Rethinking Interface Vulnerability in L2 Acquisition

Chika Okada

1. Introduction

Traditional L2 acquisition theories predict that syntactic complexity determines difficulty (Anderson, 2004; Fang & Wang, 2025), yet this study reveals a counterintuitive pattern: syntactically simple quantificational reading (Q-reading) proves more difficult than syntactically complex sloppy reading (S-reading) for Japanese learners of English. Current frameworks generate competing predictions. The Interface Hypothesis (IH) (Sorace, 2011) and Bottleneck Hypothesis (BH) (Slabakova, 2008, 2013, 2019) predict parallel patterns since both interpretations involve identical syntax-semantics interface and morphology. In contrast, computational complexity frameworks (Reinhart, 2006; Slabakova et al., 2017) predict opposite patterns if processing cost determines difficulty independently. Picture identification results reveal S-reading shows successful acquisition despite syntactic complexity, while Q-reading shows persistent difficulty despite syntactic simplicity. The reaction time (RT)/accuracy dissociation provides evidence that computational complexity, not syntactic complexity or interface type alone, determines difficulty.

2. Background

2.1. Japanese and English Object Contrast

Understanding Japanese learners' acquisition of English object interpretation requires examining cross-linguistic contrasts. Japanese and English differ fundamentally in object realization and interpretation. Japanese permits extensive null object (NullObj) omission with flexible interpretations including quantificational readings through LF-copying mechanisms (Oku 1998; Takahashi 2008), where null arguments reconstruct full quantificational structure at LF[1]. In

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[1] Japanese NullObj permit Q-reading via LF-copying (Oku 1998; Takahashi 2008), where quantificational structure is reconstructed at LF, unlike overt pronouns requiring fixed discourse antecedents.

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contrast, English requires overt pronouns that systematically constrain interpretation: quantified contexts strongly prefer Strict reading through E-type interpretation (Elbourne 2005), while parallel possessive contexts favor Sloppy reading through structural parallelism (Fiengo & May 1994). This creates multi-faceted acquisition challenges. Japanese learners must produce overt pronouns (suppressing L1 NullObj), acquire possessive structures for S-reading, and critically, restrict Q-reading with overt pronouns—unlearning L1-licensed interpretations. Wakabayashi and Negishi (2003) found asymmetric difficulty: 73% correctly rejected ungrammatical subject omissions versus only 45% for objects, suggesting object properties pose particular challenges.

2.2. Theoretical Perspectives on L2 Difficulty

Current L2 frameworks generate competing predictions about acquisition difficulty. The IH (Sorace 2011) distinguishes internal (syntax-semantics (syn-sem)) interfaces from external (syntax-discourse (syn-disc)) interfaces, predicting greater syn-disc vulnerability. However, recent findings (Ivanov 2012; Rodríguez-Ordóñez & Sainzmaza-Lecanda 2018) show advanced learners achieving native-like performance at "vulnerable" syn-disc interfaces, suggesting computational demands, not interface type alone, determine difficulty. While the IH does not claim all internal interfaces are equally stable—indeed, Sorace (2011:25) explicitly asks "Are all internal interfaces equally stable?"—the framework does not specify what determines within-interface variability. The BH (Slabakova 2008, 2013, 2019) proposes functional morphology as the primary L2 bottleneck, though Slabakova (2019) broadened this to include any factor that suppresses acquisition. Both frameworks predict similar patterns for Q-reading and S-reading: identical interface type (syn-sem) suggests parallel vulnerability (IH), while identical morphology (simple pronouns) suggests parallel acquisition trajectories (BH). These convergent predictions create a clear expectation: if interface type or morphological complexity determines difficulty, both interpretations should show similar developmental patterns.

