Probabilistic and Selectional Biases in Ambiguity Resolution during Real-time Sentence Processing

Hiroki Fujita (hiroki.fujita@uni-potsdam.de)
Department of Linguistics, University of Potsdam
Karl-Liebknecht-Str. 24–25, 14476 Potsdam, Germany

Abstract

This study examines the influence of lexical frequency bias and selectional constraints on the resolution of complement ambiguity during sentence processing. Some argue that in complement ambiguity resolution, lexical frequency bias and selectional constraints lead to the clausal complement before disambiguation, while others claim that the nominal complement is maintained until the disambiguating verb appears. The present study investigates this issue in two reading experiments using a temporal adjunct. The results suggested the rapid influence of lexical frequency bias and selectional constraints. However, the temporal adjunct introduces a bias towards the nominal complement, and ultimately overrides the influence of the lexical frequency bias and selectional constraints. These results suggest that processing preferences dynamically change, influenced by multiple biases.

Keywords: Garden path; complement ambiguity; sentence processing; language comprehension

Introduction

A central inquiry in sentence processing research lies in the influence of linguistic biases on the real-time processing of sentences. This study explores the influence of lexical frequency bias and selectional constraints on the resolution of *complement ambiguity* (Frazier & Rayner, 1982; Fujita, 2021b; Trueswell et al., 1993). For example, consider the sentence in (1) below.

(1) John remembered the boy drank the tea.

In (1), a complement ambiguity arises at NP "the boy", as the matrix verb can locally select for either a nominal complement, as in "John remembered the boy" (the left tree in Figure 1), or a clausal complement (the right tree in Figure 1), as in "John remembered ~~that~~ the boy…". In (1), the ambiguity resolves towards the clausal complement at the embedded verb because this verb indicates the presence of a finite embedded clause, where "the boy" must serve as its subject.

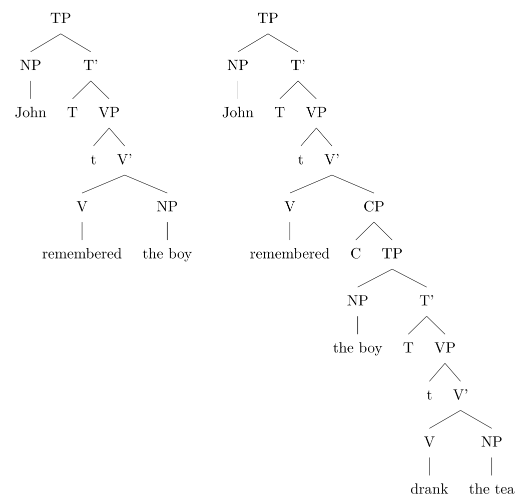

Figure 1. Tree diagrams for two locally permissible structures in (1). The left tree represents the nominal complement, and the right tree represents the clausal complement.

Previous work suggests that the parser initially favours the nominal complement when the locally ambiguous NP is a plausible object of the matrix verb and when the verb frequently takes the nominal complement, as in the case of (1). A piece of evidence for this parsing preference comes from processing difficulties called *garden-path effects* (Cunnings & Fujita, 2021; Ferreira & Henderson, 1998; Frazier & Rayner, 1982; Fujita, 2024; Fujita & Cunnings, 2020, 2021b, 2021a; Pritchett, 1992; Sturt et al., 1999). It has been shown that sentences like (1) cause garden-path effects at the disambiguating embedded verb, suggesting that the parser initially analyses the locally ambiguous NP as the direct object of the matrix verb and later has difficulty integrating the disambiguating verb into the current structure and attempts to revise it. No garden-path effects arise in sentences like the one in (2) below, where an overt complementiser ("that") prevents the nominal complement.

(2) John remembered that the boy drank the tea.

In the literature, the debate continues over whether this preference persists, even when lexical frequency and selectional constraints support the clausal complement. For example, consider the following sentence from Pickering et al. (2000).

(3) The athlete realised her exercises might make her famous.

This sentence is similar to (1), but there are two important differences. Firstly, the matrix verb "realised" often occurs with the clausal complement (Trueswell et al., 1993). Secondly, the critical NP "the boy" is not a plausible object for the matrix verb. Previous research has shown conflicting evidence regarding whether sentences like (3) induce garden-path effects at the disambiguating embedded verb. For example, Ferreira and Henderson (1990) observed that garden-path effects arise in such sentences, while other studies, like Garnsey et al. (1997), have observed no garden-path effects. Resolving these discrepancies is of theoretical importance because it leads to distinguish between different processing models.

