

Supplemental Material for: The Lingering Effect as Memory Persistence Has Distinct Predictors from the Garden-path Effect

Norming Study 1

The objective of Norming Study 1 is to control the plausibility of the stimuli using a 5-point Likert scale questionnaire. The study involved 26 native Japanese speakers aged 18–25 years (Mean = 21.00, SD = 1.95). Of the participants, 30.77% were female. Each received compensation of 1,000 JPY for 1 hour of participation.

We created 52 verb phrases using verbs and objects. Each verb phrase was paired with the subject of either the initial or revised analysis to form events. For instance, a set of events included “A pianist played the piano” and “A ballerina played the piano.” The participants were instructed to rate the likelihood of each event occurring on a scale from 1 to 5. A rating of 5 indicated that the event on the right side was highly likely, while a rating of 1 indicated that the event on the left side was highly unlikely. We created two lists for the experiment. In List 1, stimuli with the subjects of initial analyses were presented on the right side for half of the items and on the left side for the other half. In List 2, the locations of the items were the opposite of those in List 1.

We presented the stimuli randomly. Before the main task, the participants completed a practice task to establish a standard of judgment, although they were not informed that it was a practice task. A break was provided after completing half the trials. The duration of the break depended on each participant.

During the analysis, the scores were aligned such that a score of 5 indicated a likelihood of the initial analysis, while a score of 1 indicated a likelihood of the revised analysis. We then calculated the mean score for each item. Only items with a mean score higher than 3.8 were selected for inclusion in the main experiments. Consequently, 49 out of 52 items with mean scores above 3.8 were adopted for the main experiments.

Norming Study 2

The aim of Norming Study 2 is to control the processing loads of the initial structure. The participants in Norming Study 1 also took part in this experiment.

To select pre- and post-verbal words, we created two pairs of pre- and post-verbal words for each item. Based on these results, we selected one of the pairs that fit the selection criteria for each item. Finally, we confirmed that the processing costs of the initial analysis were not significantly different between the +PreV;−PostV and −PreV;+PostV conditions.

There were two pairs of sentences with pre-verbal words (PreV condition) and sentences with post-verbal words (PostV condition), resulting in a total of four conditions. For instance, a PreV condition was *Pianisto-ga piano-o tanoshisouni hiita* ("A pianist happily played the piano"), while a PostV condition was *Pianisto-ga piano-o hiita kamoshirenai* ("A pianist might have played the piano"). Fifty-two items were crossed into four lists. Overall, each participant judged 52 target and 52 filler items.

The participants took part in Norming Study 2 before Norming Study 1. The participants read entire sentences and judged whether they made sense. Before undertaking the main task, the participants practiced eight items: four that were both grammatically and semantically acceptable, and four that were grammatically acceptable but not semantically acceptable.

In the analysis, we first transformed reaction times using natural logarithms. Second, we excluded trials with incorrect responses from the analysis of reading times. Finally, we trimmed data outliers to ± 2.5 standard deviations of the means, grouping them by

PreV and PostV. We calculated the mean value according to item and condition. We adopted one pair with a smaller absolute difference between PreV and PostV compared to the other pairs. We then discarded items whose absolute difference between PreV and PostV was above 220 ms. Finally, we discarded items not adopted in Norming Study 1. We analyzed the remaining items using a linear mixed-effects model. The model included reaction time as an independent variable, garden-path type (PreV/PostV) as a fixed factor, and participants and items (random intercepts and slopes).

As a result, we discarded 20 items whose absolute difference between PreV and PostV was 220 ms or more and three items that were not adapted in Norming Study 1. Finally, we included 32 sentences in the analysis. The results of the statistical analysis revealed that the estimated coefficient was -0.01 , $SE = 0.03$, $df = 19.04$, $t = 0.38$, and $p = 0.705$. This suggests that there was no significant difference between PreV and PostV, implying that the processing load of the initial structure did not differ between +PreV;−PostV and −PreV;+PostV conditions in the main task.