2.3. Computational Complexity as Alternative Framework

An alternative perspective focuses on computational operations rather than interface classifications or morphological features. Building on Slabakova et al. (2017), this study integrates three dimensions that determine processing cost: (1) operational architecture—Q-reading requires simultaneous processing with circular dependencies (scope resolution affects reference tracking, which affects coherence), while S-reading permits sequential processing where parallel structure provides scaffolding (Reinhart 2006); (2) information status and coherence—Q-reading processes new referential information requiring complex coherence through scope-negation interactions, while S-reading processes given information benefiting from automatic coherence through Resemblance relations (Kehler 2002); (3) referential accessibility—Q-reading exhibits low accessibility due to multiple candidate antecedents and quantified domains, while S-reading exhibits high accessibility through clear parallel mapping (Ariel 1990). These dimensions interact multiplicatively. When information is given, coherence automatic, and accessibility high (S-reading), sequential processing suffices. When information is new, coherence complex, and accessibility low (Q-reading), simultaneous processing becomes necessary, potentially exceeding working memory capacity (Just & Carpenter 1992; Caplan & Waters 1999). Critically, L1-L2 scope property differences may amplify computational demands. Japanese exhibits rigid surface scope (Kuroda 1965; Kuno et al. 1999) where word order determines scope relations, while English allows flexible scope via Quantifier Raising (May 1985)—for example, "The girl didn't read four books" permits both NEG > FOUR (surface) and FOUR > NEG (inverse) scope. This L1-L2 mismatch, combined with other high-cost factors (new information, low accessibility, circular dependencies), may compound processing burden. This framework predicts a processing paradox: Q-reading, despite syntactic simplicity, may prove more difficult due to high computational cost, while S-reading, despite syntactic complexity, may be acquired successfully due to low computational cost.

3. The Present Study

The frameworks reviewed above generate competing predictions. IH and BH predict similar patterns for Q-reading and S-reading based on shared interface and morphology, while computational complexity predicts opposite patterns based on differential processing demands.

3.1. Competing Theoretical Predictions

Current frameworks generate contrasting predictions. IH and BH predict Q-reading and S-reading should pattern similarly: IH predicts similar patterns because both involve syn-sem interface, less vulnerable than syn-disc (Sorace 2011); BH predicts similar patterns because both involve identical morphology (simple pronouns), morphology constituting primary difficulty locus while syntax/semantics are acquired easily (Slabakova 2008, 2013, 2019). Since learners acquire the same forms ("them," "his," "hers"), both should show similar acquirability. These convergent predictions create expectation: parallel developmental trajectories, similar accuracy patterns, comparable processing profiles. Divergence would challenge interface type and morphological complexity as sole predictors.

In contrast, computational complexity perspective generates different predictions. If computational burden determines difficulty, Q-reading and S-reading may show opposite patterns based on three interacting dimensions: (1) operational architecture (Reinhart 2006)—Q-reading requires simultaneous processing with circular dependencies where scope resolution affects reference tracking, while S-reading permits sequential processing with parallel structure scaffolding; (2) information status and coherence (Kehler 2002)—Q-reading processes new referential information requiring complex coherence through scope-negation interactions, while S-reading processes given information benefiting from automatic coherence through Resemblance relations; (3) referential accessibility (Ariel 1990)—Q-reading exhibits low accessibility due to multiple candidate antecedents and quantified domains, while S-reading exhibits high accessibility through clear parallel mapping. These dimensions interact multiplicatively. When information is given, coherence automatic, and accessibility high (S-reading), sequential processing suffices. When information is new, coherence complex, and accessibility low (Q-reading), simultaneous processing becomes necessary, potentially exceeding working memory capacity (Just & Carpenter 1992; Caplan & Waters 1999). This predicts a processing paradox: Q-reading may prove more difficult despite syntactic simplicity, while S-reading may succeed despite syntactic complexity.

3.2. Research Question and Hypotheses

The theoretical tension between these competing predictions generates the central research question: To what extent does computational complexity, rather than syntactic complexity or interface type, determine the acquisition difficulty of English object interpretation by Japanese learners?

IH and BH fail explaining persistent difficulty when interface is syn-sem (predicted stable), morphology acquired (no bottleneck predicted), yet difficulties persist differentially. If computational complexity determines difficulty independently, opposite patterns should emerge.

This study proposes two hypotheses. First, Q-reading will pose greater challenges than S-reading despite simpler syntax, due to computational demands: quantifier scope resolution with ambiguous interactions, scope-negation requiring simultaneous processing, reference determination under ambiguity, and suppression of L1 LF-copying favoring E-type strategies. Second, S-reading will show successful acquisition despite syntactic complexity, due to computational advantages: given information reducing cognitive load, automatic coherence through parallelism, high accessibility through parallel mapping, transferable universal principles.

If both are supported, three insights emerge: First, computational complexity, not syntactic complexity or interface type alone, determines difficulty. Second, findings distinguish constraint types: morphological bottlenecks (form-based, time-sensitive, acquirable) versus computational bottlenecks (capacity-based, proficiency-resistant, persistent). Third, semantic transparency can override structural complexity.