The finding of garden-path effects could be accounted for by a structure-based model. A model is structure-based if its explanation is based *solely* on syntactic structure. For example, the Minimal Attachment principle posits that incoming material is integrated into the current structure using the fewest nodes (i.e., simplest structure; ; see Figure 1) consistent with the well-formedness rules of the language (Frazier & Fodor, 1978). The application of the Minimal Attachment principle to the observation of garden-path effects in (3) depends on the definition of well-formedness. Ferreira and Henderson (1990) take their finding as evidence for the Minimal Attachment principle. Regardless, the key point here is that if sentences like (3) induce garden-path effects, we can attribute this phenomenon to a structure-based hypothesis, such that the parser consistently prefers an analysis with minimal structure, unless the analysis becomes structurally impermissible.

On the other hand, the absence of garden-path effects aligns well with the interactive constraint-based model (McRae et al., 1998; Spivey-Knowlton & Tanenhaus, 1998). This model predicts that multiple biases synergise to immediately influence ambiguity resolution, and they dynamically affect sentence processing. In the constraint-based model, the level of contributions from each bias is quantified as the amount of activation, and processing preferences are determined by a so-called three-step normalised recurrence process (Spivey-Knowlton, 1996). During this process, the activation value (S) for each bias ($b_1, b_2, \ldots\ b_n$) is initially normalised for competing analyses ($a_1, a_2, \ldots, a_n$) as follows:

(4) $S'_{b,a} = \frac{S_{b,a}}{\sum_a S_{b,a}}$.

The activation values are then aggregated for each analysis by:

(5) $i_a = \sum_b w_b S'_{b,a}$

where w represents weights. Lastly, the activation value for each bias is updated by:

(6) $S_{b,i} = S'_{b,a} + i_a w_b S'_{b,a}$

In the constraint-based model, this process is repeated until one of the analyses reaches an activation threshold (T): $T = 1 - xy$, where y represents the number of cycles, and x is a constant. As the equations imply, when competing analyses receive a similar amount of activation, it takes more time to reach the threshold, leading to more time to process the incoming material. Since, in (3), there are strong biases towards the clausal complement, while the nominal complement is not supported, the proponents of the constraint-based model argue for no discernible difficulty at the disambiguating region.

Experiment 1

To investigate how lexical frequency bias and selectional constraints influence the resolution of complement ambiguity during real-time sentence processing, Experiment 1 tested sentences like (7a/b) below.

(7a) ***Complementiser-Absent*, *Gender Match***
John hoped the boy after washing himself in the bathroom took some time to rest from studying.

(7b) ***Complementiser-Absent*, *Gender Mismatch***
John hoped the girl after washing himself in the bathroom took some time to rest from studying.

These sentences are similar to (3) in terms of lexical frequency bias and selectional constraints. That is, the matrix verb often co-occurs with the clausal complement, and the critical NP "the boy/girl" is not a plausible object of this verb. In (7a/b), this NP is followed by a temporal adjunct that contains a reflexive pronoun ("after washing himself in the bathroom"). A reflexive corefers with an NP in a structurally permissible position (Chomsky, 1981). Crucially, if the nominal complement is adopted, the reflexive in (7) corefers with the matrix subject NP "John" (Fujita, 2021b). However, if the clausal complement is adopted, the reflexive corefers with the critical NP "the boy/girl" (Boeckx et al., 2010). This NP matches the reflexive in gender in (7a) but mismatches in (7b). In the literature, there is substantial evidence suggesting that processing difficulties occurs when the parser recognises that two dependency entries mismatch in certain features (e.g., phi-features) and violate agreement conditions (Fujita, 2023; Fujita & Cunnings, 2022, 2023, 2024; Fujita & Yoshida, 2024; González Alonso et al., 2021; Kazanina et al., 2007; Kim et al., 2020; Orth et al., 2021; Sturt, 2003; Wagers et al., 2009; Yoshida et al., 2013, 2014). In this paper, this difficulty will be referred to as *gender mismatch effects* to indicate agreement violation between a pronoun and its antecedent in gender (Sturt, 2003). Thus, if the clausal complement is adopted, gender mismatch effects should be observed at the reflexive in (7b) compared to (7a). However, if the nominal complement is adopted, readers should attempt to associate the reflexive with the matrix subject NP “John”. Since this NP matches the reflexive in gender in both (7a) and (7b), the nominal complement should lead to no gender mismatch effects. Experiment 1 tested sentences like (7a) and (7b), and control sentences where an overt complementiser “that” follows the matrix verb, such as the following:

(8a) ***Complementiser-Present*, *Gender Match***
John hoped that the boy after washing himself in the bathroom took some time to rest from studying.

