Syntactic or Overloading? Adverbial Effects on the Processing of *that*-Trace Structures in L1 and L2 Grammars

Kasumi Takahashi and Yuichi Ono

1. Introduction

This study explores the interplay between structural constraints and cognitive load in the real-time comprehension in both first language (L1) and second language (L2) grammars. Specifically, we examine how L1 English speakers and Japanese learners of English (JLEs) process adverbial interventions in *that*-trace structures. The *that*-trace effect refers to the phenomenon in which the complementizer *that* cannot be followed immediately by a subject gap (e.g., Chomsky & Lasnik, 1977; Perlmutter, 1971), as illustrated in (1b).

(1) a. What/who do you think ___ broke the window?
b. * What do you think **that** ___ broke the window?
(Perpiñán & Putnam 2024: 7)

Example (1b) illustrates a *that*-trace violation, in which *what* is extracted from the embedded *that*-clause and moves to the main clause. If the overt complementizer *that* is omitted, the subject can be extracted, as shown in (1a). Notably, the *that*-trace violation is ameliorated when an adverbial is placed between the complementizer *that* and the subject gap. This ameliorating effect of intervening adverbials is well-known as the adverb effect (e.g., Bresnan, 1977; Culicover, 1993), as shown in (2).

(2) a. * Who does John think **that** ___ served as president?
b. Who does John think **that** *for all intents and purposes* ___ served as president? (Brillman & Hirsch 2016: 6)

In (2b), the adverbial phrase *for all intents and purposes* intervenes between *that* and the subject gap, which ameliorates the ungrammaticality of the *that*-trace sentence observed in (2a). To account for the *that*-trace effect and its amelioration

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via adverbial intervention, two compelling explanations have been proposed: a syntactic approach (e.g., the anti-locality constraint) and a non-syntactic approach (e.g., processing- or production-based accounts). Although previous studies have investigated these analyses in the context of L2 grammar, most have relied on offline judgment tasks, even those advocating for processing-based accounts.

To address this gap, this study examines whether L2 learners activate syntactic knowledge online or rely on general cognitive resources, using an adverbial intervention in a *that*-trace structure as a diagnostic test. We conducted three experiments with native English speakers (NSs) and JLEs: (i) an acceptability judgment task (AJT) that manipulates adverb type (sentential vs. manner) and its position (sentence-initial vs. sentence-final); (ii) a second AJT manipulating adverb type and the presence of the complementizer *that* to test whether adverbial intervention ameliorates the *that*-trace effect; and (iii) a self-paced reading task (SPRT) to measure word-by-word reading times. Based on findings from the combined offline and online experiments, we discuss whether adverbial intervention modulates the processing of *that*-trace structures and how such effects elucidate the interaction between structural knowledge and the general processing burden in L1 and L2 grammar.

2. Previous studies

A recent syntactic account of the *that*-trace effect is based on the anti-locality constraint, which prohibits a movement that is too short (e.g., Bošković, 2016; Erlewine, 2020). The central claim is that the subject in the embedded clause moves from Spec-TP to Spec-CP to escape the C phase. This movement crosses only one maximal projection, thereby violating the anti-locality constraint and resulting in the *that*-trace effect. The anti-locality constraint also explains the ameliorating effects of intervening adverbials (i.e., the adverb effect), in which the ungrammaticality is ameliorated when an adverbial intervenes between the complementizer *that* and the subject trace. On the other hand, other theoretical accounts argue that the ameliorating effects of intervening adverbials arise not from purely syntactic/structural constraints but from non-syntactic factors (e.g., processing, prosody). In this view, the intervening adverbial just breaks an illicit adjacency between *that* and the subject gap (e.g., Perpiñán & Putnam, 2024). These opposing views raise the question of whether a syntactic account or a non-syntactic account better explains the *that*-trace effect in L2 grammar.