Traditional syntactic complexity accounts predict greater S-reading difficulty; computational complexity accounts predict greater Q-reading difficulty despite simpler syntax. If computational complexity determines difficulty, several patterns should emerge: Q-reading showing lower accuracy than S-reading despite simpler syntax, higher variance reflecting capacity constraints, similar RTs indicating representational rather than temporal constraints, and limited proficiency gains compared to S-reading's clear developmental trajectory.

4. Method

4.1. Participants

The study recruited 58 Japanese learners of English per group (aged 18-32) through a two-phase selection process to identify learners demonstrating both persistent L1 influence and developing L2 competence. From this initial pool of 116 learners, 64 participants proceeded to Phase 2: 32 beginners (Oxford Placement Test (OPT) *M* = 44.3) and 32 intermediates (OPT *M* = 68.1). Additionally, 32 native English-speaking controls (aged 18-54) completed the task via distributed online links.

4.2. Design and Materials

4.2.1. Phase 1: Pre-test for Participant Selection

58 Japanese learners of English per proficiency group completed an Acceptability Judgment Task using a 5-point Likert scale, contrasting grammatical overt pronouns against ungrammatical NullObj. The selection criterion required participants to score above 3.0 (scale midpoint) on null-object items, ensuring measurable L1 transfer effects while possessing sufficient English competence. Even intermediate learners showed residual acceptance of ungrammatical NullObj (cf. Wakabayashi & Negishi, 2003), confirming persistent L1 influence across proficiency levels.

4.2.2. Phase 2: Main Picture Identification Task

The main experiment employed a 3×3×2 mixed factorial design with Group (beginners, intermediates, native controls) as between-subjects factor and Interpretation Type (PN-reading, Q-reading, S-reading) and Object Type (overt pronoun, NullObj) as within-subjects factors. The task consisted of 24 test items (4 tokens per condition) distributed across four presentation lists using a 2×2 Latin square design.

4.3. Stimuli

Test sentences contrasted overt and NullObj conditions across three interpretation types.

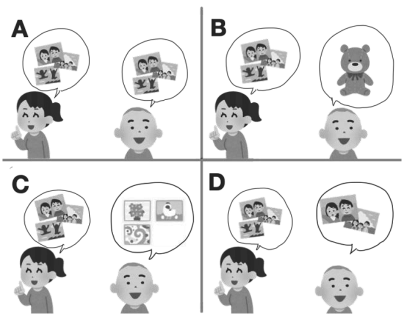
(1) NullObj/Obj+Q-: The boy read four books in the library, but the girl didn't read [them/Ø].
(2) NullObj/Obj+PN: Sarah found her keys, but David couldn't find [his/Ø].
(3) NullObj/Obj+S-: The boy picked up his toys, but the girl didn't pick up [hers/Ø].

All stimuli featured countable nouns with numerical quantifiers or possessives, simple action verbs, and parallel syntactic structures with contrastive subjects. Stimuli were presented bimodally (simultaneous audio and visual) using

AI voice synthesis balanced between male and female voices (50% each), with speech rate adjusted for comprehensibility based on piloting.

4.4. Procedure

Each trial followed a three-stage sequence: (1) participants heard and saw a context sentence simultaneously, (2) they then heard and saw the test sentence (also presented bimodally), and (3) they selected all pictures matching their interpretation. Participants were instructed to respond as quickly as possible while maintaining accuracy. No time limit was imposed; reaction time was measured from audio file completion (stimulus offset) to Enter key press confirming picture selections.



Picture interpretations:

A (S-): The boy didn't buy the same three postcards (4p)
B (Filler): The boy bought an unrelated item (0p)
C (Q-): The boy didn't buy any three postcards / bought a different set of three (2p)
D (Parallel reference): The boy bought his own postcards (1p)

Context sentence:"The girl and the boy were looking at postcards in a souvenir shop."
Test sentence (NullObj/Obj+Q-):"The girl bought three postcards, but the boy didn't buy [*them/Ø*]."

Figure 1. Trial structure and picture selection task with scoring criteria

Four picture options were displayed in a 2×2 grid with assigned point values reflecting proximity to native-like interpretation patterns. Participants selected all pictures matching their interpretation, revealing the full interpretation space. Total scores (0-6 points per trial) indicated how closely participants approximated native-like patterns. Reaction time outliers (±2.5 SD) were removed (~3% observations). Response accuracy and log-transformed reaction time were analyzed using mixed-effects models with random intercepts for participants and items.