(8b) ***Complementiser-Present*, *Gender Mismatch***
John hoped that the girl after washing himself in the bathroom took some time to rest from studying.

In (8a/b), we can expect clear gender mismatch effects at the reflexive, given that the nominal complement is prevented by the overt complementiser, and thus, the clausal complement must be adopted (i.e., the reflexive corefers with the critical NP “the boy/girl”). Experiment 1 consists of the four conditions.

Participants

In total, 216 native English speakers participated in Experiment 1. These participants were recruited through the Prolific platform. The participants held university degrees, British citizens, and had primarily lived in the UK before turning 18.

Stimuli, Norming, Procedure and Analysis

For Experiment 1, 24 item sets were prepared, as exemplified in (7a/b) and (8a/b) (24 item sets × 4 conditions = 96 items). In a Latin-square design, participants saw six experimental stimuli from each condition. These stimuli were interspersed with 72 filler items.

For lexical frequency bias, clausal-complement-biased-verbs (“hoped” in (7a/b) and (8a/b)) were taken from previous research that conducted a sentence completion norming task (e.g., Trueswell et al., 1993). To ensure selectional bias towards the clausal complement, this study conducted a plausibility norming task. In this task, 40 native English speakers were presented the experimental sentences up to the critical NP (e.g., “John hoped the boy” for (7a)), and rated the plausibility of the sentences on a scale from 1 (*highly implausible*) to 7 (*highly plausible*). The results indicated a mean rating of 1.9, suggesting that each temporarily ambiguous NP used in the experimental sentences was deemed implausible as a direct object of the preceding matrix verb.

Participants’ reading times were measured using lexicality maze tasks. In this task, each sentence was presented word by word, accompanied by a pseudoword. Participants were required to choose the appropriate words to advance in reading the sentences. If a pseudoword was chosen, the trial was immediately terminated, feedback was presented, and the next trial began. Figure 2 provides a visual representation of the progression of the lexicality maze task. The maze task was created using code available online (Fujita, 2021a).

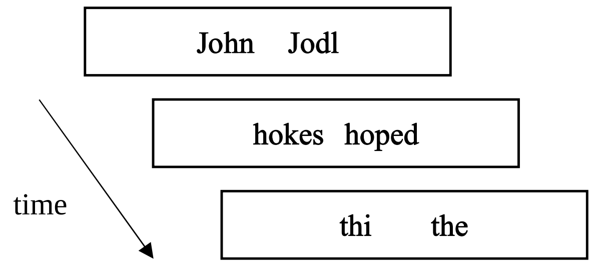

Figure 2. *An example trial of the lexicality maze task.*

For data analysis, reading times at four regions were analysed as the dependent variable. These regions included the reflexive (“himself”), post-reflexive (“in”), verb (“took”) and post-verb (“some”) regions. Reading times were log-transformed before data analysis. Log-transformed reading times were analysed using linear mixed effects models (Bates et al., 2015) in R (R Core Team, 2022). Random effects included random intercepts and all pertinent slopes for participants and stimuli (Barr et al., 2013). The models included sum-coded (.5/–.5) fixed effects of Complementiser (present/absent) and Gender (match/mismatch), along with their interaction.

Results

Figure 3 illustrates log-transformed reading times at the four regions.

Reflexive region: There was a significant main effect of Gender ($p < .001$), with longer reading times in the gender-mismatch conditions than in the gender-match conditions. This effect indicates gender mismatch effects. The interaction between Complementiser and Gender was also statistically significant ($p = 018$). To examine the effect of Gender within each level of Complementiser, a follow-up analysis was conducted. This analysis suggested gender mismatch effects in both the complementiser-absent (p = .005) and complementiser-present ($p < .001$) conditions.