Previous L2 studies have addressed this theoretical question and provided mixed results regarding learners' sensitivity to *that*-trace violations. Kim and Goodall (2024) reported that two groups of L2 English speakers (L1-Korean and L1-Spanish, whose L1s do not exhibit *that*-trace violations) did not show sensitivity to *that*-trace violations in acceptability judgments. Similarly, Aldosari and Covey (2024) partially replicated Kim and Goodall's study, demonstrating that lower-proficiency Najdi Arabic learners of English, whose L1 displays the *that*-trace effect, were insensitive to *that*-trace violations, although sensitivity

developed with increased proficiency. These authors concluded that L2 learners' difficulty with *that*-trace structures is attributed to their limited capacity in cognitive systems (e.g., planning ability in sentence production). Thus, these studies support a non-syntactic approach to the *that*-trace effect in L2 grammar. On the other hand, Takahashi and Ono (in press) argued for a syntactic account of the *that*-trace and adverb effects. They found that Japanese learners of English, whose L1 does not display the *that*-trace effect, exhibited sensitivity not only to the *that*-trace violation, but crucially, to the ameliorating effect of intervening adverbials in acceptability judgments. Takahashi and Ono argued that these findings suggest that a universal constraint on syntactic movements (e.g., the anti-locality constraint) operates in L2 grammar.

Based on these findings, two academic gaps rise in the literature. First, previous studies have predominantly employed an offline method (e.g., AJT). In other words, few studies have examined online comprehension of *that*-trace sentences, which is surprising given that these non-syntactic approaches often rely on processing-based explanations. Therefore, it is crucial to test how L2 learners process these sentences in real-time, to unveil the validity of processing-based accounts. The second issue is involved with the adverbial amelioration effect on *that*-trace structures. Takahashi and Ono did not confirm whether JLEs know the base-generated position of an adverb in simple sentences, different from its behavior in complex embedded *that*-clauses. According to Brillman and Hirsch's (2016) anti-locality analysis, a sentential (or speaker-oriented) adverb ameliorates the *that*-trace violation, whereas a manner adverb does not, because only high-attaching adverbs intervene between the CP and TP and then obviate the *that*-trace violation. However, it remains unclear whether JLEs who exhibit sensitivity to adverbial amelioration effects distinguish the base-generated positions of these two adverb types. Specifically, a sentential adverb (e.g., *fortunately*) should canonically appear in the sentence initially, while a manner adverb (e.g., *carefully*) should be positioned in the sentence finally. To address these issues, we examine whether and how L1 English speakers and L2 learners exhibit sensitivity to the adverb intervention in *that*-trace structures in offline judgments and online processing, integrating offline and online measures with NSs and JLEs.

3. Experiment 1: An acceptability judgment task 1

3.1. Purpose and research question

Experiment 1 was designed to establish a baseline for the participants' knowledge of the structural relationship between adverb type and structural position in simple clauses. Before examining adverbial interventions in *that*-trace configurations, it is crucial to confirm whether NSs and JLEs are both sensitive to the well-documented distinction between sentential and manner adverbs, and their preferred positions. Thus, we address the following research question: Do JLEs distinguish between the preferred positions of a manner adverb and a sentential adverb in a simple clause?

3.2. Method

The participants in all experiments were 21 native English speakers (NSs) and 21 Japanese learners of English (JLEs). All JLEs were university students in Japan, and their English proficiency levels ranged from B1 to B2 on the CEFR, based on their TOEIC scores (TOEIC-IP program, Listening & Reading). NSs lived in the U.S. or U.K. at the time of testing and were recruited via Prolific. All experiments were implemented on the *Ibex Farm* (Drummond, 2013). The test stimuli were manipulated in a 2×2 factorial design: (i) *Adverb type* (Sentential vs. Manner) and (ii) *Position* (Initial vs. Final), as presented in (3).

(3) a. *Fortunately*, John cleaned the room. (Sentential-Initial)
b. ?? John cleaned the room *fortunately*. (Sentential-Final)
c. ?? *Carefully*, John cleaned the room. (Manner-Initial)
d. John cleaned the room *carefully*. (Manner-Final)

Sentential adverbs (e.g., *fortunately*) were predicted to be preferred sentence-initially as in (3a), whereas manner adverbs (e.g., *carefully*) were expected to be preferred sentence-finally as in (3d). Incongruent conditions (3b, c) tested participants' sensitivity to preferred positions of these adverbs. Eight tokens per condition were distributed across two lists (16 targets, 16 fillers each). Participants rated each sentence using a 5-point Likert scale (1 = *completely acceptable*, 5 = *completely unacceptable*) following four practice trials.

3.3. Results

Table 1 presents the descriptive results and Figure 1 illustrates them. The both groups exhibited the similar pattern in preference structure, favoring congruent combinations ([sentential_initial], [manner_final]) over incongruent combinations ([sentential_final], [manner_initial]).

Table 1. Descriptive statistics for each Condition by Group.