Supplemental Results of Experiment 1

Accuracy

Table S1

Estimated Effects of PreV and PostV for Accuracy in Experiment 1 (Simple Model)

	Coefficient	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	4.77	0.43	4.02	5.69	
PreV	0.07	0.20	−0.35	0.47	0.19
PostV	−0.05	0.19	−0.42	0.32	0.15
PreV × PostV	−0.20	0.22	−0.65	0.23	0.55

Note. No effects are shown.

Table S2

Estimated Effects of PreV, PostV, and Surprisal for Accuracy in Experiment 1 (Complex Model)

	Coefficient	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	4.79	0.43	4.02	5.73	
PreV	0.09	0.21	−0.33	0.49	0.18
PostV	0.02	0.28	−0.53	0.58	0.23
Surprisal	−0.04	0.13	−0.29	0.21	0.08
PreV × PostV	−0.21	0.23	−0.66	0.24	0.08

Note. No effects are shown.

Reading Times at the Spill-over Region

Table S3 (simple model) and Table S4 (complex model) show the estimations for the spill-over region. The results revealed no effects.

Table S3

Estimated Effects of PreV and PostV for Reading Times at the Spill-over in Experiment 1 (Simple Model)

	Coefficient	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	6.38	0.05	6.28	6.48	
PreV	0.00	0.01	−0.02	0.01	0.01
PostV	0.00	0.01	−0.02	0.02	0.01
PreV × PostV	0.00	0.01	−0.02	0.02	0.01

Table S4

Estimated Effects of PreV, PostV, and Surprisal for Reading Times at the Spill-over in Experiment 1 (Complex Model)

	Coefficient	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	6.38	0.05	6.28	6.48	
PreV	0.00	0.01	−0.02	0.01	0.01
PostV	−0.01	0.01	−0.04	0.02	0.02
Surprisal	0.01	0.01	−0.01	0.02	0.01
PreV × PostV	0.00	0.01	−0.02	0.02	0.01

Follow-up Experiment of Experiment 1

Because Experiment 1 manipulated whether the stimulus was garden-path or not, the follow-up experiment examines whether the head-position effect actually exists (replication of Experiment 1).

Methods

Participants

104 native Japanese speakers, aged 27–60 years (Mean = 43.21; SD = 8.08), participated in the study. 50.00% of the participants were female. They were recruited via CrowdWorks, a crowdsourcing service, and were paid 1,000 JPY for 1 hour of their participation.

Design and Stimuli

We manipulated the head-position (+PreV and +PostV) and whether the sentence is garden-path or not (garden-path: GP and non-garden-path: Non-GP). Example stimuli are shown below.

- (1) a. Non-GP; +PreV

piano-o tanoshisouni hiita bareriina-o pianisuto-ga mitsuketa.
_{RC}[piano-ACC happily played] ballerina-ACC pianist-NOM found

- b. Non-GP; +PostV

piano-o tanoshisouni hiita bareriina-o pianisuto-ga mitsuketa.
_{RC}[piano-ACC happily played] ballerina-ACC pianist-NOM found

- c. GP; +PreV

Pianisuto-ga piano-o tanoshisouni hiita bareriina-o mitsuketa.
 pianist-NOM _{RC}[piano-ACC happily played] ballerina-ACC found

d. GP; +PostV

Pianisuto-ga piano-o hiita kamoshirenai bareriina-o mitsuketa.
 pianist-NOM _{RC}[piano-ACC played might] ballerina-ACC found

“A pianist found a ballerina who (might) have (happily) played the piano.”

Procedure

The procedure is the same as Experiment 1.

Analysis

Analysis methods are the same as those in Experiment 1, except that the independent variables are Garden-Path and Modifier, rather than PreV and PostV. We analyzed only the disambiguation region because the spill-over regions consist of different words across conditions, as shown in (1).

Results

Accuracy

Table S5 lists the comprehension accuracy for each condition. The accuracy was around 80% under all conditions. The estimations do not show any effects (see Table S6 and S7).