Post-reflexive region: There was a significant main effect of Gender (p = .004), suggesting gender-mismatch effects. Other effects were not statistically significant.

Verb region: No effects were statistically significant.

Post-verb region: There was a significant main effect of Complementiser (p = .045), with longer reading times in the complementiser-absent conditions than in the complementiser-present conditions. This reading time pattern is compatible with garden-path effects.

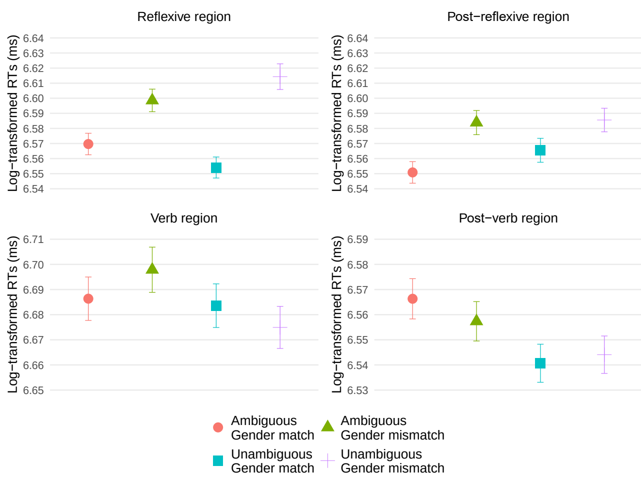

Figure 3. Log-transformed reading times (RTs) in Experiment 1.

Discussion: Experiment 1 observed several important finings. First, gender mismatch effects were observed at the reflexive region and the post-reflexive region in both the complementiser-absent and complementiser-present conditions. This finding suggests that lexical frequency bias and selectional constraints lead to the clausal complement analysis before disambiguation. This finding aligns with the constraint-based model but contradicts the results of Ferreira and Henderson (1990). However, the data analysis also revealed garden-path effects at the post-verb region, which is consistent with Ferreira and Henderson (1990). This garden-path effect suggests that the parser ultimately adopts the nominal complement at the end of the temporal adjunct.

How do we account for these apparently contradictory observations? A possible account is that the temporal adjunct (“after washing…”) introduces a bias towards the nominal complement. This bias is conceivable, given that a temporal clause, unless it is topicalised, almost always follows the verb it modifies, as in (9a), rather than preceding it, as in (9b) below.

(9a) The boy telephoned the girl after washing in the bathroom.

(9b) The boy, after washing in the bathroom, telephoned the girl.

Additionally, we must assume that this bias was strengthened and became more influential than lexical frequency bias and selectional constraints as readers were exposed to the lexical items in the adjunct clause (for relevant discussuon, see Crocker, 1996; Ferreira & Henderson, 1991; Fujita & Cunnings, 2020). Summarising this account, lexical frequency bias and selectional constraints lead the parser to immediately adopt the clausal complement at the point of the critical NP (i.e., “the boy/girl” in (7)). However, when the parser recognises the temporal adjunct, a bias is given towards the nominal complement. At the reflexive region, the clausal complement is still more supported. Thus, the parser attempts to associate the reflexive with the embedded subject NP, leading to gender mismatch effects. However, due to the bias from the temporal adjunct towards the nominal complement, the parser becomes more committed to the nominal complement. Consequently, near the end of the temporal adjunct, the parser adopts the nominal complement, leading to garden-path effects. If this account is correct, garden-path effects should not be observed when there is no temporal adjunct, as below.

(10) John hoped the boy took some time to rest from studying.

Experiment 2 aimed to investigate whether this account is valid by directly comparing sentences with and without the temporal adjunct.

Experiment 2

Participants

In Experiment 2, 140 English speakers were recruited from the same participant pool as in Experiment 1. These participants completed Experiment 2 online via Prolific as in Experiment 1.

Stimuli, Procedure and Analysis

For Experiment 2, 24 item sets, as exemplified below, and 72 fillers were prepared.

(11a) ***Adjunct-present***, ***Complementiser-absent***
John hoped the boy after washing in the bathroom took some time to rest from studying.

(11b) ***Adjunct-present***, ***Complementiser-present***
John hoped that the boy after washing in the bathroom took some time to rest from studying.

(11c) ***Adjunct-absent***, ***Complementiser-absent***
John hoped the boy took some time to rest from studying.