5. Results

Response accuracy (total points per trial) and log-transformed reaction time were analyzed across three interpretation types (Q-reading, S-reading, PN-reading) in both grammatical overt object (Obj) and ungrammatical NullObj conditions. Mixed-effects models were specified as: Response/logRT ~ Group ×

InterpType + List + (1|Individual) + (1|Item), where Group (beginners, intermediates, native controls) and InterpType served as fixed effects, List controlled for counterbalancing, and random intercepts captured participant and item variation.

5.1. Interpretation Accuracy by Object Type

The Obj condition showed significant main effects of *Group* ($F(2,462) = 8.45$, $p < .001$) and *InterpType* ($F(2,1143) = 12.78$, $p < .001$), with significant interaction ($F(4,1143) = 3.88$, $p < .01$). All groups performed at high levels (>89%), though Q-reading showed wider variance (SD = 0.62-1.24) than S-reading (SD = 0.48-0.89), indicating interpretive instability despite high accuracy.

The NullObj condition revealed dramatically larger effects: *Group* ($F(2,462) = 167.33$, $p < .001$, η^2p = .420), *InterpType* ($F(2,1143) = 62.58$, $p < .001$, η^2p = .099), and interaction ($F(4,1143) = 33.68$, $p < .001$, η^2p = .105)—nine times larger than Obj. Q-reading collapsed catastrophically: only 6.2% of beginners achieved native-like interpretation (M = 1.29, SD = 1.48), a 90% decline from Obj's 96.1%. Intermediates improved to 26.6% (M = 2.24, SD = 1.89), a 70% decline. Beginner S-reading maintained 50% (M = 3.24, SD = 1.67), while intermediate S-reading showed 49.2% (M = 3.78, SD = 1.52). Q-reading exhibited bimodal distributions (variance: 2.19-3.57), indicating categorical failure, while S-reading showed uniform distributions suggesting gradual difficulty (Figure 2). Native speakers maintained distinctively high performance (Q: 94.5%; S: 86.7%).

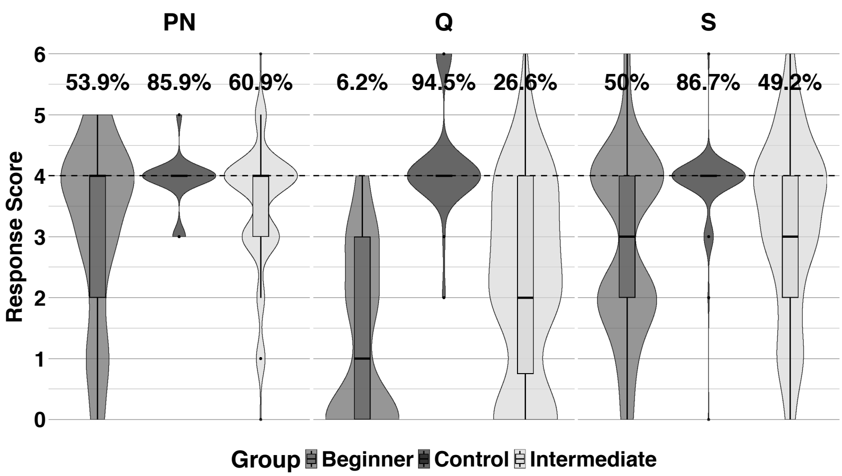


Figure 2. Response distributions for NullObj condition. Dashed line indicates baseline threshold (≥4). Percentages indicate proportion of responses at or above baseline for each group.

5.2. Reaction Time Patterns

Log-transformed RT analysis revealed no significant effects in either condition: *Group* (Obj: $F(2,462) = 1.18$, $p = .31$; NullObj: $F(2,459) = 1.22$, $p = .30$), *InterpType* (Obj: $F(2,1143) = 0.92$, $p = .40$; NullObj: $F(2,1138) = 0.87$, $p = .42$), and interaction (both ps > .59). Back-transformed means ranged from 2,707—2,883ms (maximum difference: 176ms), well within measurement variability (Figure 3).