Table S5

Mean Accuracy Rate of Each Condition in Follow-up Experiment

Garden-Path	Modifier	Mean
Non-GP	+PreV	0.81
Non-GP	+PreV	0.82
GP	+PostV	0.84
GP	+PostV	0.82

Table S6

Estimated Effects of Garden-Path and Modifier for Accuracy in Follow-up Experiment (Simple Model)

	Coefficient	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	2.26	0.22	1.85	2.69	
Garden-Path	0.07	0.09	−0.11	0.26	0.16
Modifier	−0.03	0.07	−0.17	0.10	0.07
Garden-Path × Modifier	−0.06	0.07	−0.19	0.07	0.02

Note. No effects are shown.

Table S7

Estimated Effects of Garden-Path, Modifier, and Surprisal for Accuracy in Follow-up Experiment (Complex Model)

	Coefficient	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	2.26	0.22	1.85	2.71	
Garden-Path	0.05	0.09	−0.13	0.24	0.05
Modifier	−0.15	0.10	−0.34	0.04	0.24
Surprisal	0.04	0.03	−0.01	0.09	0.04
Garden-Path × Modifier	−0.07	0.07	−0.20	0.06	0.13

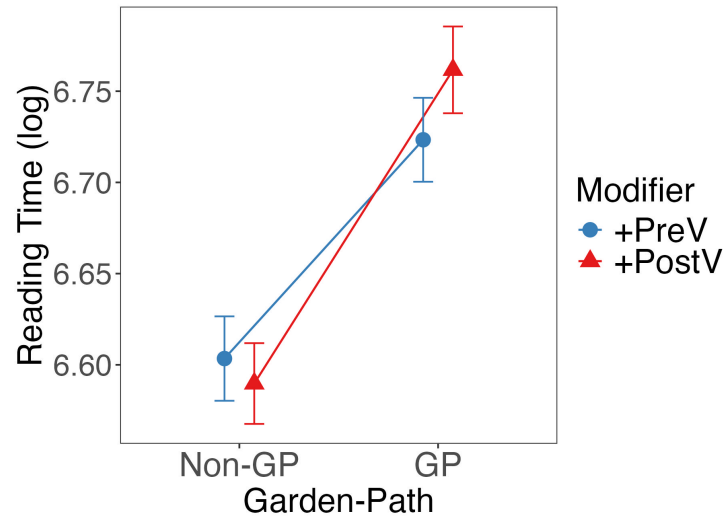
Note. No effects are shown.

Reading Times

Figure S1 shows mean reading times in the critical region (i.e., the disambiguation region). Tables S8 and S9 reveal that garden-path sentences require longer reading times in the disambiguation region than non-garden-path sentences. The results do not show the effects of Modifier, Surprisal, or their interaction, suggesting that head-position does not affect the garden-path effect and Surprisal is not a confounder.

Figure S1

Mean reading times in Follow-up Experiment (same as Figure 5 in the main text)



Note. Error bars represent standard errors.

Table S9

Estimated Effects of Garden-Path, Modifier, and Surprisal for Reading Times at the Critical Region in Follow-up Experiment (Complex Model)

	Coefficient	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	6.66	0.05	6.56	6.76	
Garden-Path	0.08	0.01	0.06	0.10	1.47×10 ⁹
Modifier	0.02	0.01	−0.00	0.04	0.01
Surprisal	0.01	0.01	−0.01	0.00	0.01
Garden-Path × Modifier	0.00	0.01	−0.01	0.02	0.01

Table S8

Estimated Effects of Garden-Path and Modifier for Reading Times at the Critical Region in Follow-up Experiment (Simple Model)

	Estimate	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	6.66	0.05	6.56	6.76	
Garden-Path	0.08	0.01	0.06	0.10	2.74×10 ⁸
Modifier	0.01	0.01	−0.01	0.02	0.02
Garden-Path × Modifier	0.00	0.01	−0.01	0.02	0.01

Supplemental Results of Experiment 2

Accuracy

Table S10

Estimated Effects of PreV and PostV for Accuracy in Experiment 2 (Simple Model)

	Coefficient	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	3.89	0.45	3.06	4.83	
PreV	0.09	0.19	−0.29	0.48	0.18
PostV	0.18	0.20	−0.18	0.60	0.24
PreV × PostV	−0.22	0.20	−0.60	0.19	0.42

Note. No effects are shown.