(11d) ***Adjunct-absent***, ***Complementiser-present***
John hoped that the boy took some time to rest from studying.

The procedure and data analysis were similar to those of Experiment 1, but there were a few differences. These differences were that the models included a fixed effect of Adjunct (present/absent) instead of Gender, and the regions that were analysed only included the verb and post-verb regions.

Results

Figure 4 illustrates log-transformed reading times at the verb region and the post-verb region.

Verb region: The data analysis showed a significant main effect of complementiser (p = .039), with longer reading times in the complementiser-absent conditions than in the complementiser-present conditions (i.e., garden-path effects). Crucially, there was a significant interaction between Adjunct and Complementiser (p = .025). To examine this interaction, a follow-up analysis was conducted by fitting a model examining the effect of Complementiser within each level of Adjunct. This follow-up analysis suggested that garden-path effects was present only in the adjunct-present conditions (p = .003), and absent in the adjunct-absent conditions (p = .943).

Post-verb region: There was a significant Adjunct by Complementiser interaction (p = .049). The observed processing pattern is consistent with that at the verb region, but a follow-up analysis, which examined the effect of Complementiser within each level of Adjunct, did not show any significant effects.

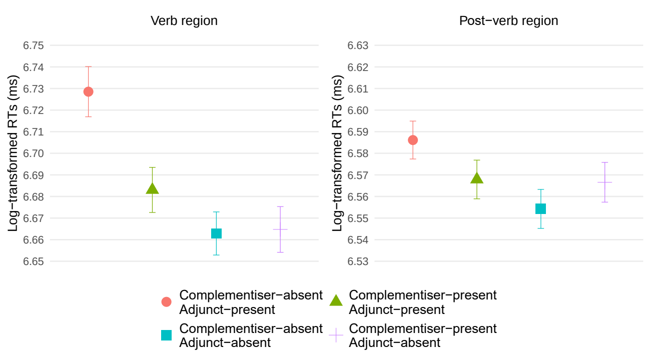

Figure 4. Log-transformed reading times (RTs) in Experiment 2.

Discussion

The aim of Experiment 2 was to investigate whether the source of the garden-path effects observed in Experiment 1 was due to the presence of the temporal adjunct. This is to test the hypothesis that the temporal adjunct introduces a bias towards the nominal complement, and that this bias overrides the influence of the lexical frequency bias and selectional constraints as the parser analyses the temporal adjunct. Consistent with this hypothesis, garden-path effects were observed at the verb region in Experiment 2 when the temporal adjunct was present, but not when it was absent. This finding suggests that in Experiment 1, lexical frequency bias and selectional constraints, which provide a bias towards the clausal complement, led readers to adopt the clausal complement at the temporarily ambiguous NP; however, the temporal adjunct also provides a bias but towards the nominal complement. As a result, readers adopted the nominal complement before the embedded verb appeared, which led to garden-path effects. Below is a summary of the results of Experiments 1 and 2.

(A) Gender mismatch effects were observed at the reflexive region and the post-reflexive region in Experiment 1. This effect indicates that the parser attempts to establish a coreference relation between the reflexive pronoun in the temporal adjunct and the temporarily ambiguous NP. It suggests that the parser ultimately adopts the clausal complement rather than the nominal complement at the temporarily ambiguous NP.

(B) Garden-path effects were observed at the verb region (Experiment 2) or the post-verb region (Experiment 1) when the temporal adjunct was present. This finding suggests that, at the point of the embedded verb region, the parser has a preference for the nominal complement over the clausal complement.

(C) This garden-path effect was not observed when the temporal adjunct was absent (Experiment 2).

These findings are difficult to explain based *solely* on the structure-based hypotheses, such as the Minimal Attachment principle. Recall that the Minimal Attachment principle states that the parser always favours an analysis with the fewest nodes (i.e., the simplest structure) as long as the analysis results in a well-formed structure. If the nominal complement is considered structurally ill-formed in the complementiser-absent sentences tested in this study (because the temporarily ambiguous NP is not a plausible object), the Minimal Attachment principle predicts that the parser should adopt the clausal complement. This prediction is consistent with the finding of the gender mismatch effects observed at the reflexive region in Experiment 1. However, it cannot explain why garden-path effects were observed at the verb region or the post-verb region in the presence of the temporal adjunct. If the structure-based hypothesis predicts that the nominal complement is adopted because the parser always favours an analysis with the fewest nodes, it can explain the observation of garden-path effects. However, in this case, this hypothesis cannot explain the gender mismatch effects observed in Experiment 1 as well as the absence of garden-path effects, as observed in Experiment 2 when there was no temporal adjunct.