Group	Condition	M (SD)	95% CI
JLE	Manner_Final	4.24 (0.99)	[4.08, 4.41]
	Manner_Initial	3.03 (1.62)	[2.63, 3.44]
	Sentential_Final	2.89 (1.63)	[2.48, 3.30]
	Sentential_Initial	3.55 (1.34)	[3.32, 3.78]
NS	Manner_Final	4.70 (0.61)	[4.60, 4.80]
	Manner_Initial	3.03 (1.41)	[2.86, 3.20]
	Sentential_Final	3.13 (1.49)	[2.95, 3.31]
	Sentential_Initial	3.87 (1.17)	[3.68, 4.06]

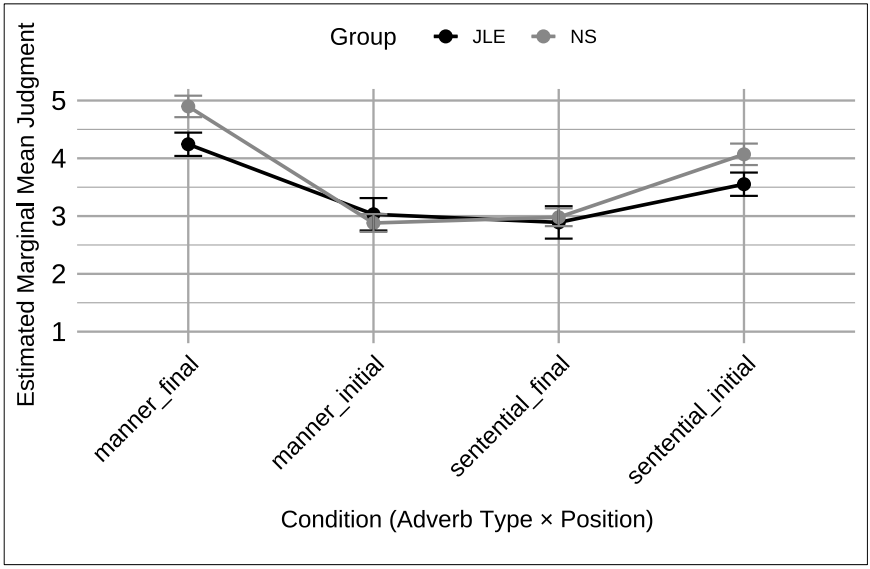

Figure 1. Results of Experiment 1.

The data were analyzed using a linear mixed-effects (LME) model (*lme4 package*; Bates et al., 2015) in *R* (R Core Team 2023, version 4.3.3). The converged model included *Condition* (adverb type × position), *Group* (NS vs. JLEs), and their interaction as fixed effects, as well as random intercepts for participants and items. It revealed significant main effects of *Group* (NSs > JLEs, β = 0.66, *SE* = 0.25, *t* = 2.65, *p* = .009) and *Condition* (*p* < .001), with the [manner_final] condition being the highest acceptability ratings, and a significant interaction between *Group* and *Condition* for the [manner_initial] condition (β = -0.81, *SE* = 0.38, *t* = -2.11, *p* = .037).[1] These parallel patterns across groups indicate that JLEs, like NSs, successfully distinguish between sentential and manner adverbs, which suggests that preferred syntactic positions are shared between NSs and JLEs. This finding establishes a critical baseline for subsequent experiments on the adverb amelioration effect of *that*-trace violations.

[1] Subsequent post-hoc comparison using *emmeans* confirmed that JLEs provided significantly lower acceptability than NSs specifically in the [manner_final] (ΔM = -0.66, *SE* = 0.25, *t* = -2.64, *p* = .009) and in the [sentential_initial] conditions (ΔM = -0.52, *SE* = 0.25, *t* = -2.09, *p* = .039).

4. Experiment 2: An acceptability judgment task 2

4.1. Purpose and research question

Experiment 2 tested the second question of whether JLEs are sensitive to the adverb amelioration effect and whether this effect exclusively emerges particular in sentential adverbs. Following the anti-locality account, and based on the findings of Experiment 1, JLEs are expected to exhibit an adverb amelioration effect only when sentential adverbs are inserted. Therefore, we address the following research questions: In embedded *that*-clauses, are JLEs sensitive to the adverbial amelioration effect, and does this amelioration effect exclusively emerge particular in sentential adverbs?