Table S11

Estimated Effects of PreV, PostV, and Surprisal for Accuracy in Experiment 2 (Complex Model)

	Coefficient	SE	Lower-Crl	Upper-Crl	BF ₁₀
Intercept	3.90	0.45	3.07	4.83	
PreV	0.09	0.20	−0.29	0.48	0.25
PostV	0.15	0.25	−0.32	0.67	0.32
Surprisal	0.02	0.11	−0.19	0.23	0.12
PreV × PostV	−0.22	0.20	−0.61	0.19	0.55

Note. No effects are shown.

Supplemental Results of Experiment 3

Accuracy

Table S12

Estimated Effects of PreV and PostV for Accuracy in Experiment 3 (Simple Model)

	Coefficient	SE	Lower-CrI	Upper-CrI	BF ₁₀
Intercept	4.58	0.61	3.46	5.85	
PreV	0.32	0.25	−0.17	0.82	0.60
PostV	−0.06	0.21	−0.45	0.37	0.19
PreV × PostV	−0.30	0.21	−0.75	0.10	0.68

Note. No effects are shown.

Table S13

Estimated Effects of PreV, PostV, and Surprisal for Accuracy in Experiment 3 (Complex Model)

	Coefficient	SE	Lower-CrI	Upper-CrI	BF ₁₀
Intercept	4.60	0.60	3.49	5.85	
PreV	0.31	0.25	−0.18	0.83	0.48
PostV	−0.12	0.28	−0.66	0.45	0.34
Surprisal	0.04	0.12	−0.20	0.28	0.11
PreV × PostV	−0.30	0.21	−0.74	0.11	0.60

Note. No effects are shown.

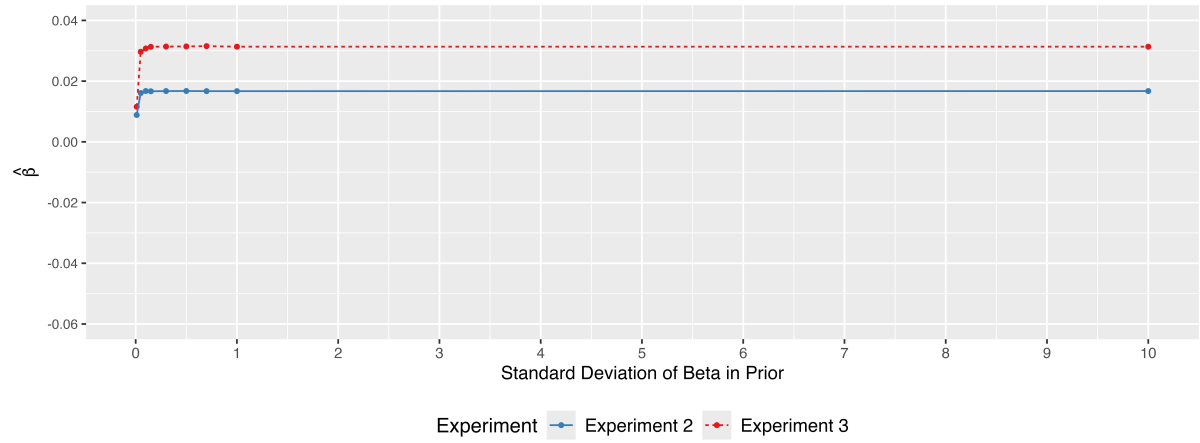
Sensitivity Analysis in Experiments 2 and 3

We employed sensitivity analysis in Experiments 2 and 3 in order to examine whether the effects of PreV and PostV were larger in Experiment 3 than in Experiment 2. In the analysis, we estimated the posterior distributions and Bayes factors of PreV, PostV, and their interactions in several different prior settings. We used nine standard deviations of β , which were 0.01, 0.05, 0.1, 0.15, 0.2, 0.5, 0.7, 1, and 10 (the standard deviation in the main analyses was 1). The results are shown below.