It is easier to explain (or model) the results of Experiments 1 and 2 based on the idea that different biases combine to dynamically influence real-time sentence processing, as predicted in the constraint-based model. The constraint-based model predicts that in the sentences tested in this study, the parser adopts the clausal complement after encountering the critical NP (i.e., "the boy/girl" in (7a/b)). Thus, according to this model, gender mismatch effects should be observed at the reflexive in Experiment 1. However, when the temporal adjunct appears, it introduces a bias towards the nominal complement. Then, assuming that the parser becomes more committed to the nominal complement as it analyses each lexical item in the temporal adjunct, we can explain why garden-path effects occur at the embedded verb.

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References

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using **lme4**. *Journal of Statistical Software*, *67*(1). https://doi.org/10.18637/jss.v067.i01

Boeckx, N., Cedric, H., & Nunes, J. (2010). *Control as Movement*. Cambridge University Press. https://doi.org/10.1017/CBO9780511761997

Chomsky, N. (1981). *Lectures on Government and Binding: The Pisa Lectures*. Foris.

Crocker, M. W. (1996). *Computational psycholinguistics: An interdisciplinary approach to the study of language* (Vol. 20). Springer Netherlands.

Cunnings, I., & Fujita, H. (2021). Quantifying individual differences in native and nonnative sentence processing. *Applied Psycholinguistics*, *42*(3), 579–599. https://doi.org/10.1017/S0142716420000648

Ferreira, F., & Henderson, A. M. (1991). Recovery from misanalyses of garden-path sentences. *Journal of Memory and Language*, *30*(6), 725–745. https://doi.org/10.1016/0749-596X(91)90034-H

Ferreira, F., & Henderson, J. M. (1990). Use of Verb Information in Syntactic Parsing: Evidence From Eye Movements and Word-by-Word Self-Paced Reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*(4), 555–568. https://doi.org/10.1037//0278-7393.16.4.555

Ferreira, F., & Henderson, J. M. (1998). Syntactic reanalysis, thematic processing, and sentence comprehension. In *Reanalysis in sentence processing* (Fodor J.D., Ferreira F. (eds), Vol. 21, pp. 73–100). Springer Netherlands. https://link.springer.com/chapter/10.1007/978-94-015-9070-9_3

Frazier, L., & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition*, *6*(4), 291–325. https://doi.org/10.1016/0010-0277(78)90002-1

Frazier, L., & Rayner, K. (1982). Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology*, *14*(2), 178–210. https://doi.org/10.1016/0010-0285(82)90008-1

Fujita, H. (2021a). *An R Package for Creating Experimental Files in IbexFarm.* [Computer software]. https://doi.org/10.17605/OSF.IO/7RVX6

Fujita, H. (2021b). On the parsing of garden-path sentences. *Language, Cognition and Neuroscience*, *36*(10), 1234–1245. https://doi.org/10.1080/23273798.2021.1922727

Fujita, H. (2023). Predictive structure building in language comprehension: A large sample study on incremental licensing and parallelism. *Cognitive Processing*, *24*(2), 301–311. https://doi.org/10.1007/s10339-023-01130-8

Fujita, H. (2024). Online revision process in clause-boundary garden-path sentences. *Memory & Cognition*, *52*, 73–90. https://doi.org/10.3758/s13421-023-01444-0

Fujita, H., & Cunnings, I. (2020). Reanalysis and lingering misinterpretation of linguistic dependencies in native and non-native sentence comprehension. *Journal of Memory and Language*, *115*, 104154. https://doi.org/10.1016/j.jml.2020.104154

Fujita, H., & Cunnings, I. (2021a). Lingering misinterpretation in native and nonnative sentence processing: Evidence from structural priming. *Applied Psycholinguistics*, *42*(2), 475–504. https://doi.org/10.1017/S0142716420000351

Fujita, H., & Cunnings, I. (2021b). Reanalysis processes in non-native sentence comprehension. *Bilingualism: Language and Cognition*, *24*(4), 628–641. https://doi.org/10.1017/S1366728921000195