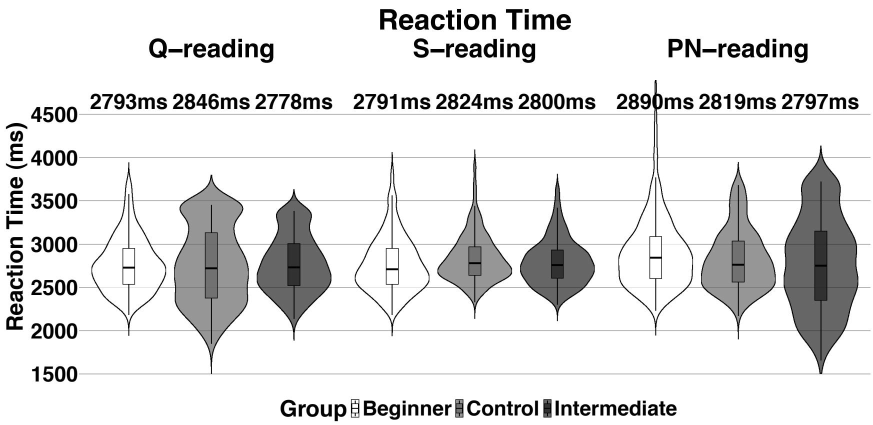


Figure 3. Reaction time distributions (Obj + NullObj). Numbers above each distribution show median reaction times (ms).

5.3. RT/Accuracy Divergence Pattern

The critical pattern emerges from RT/Accuracy comparison (Table 1). Q-reading showed catastrophic accuracy decline (beginner: 90%; intermediate: 70%) with minimal RT variation (maximum 5%), indicating representational rather than temporal constraints. S-reading showed moderate decline (beginner: 40%; intermediate: 50%) with similarly minimal RT changes (maximum 4.2%), demonstrating differential vulnerability despite identical L1 interference and processing times.

Table 1. RT/Accuracy Divergence Patterns

	Beginner		Intermediate		Control	
Measure	Obj	Null	Obj	Null	Obj	Null
Q-Accuracy	96.1%	6.2%	96.9%	26.6%	96.5%	94.5%
Q-RT (ms)	2739	2847	2849	2707	2883	2809
S-Accuracy	90.0%	50.0%	99.2%	49.2%	93.8%	86.7%
S-RT (ms)	2733	2849	2820	2780	2809	2839
PN-Accuracy	91.4%	53.9%	96.9%	60.9%	96.9%	65.9%
PN-RT (ms)	2809	2971	2781	2812	2759	2979

This asymmetric vulnerability, Q-reading's 90% decline versus S-reading's 40% decline in beginners, despite identical L1 interference, demonstrates computational complexity, not grammaticality or interface type, determines acquisition difficulty. The 8-fold interaction increase (η^2p: .013→.105) reflects multiplicative rather than additive effects. Power analysis[2] (>.89) confirmed non-significant RT results reflect genuine absence of processing differences rather than insufficient power.

6. Discussion

6.1. The Processing Paradox in L2 Pronoun Interpretation

Our findings reveal a paradox: beginner learners maintained 50.0% accuracy for syntactically complex S-reading while collapsing to 6.2% for syntactically simple Q-reading in NullObj contexts, despite identical L1 interference and grammatical violations. This asymmetric vulnerability contradicts syntactic complexity accounts (Anderson, 2004; Fang & Wang, 2025) predicting easier Q-reading. Both interpretations involve the same syn-sem interface yet show opposite acquisition patterns. The interaction effect increased 8-fold from overt (η^2p = .013) to null conditions (η^2p = .105), demonstrating multiplicative interaction between computational complexity and processing constraints rather than simple additive effects.

RT/Accuracy dissociation provides diagnostic evidence. Processing times remained equivalent across all conditions (2,732-2,856ms, <3.3% variation), yet accuracy diverged dramatically. Q-reading showed catastrophic decline (Beginner: 90%; Intermediate: 70%) while S-reading showed moderate decline (Beginner: 40%; Intermediate: 50%). Automatization deficits would produce longer RTs; instead, learners responded at normal speed with unstable representations. Q-reading's bimodal distribution (variance: 2.19-3.57 vs. 0.50 natives) contrasts with S-reading's gradual progression (2.79-2.31), indicating

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[2] Power analysis (G*Power 3.1; Faul et al., 2007) confirmed adequate sensitivity (power > .89) for detecting small effects given N=1,394 observations from 96 participants, indicating null RT findings reflect genuine absence rather than Type II error.

categorical representational failure rather than developmental delay. This within-interface variability (same interface, opposite outcomes) challenges interface classifications (Sorace, 2011) and demands finer-grained accounts of L2 difficulty.