4.2. Method

The test stimuli were designed to test whether the intervening adverb ameliorates *that*-trace violations and whether the amelioration effect differs by adverb types. We employed the four target conditions, as shown in (4):

(4) a. Without *that* + Without adverb
What do you think __ will happen?
b. With *that* + Sentential adverb
What do you think **that** *unfortunately* __ will happen?
c. With *that* + Manner adverb
*/? Who do you think **that** *carefully* __ will handle the task?
d. With *that* + Without adverb (the *that*-trace violation)
* Who do you think **that** __ will handle the task?

(4a) served as the grammatical baseline, while (4d) represented the ungrammatical *that*-trace violation. Crucially, we compared sentential (4b) and manner (4c) adverbs: the anti-locality account predicts higher acceptability for (4b) due to structural intervention between CP and TP, whereas processing accounts predict no such difference. The experiment used 32 target items (8 per condition) and 24 fillers. Participants and procedure were identical to Experiment 1.

4.3. Results

Table 2 reports the descriptive results and Figure 2 illustrates estimated mean acceptability ratings.[2]

[2] Five participants whose baseline ratings of [Without *that* + Without adverb] were ≤ 3.0 were excluded as low-baseline outliers. In addition, four items were excluded based on distributional checks during screening. After trimming, the analyzed dataset contained 525 observations, with 45 participants and 46 items.

Table 2. Descriptive statistics by Group and Condition.

Group	Condition	M (SD)	95% CI
JLE	[Without *that* + Without adverb]	4.13 (1.05)	[3.91, 4.34]
	[With *that* + Without adverb]	3.36 (1.30)	[3.09, 3.63]
	[With *that* + Manner adverb]	3.08 (1.44)	[2.67, 3.48]
	[With *that* + Sentential adverb]	2.76 (1.27)	[2.40, 3.12]
NS	[Without *that* + Without adverb]	4.68 (0.90)	[4.48, 4.89]
	[With *that* + Without adverb]	2.70 (1.73)	[2.31, 3.08]
	[With *that* + Manner adverb]	2.34 (1.54)	[1.85, 2.83]
	[With *that* + Sentential adverb]	2.05 (1.36)	[1.62, 2.47]

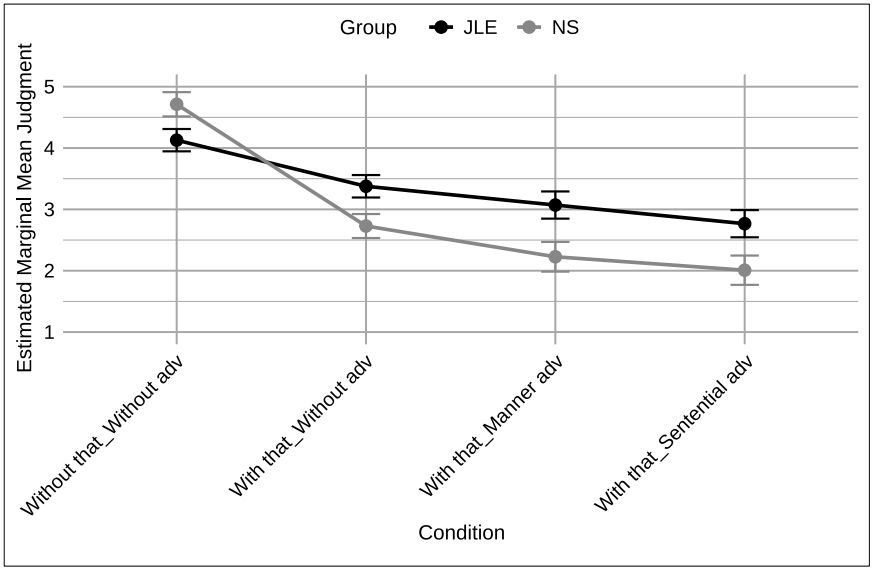

Figure 2. Results of Experiment 2.

Acceptability data were analyzed using an LME model that included *Group* (NS vs. JLE), *Condition*, and their interactions, along with random intercepts for both participants and items. The LME results revealed significant main effects of *Group* and *Condition* and a significant interaction between them. The [Without *that* + Without adverb] condition was rated the most acceptable than the others, with NSs providing overall higher ratings than JLEs ($\beta = 0.59$, $SE = 0.25$, $t = 2.31$, $p = .023$). Compared to [Without *that* + Without adverb], all conditions with *that* showed significant degradation ($ps < .001$). Crucially, adverb intervention failed to ameliorate *that*-trace violations, which is inconsistent with the results of Takahashi and Ono. Instead, sentential adverbs yielded the lowest ratings within each group ($\beta = -1.36$, $p < .001$). A significant interaction between *Group* and

Condition (*p*s < .001) was also observed, which indicates that the degradation associated with *that* was systematically significant for NSs than for JLEs.