Figure S2*Estimates of PreV in the Different Priors in Experiments 2 and 3***Figure S3***Estimates of PostV in the Different Priors in Experiments 2 and 3*

Figure S4

Estimates of the Interaction between PreV and PostV in the Different Priors in Experiments 2 and 3

**Figure S5**

Bayes Factors (BF) of PreV in the Different Priors in Experiments 2 and 3

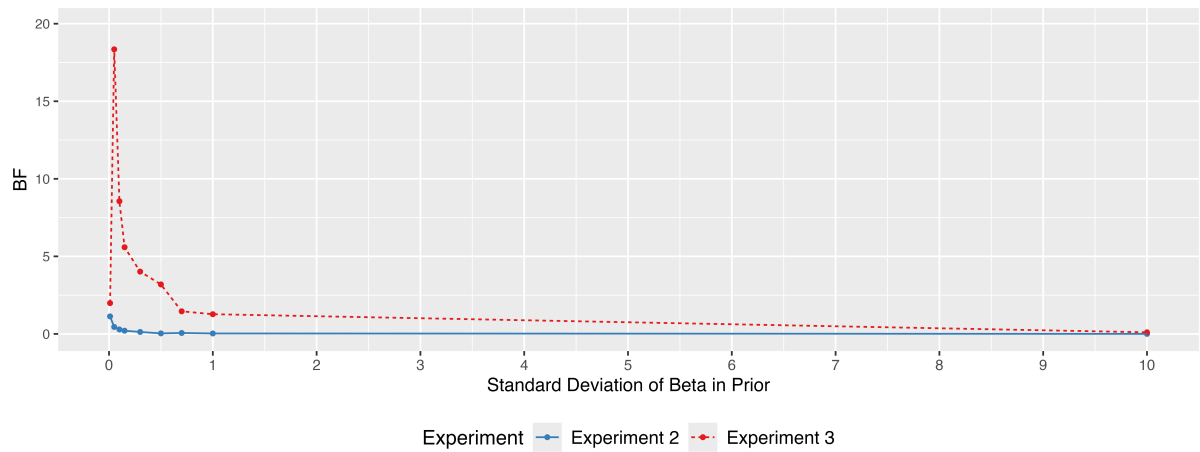
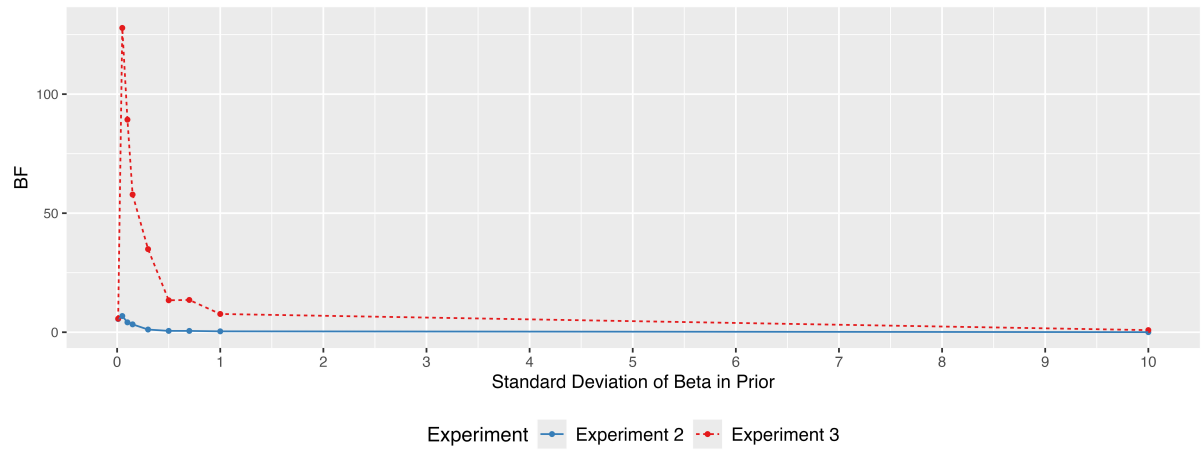


Figure S6

Bayes Factors (BF) of PostV in the Different Priors in Experiments 2 and 3

**Figure S7**

Bayes Factors (BF) of the Interaction between PreV and PostV in the Different Priors in Experiments 2 and 3