Fujita, H., & Cunnings, I. (2022). Interference and filler-gap dependency formation in native and non-native language comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *48*(5), 702–716. https://doi.org/10.1037/xlm0001134

Fujita, H., & Cunnings, I. (2023). Interference in quantifier float and subject-verb agreement. *Language, Cognition and Neuroscience*, *38*(7), 1001–1019. https://doi.org/10.1080/23273798.2023.2189738

Fujita, H., & Cunnings, I. (2024). Subject-verb dependency formation and semantic interference in native and non-native language comprehension. *Applied Psycholinguistics*, *45*(1), 81–109. https://doi.org/10.1017/S0142716423000498

Fujita, H., & Yoshida, M. (2024). Online reflexive resolution and interference. *Language, Cognition and Neuroscience*, 1–14. https://doi.org/10.1080/23273798.2024.2329269

González Alonso, J., Cunnings, I., Fujita, H., Miller, D., & Rothman, J. (2021). Gender attraction in sentence comprehension. *Glossa: A Journal of General Linguistics*, *6*(1), 20. https://doi.org/10.5334/gjgl.1300

Kazanina, N., Lau, E. F., Lieberman, M., Yoshida, M., & Phillips, C. (2007). The effect of syntactic constraints on the processing of backwards anaphora. *Journal of Memory and Language*, *56*(3), 384–409. https://doi.org/10.1016/j.jml.2006.09.003

Kim, N., Brehm, L., Sturt, P., & Yoshida, M. (2020). How long can you hold the filler: Maintenance and retrieval. *Language, Cognition and Neuroscience*, *35*(1), 17–42. https://doi.org/10.1080/23273798.2019.1626456

McRae, K., Spivey-Knowlton, M., & Tanenhaus, M. K. (1998). Modeling the Influence of Thematic Fit (and Other Constraints) in On-line Sentence Comprehension. *Journal of Memory and Language*, *38*(3), 283–312. https://doi.org/10.1006/jmla.1997.2543

Orth, W., Yoshida, M., & Sloggett, S. (2021). Negative polarity item (NPI) illusion is a quantification phenomenon. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *47*(6), 906–947. https://doi.org/10.1037/xlm0000957

Pritchett, B. L. (1992). *Grammatical Competence and Parsing Performance*. University of Chicago Press.

R Core Team. (2022). *R: A language and environment for statistical computing* [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/

Spivey-Knowlton, M. (1996). *Integration of visual and linguistic information: Human data and model simulations* [PhD Thesis]. University of Rochester.

Spivey-Knowlton, M., & Tanenhaus, M. K. (1998). Syntactic Ambiguity Resolution in Discourse: Modeling the Effects of Referential Context and Lexical Frequency. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*(6), 1521–1543. https://doi.org/10.1037/0278-7393.24.6.1521

Sturt, P. (2003). The time-course of the application of binding constraints in reference resolution. *Journal of Memory and Language*, *48*(3), 542–562. https://doi.org/10.1016/S0749-596X(02)00536-3

Sturt, P., Pickering, M. J., & Crocker, M. W. (1999). Structural Change and Reanalysis Difficulty in Language Comprehension. *Journal of Memory and Language*, *40*(1), 136–150. https://doi.org/10.1006/jmla.1998.2606

Trueswell, J. C., Tanenhaus, M. K., & Kello, C. (1993). Verb-Specific Constraints in Sentence Processing: Separating Effects of Lexical Preference From Garden-Paths. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(3), 528–553. https://doi.org/10.1037/0278-7393.19.3.528

Wagers, M., Lau, E. F., & Phillips, C. (2009). Agreement attraction in comprehension: Representations and processes. *Journal of Memory and Language*, *61*(2), 206–237. https://doi.org/10.1016/j.jml.2009.04.002

Yoshida, M., Dickey, M. W., & Sturt, P. (2013). Predictive processing of syntactic structure: Sluicing and ellipsis in real-time sentence processing. *Language and Cognitive Processes*, *28*(3), 272–302. https://doi.org/10.1080/01690965.2011.622905

Yoshida, M., Kazanina, N., Pablos, L., & Sturt, P. (2014). On the origin of islands. *Language, Cognition and Neuroscience*, *29*(7), 761–770. https://doi.org/10.1080/01690965.2013.788196