5. Experiment 3: A self-paced reading task

5.1. Purpose and research question

To explore what causes the lack of adverb amelioration effect in offline judgments in Experiment 2, Experiment 3 examines how adverbial intervention affects online sentence processing, and whether this processing cost differs by adverb type and speaker group. If adverbial intervention in *that*-trace structures imposes a processing cost during real-time comprehension, then the unacceptability of sentences with adverb interventions observed in Experiment 2 would arise from processing difficulty in online processing. The research question is as follows: Does adverbial intervention in *that*-trace structures impose processing cost during real-time comprehension?

5.2. Method

The test stimuli were designed to target the processing cost of adverbial intervention in the embedded *that*-clause. These materials were identical in structure to those used in Experiment 2, and consisted of *wh*-questions involving subject extraction, as illustrated in (5).

(5) Examples of test stimuli and region setting:

a. Without *that* + Without adverb
Who | do | you | think | | | won | the | game | yesterday?

b. With *that* + Sentential adverb
Who | do | you | think | that | *unfortunately* | won | the | game | yesterday?

c. With *that* + Manner adverb
Who | do | you | think | that | *carefully* | won | the | game | yesterday?

d. With *that* + Without adverb (the *that*-trace violation)
Who | do | you | think | that | | won | the | game | yesterday?

Participants were presented with test sentences word by word in a non-cumulative moving-window design, in which each sentence first appeared as a series of dashes, and was then replaced by words from left to right every time the participant pressed the space bar. In this way, they read a total of 36 test sentences by pressing the space bar, followed by simple yes-no comprehension questions, which allowed them to concentrate on reading the sentences.

5.3. Results

Before data analysis, the comprehension accuracy rate with low baseline performance was removed. RTs shorter than 80 ms or longer than 5000 ms were

excluded, and then RTs out of ±3.0 SD were also removed as outliers.[3] The remaining RTs were log-transformed and analyzed using LME models. The converged model included fixed effects for *Group*, *Region*, *Condition*, and two-way interactions for *Group* × *Region* and *Region* × *Condition*, as well as random intercepts for participants and items.[4]

The results showed a significant main effect of *Region* ($p < .001$) but no main effect of *Group*, which indicates comparable overall RTs across NSs and JLEs. The interactions of *Group* × *Region* and *Region* × *Condition* were also significant ($ps < .001$). Crucially, no interaction was observed between *Group* and *Condition*, which suggests that both groups exhibited similar online sensitivity to intervening adverbs in *that*-trace structures.

As illustrated in Figure 3, three consistent patterns were observed: (i) the baseline condition without both *that* and adverb ([Without *that* + Without adverb]) yielded faster RTs than the other three conditions with *that*; (ii) illicit *that*-trace structures ([With *that* + Without adverb] condition) increased processing cost, mirroring the offline degradation found in Experiment 2; and (iii) both groups exhibited significant slowdowns in regions following inserted adverbs, particularly sentential adverbs. The overall patterns indicate that adverbial insertion does not facilitate online processing; instead, it appears to impose additional processing costs on both groups. These findings suggest an interplay between offline judgments and online processing, showing that reduced acceptability may be attributed to increased cognitive burden, particularly among L2 learners with limited processing resources.

[3] The final dataset contained 3601 observations, with 34 participants and 49 items.

[4] The formula is "logRT ~ Group × region × Condition + (1 | subject) + (1 | item)."