6.2. Refining L2 Frameworks Through Computational Cost

Current L2 theory approaches acquisition difficulty from two perspectives. The IH (Sorace, 2011) predicts syn-sem interfaces are more stable than syn-disc interfaces, yet our data show dramatic within-interface variability: S-reading showed resilience while Q-reading collapsed, despite identical interface properties. The BH (Slabakova, 2019) expands potential bottlenecks beyond morphological features to include computational factors, yet does not specify how to distinguish them empirically. Sorace (2011:25) posed: "Are all internal interfaces equally stable?" Our data answer decisively: interface stability depends on computational cost of required operations, not interface type alone.

This study's framework distinguishes operations by computational cost rather than cognitive domain classification. Information status, coherence relations (Kehler 2002), and accessibility (Ariel 1990)—factors often associated with discourse processing—affect computational burden of any semantic interpretation regardless of interface type. Low-cost operations (S-reading: sequential processing of given information with automatic coherence and high accessibility) remain within capacity under adverse conditions; high-cost operations (Q-reading: simultaneous processing of new information with complex coherence and low accessibility) exceed capacity, creating bottlenecks. This cost-based framework integrates interface properties with processing constraints, explaining opposite patterns within a single interface type.

The current study interprets findings within capacity-based working memory frameworks (Just & Carpenter 1992; Caplan & Waters 1999) rather than experience-based accounts (MacDonald & Christiansen 2002). This study's design isolates computational capacity: same L1 background, proficiency levels, and syntactic structure, with only computational profiles differing. RT/Accuracy dissociation provides decisive evidence against experience-based accounts. Insufficient exposure would produce learning effects; instead, beginners succeed for S-reading while failing for Q-reading despite equivalent exposure. Q-reading's bimodal distribution indicates categorical failure: learners either achieve native-like interpretation or fail completely, reflecting capacity constraints where simultaneous maintenance of scope, reference, and coherence representations exceeds available resources. Correlation analyses confirmed RT and accuracy were uncorrelated (all $|r|$s $< .11$), supporting representational rather than temporal accounts. While our single-L1 design isolates computational complexity, L1-L2 scope property differences (Japanese rigid surface scope vs. English flexible scope) may amplify processing demands, warranting cross-linguistic investigation.

6.3. Theoretical and Practical Implications

The current study aimed to refine two major L2 acquisition frameworks by demonstrating computational cost, not interface type or morphological features alone, determines difficulty. Traditional IH (Sorace, 2011) posits interface type (syn-sem vs. syn-disc) determines vulnerability. This study proposes interface type determines which computational operations are required, while computational cost determines whether those operations create bottlenecks. This explains why not all syn-sem interfaces are equally stable: both Q-reading and S-reading involve syn-sem yet show opposite patterns. S-reading's low-cost operations (sequential processing of given information with high accessibility) remain within capacity; Q-reading's high-cost operations (simultaneous processing of new referential distinctions with low accessibility) exceed capacity, causing categorical failure.

Traditional BH (Slabakova, 2019) identifies multiple difficulty sources but does not specify how to distinguish them empirically. The current study proposes processing signatures distinguish bottleneck types. Morphological bottlenecks (TYPE 1) stem from missing features, showing slower processing, practice effects, and proficiency-sensitive improvement. Computational bottlenecks (TYPE 2) arise when operations exceed working memory capacity, showing RT/Accuracy dissociation (normal speed, low accuracy), limited practice effects, and proficiency resistance. Our Q-reading data exemplify Type 2: bimodal distribution indicates categorical failure, with modest proficiency gains but persistent difficulty at intermediate levels. This contrasts with morphological bottlenecks producing steady gains.

7. Conclusion

L2 acquisition difficulty cannot be reduced to syntactic complexity or interface type alone. The Q-reading paradox reveals computational cost's critical role: learners maintain moderate S-reading accuracy (50%) despite syntactic complexity while showing Q-reading failure (6.2%) despite syntactic simplicity. RT/Accuracy dissociation confirms difficulty reflects capacity constraints rather than automatization deficits. Integrating IH and BH through computational cost, the current study's framework moves beyond cataloguing what is difficult to explaining why and how difficulty manifests based on computational demands.

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