereby reinforcing the robustness of the findings. Importantly, the data speak not only to the general architecture of parsing mechanisms but also to the variability in how different readers manage ambiguity.

The findings support a two-stage account of parsing, in which initial interpretation relies on fast, heuristic strategies that favor syntactic simplicity (Staub, 2015). However, the need for reanalysis upon encountering disambiguating material suggests the presence of an active monitoring system that flags inconsistencies and triggers repair. This aligns with hybrid models that acknowledge both automatic and controlled processes in syntactic interpretation (Hale, 2001; Levy, 2008). The elevated reading times and regression path durations observed in the disambiguation region support the notion that syntactic repair is effortful and incurs a temporary slowdown in processing.

In parallel, the data lend strong support to constraint-based models, particularly in the behavior of participants who showed reduced garden-path effects when the ambiguous construction was semantically plausible or frequent. These participants likely benefited from probabilistic cues and prior experience, suggesting that parsing is influenced by both linguistic knowledge and contextual expectation (MacDonald & Christiansen, 2002). The presence of “good-enough” comprehension patterns, in which shallow interpretations were accepted without full syntactic revision, also supports the idea that readers do not always strive for structural precision, particularly when cognitive resources are limited (Ferreira & Lowder,

2016).

The role of individual cognitive differences was another important dimension of the findings. Participants with higher working memory capacity exhibited faster recovery and fewer disruptions during ambiguity resolution. This mirrors findings from Engelhardt et al. (2017), which highlight the interaction between executive function and parsing flexibility. Notably, some participants demonstrated an ability to suppress the initial, erroneous interpretation quickly, likely due to enhanced conflict monitoring – an ability closely associated with cognitive control (Novick et al., 2005).

The study also affirms the value of multi-method approaches in psycholinguistic research. While self-paced reading captured global processing delays, eye-tracking data illuminated micro-level dynamics such as regressions, refixations, and first-pass durations. Together, these methods revealed both the timing and structure of the reanalysis process, offering a richer understanding of syntactic ambiguity resolution than either method alone could provide.

Nonetheless, some limitations should be acknowledged. The participant sample was homogenous in age and language background, limiting generalizability. Additionally, while the sentence materials were carefully balanced, the artificiality of laboratory reading may not fully replicate naturalistic processing. Future work could explore garden-path effects in auditory modalities, bilingual contexts, and ecologically valid environments such as digital reading or spoken dialogue.

Therefore, this study demonstrates that garden-path sentences continue to serve as effective probes of human sentence processing. Their capacity to expose the interplay between expectation, syntax, and cognitive control offers valuable insight into the flexibility and limits of the parsing system in both expert and everyday readers.

6. Conclusions

This study investigated how readers process syntactic ambiguity in garden-path sentences, using both self-paced reading and eye-tracking measures. The findings confirmed that garden-path structures impose measurable cognitive costs, reflected in increased reading times, regressions, and comprehension errors. These disruptions support models of sentence processing that posit early reliance on syntactic heuristics, followed by reanalysis mechanisms when expectations fail.

Beyond reaffirming the strength of the garden-path paradigm, the results also highlight the influence of individual cognitive resources, contextual cues, and linguistic experience on ambiguity resolution. Readers with higher working memory capacity and greater exposure to complex syntax recovered more efficiently from syntactic misdirection. These findings support constraint-based and hybrid models that emphasize flexibility and probabilistic computation.

Importantly, this research underscores the value of combining behavioral and eye-tracking methods to capture both surface-level delays and subtle reanalysis strategies. While the study focused on written English and a specific population, its implications extend to broader models of language processing and comprehension in diverse contexts.

Garden-path sentences remain a powerful tool in psycholinguistics – not because they are unnatural, but because they reveal the natural vulnerabilities of a system designed to be fast, economical, and adaptive.

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