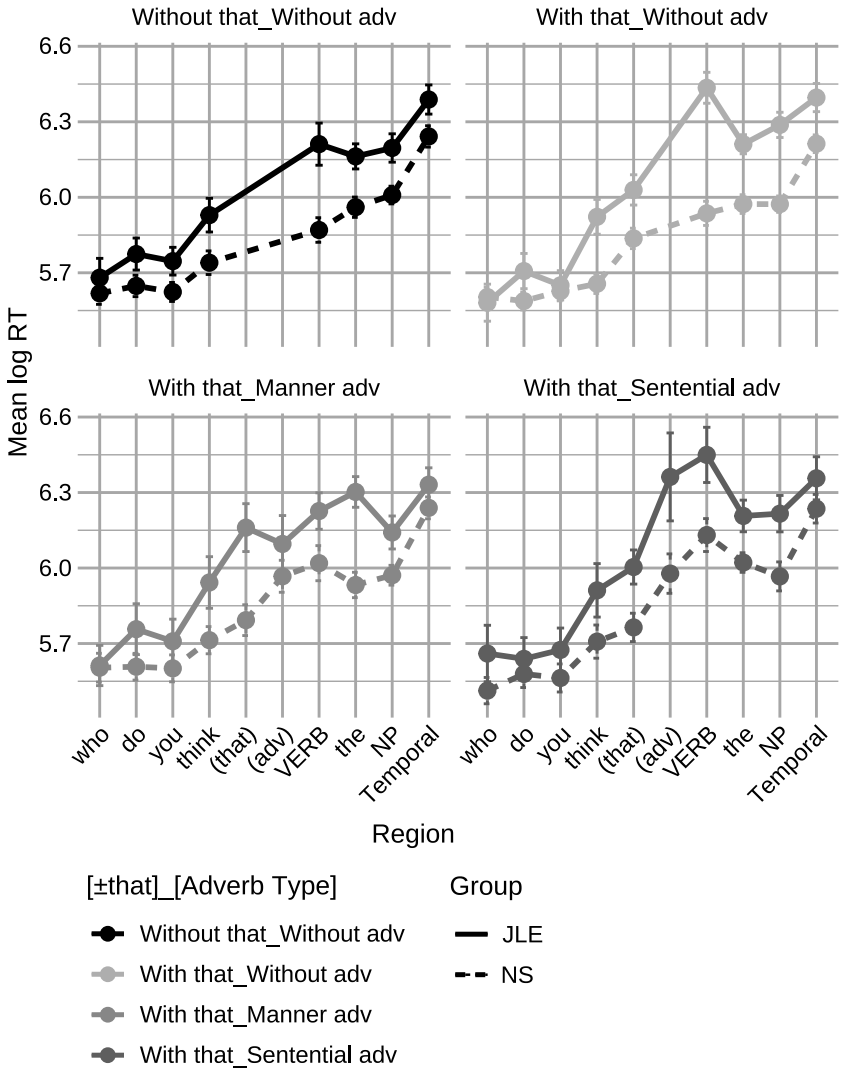

Figure 3. Results of Experiment 3.

6. General discussion and conclusion

In this study, we examined how NSs and JLEs processed adverbial interventions in *that*-trace structures through both offline judgments and online processing tasks. Our goal was to explore the relationship between structural constraints and cognitive load during real-time comprehension in L1 and L2.

In Experiment 1, both NSs and JLEs shared their knowledge of adverb types and their surface positions in simple clauses. The identical patterns observed

across groups indicate that JLEs, like NSs, are sensitive to the distinction between sentential and manner adverbs and their preferred surface positions. However, when these adverbs were inserted into embedded *that*-trace structures (i.e., between *that* and the subject gap), neither group was sensitive to the adverb amelioration effect in Experiment 2; instead, acceptability ratings degraded significantly, particularly with sentential adverbs. This finding is inconsistent with the prediction of anti-locality accounts (e.g., Brillman & Hirsch, 2016; Erlwine, 2020), which posit that a sentential adverb ameliorates *that*-trace violation, whereas a manner adverb should not. The lack of an adverb amelioration effect suggests that non-syntactic (i.e., non-structural) factors are likely involved. Crucially, this interpretation is supported by the findings of the SPRT in Experiment 3, in which both NSs and JLEs exhibited a slowdown in the inserted adverb region. This indicates that adverbial insertion in *that*-trace structures imposes an online processing cost on both groups, which suggests that this increased processing burden affects acceptability ratings in offline judgments in Experiment 2. These findings may reflect general sentence-processing mechanisms, supporting non-syntactic approaches to the *that*-trace effect in L2 (and possibly L1) grammar (e.g., Aldosari & Covey, 2024; Kim & Goodall, 2024).

It is worth noting that Takahashi and Ono (in press) found that JLEs exhibited adverbial amelioration effects in *that*-trace structures in an offline judgment task. These divergent results could be attributed to differences in the materials used and/or task-ordering effects. Takahashi and Ono employed a wider variety of adverbials (e.g., parenthetical phrases, clauses) without strictly manipulating their length and function. Given processing-based approaches, it is expected that L2 learners develop sensitivity to the ameliorating effects of longer-length adverbials in *that*-trace structures. Future research should incorporate these types of adverbials to further examine the interaction between grammatical and processing mechanisms in L1 and L2.

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