The processing of subject-predicate dependency in Japanese: Evidence from self-paced reading experiments

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Abstract

In this study, three self-paced reading experiments were conducted to investigate if the integration of the matrix subject and the matrix predicate is sensitive to distance between them in nested structures (i.e., showing locality effects) in Japanese real-time sentence comprehension. Experiment 1 showed the case where the greater processing difficulty occurred in the integration when the matrix subject was an NPI and contained a wh-phrase in nested structures. Experiments 2 and 3 showed that the locality effects were observed regardless of the presence of wh-phrase and of the predicate types.

Key Words: Japanese, sentence processing, subject-predicate dependency, locality effects, self-paced reading experiment

1. Introduction

In real-time sentence comprehension, linguistic inputs are associated with each other to complete dependencies, such as subject-predicate dependencies, that is, when a predicate is input, it is integrated with its subject to complete the dependency. Previous studies have shown that when a sentence has multiple embedded structures, the higher the number of clauses, the more difficult it is to understand as in (1) (e.g., Gibson, 1998, 2000; Grodner & Gibson, 2005).

(1) a. The reporter disliked the editor.
b. The reporter [$_{S'}$ who the senator attacked] disliked the editor.
c. #The reporter [$_{S'}$ who the senator [$_{S'}$ who John met] attacked] disliked the editor.
(Gibson, 2000: 96, (1))

(1c) is less processable compared to (1a) and (1b), and such difficulty due to the intervening elements in a dependency is called “locality effect”. It is assumed that the processing difficulties

associated with dependency length also result in an increase in reading times in online experiments.

The processing difficulties can be explained by memory load in real-time sentence comprehension. For example, Cue-based parsing accounts assume three stages: encoding, storage, and retrieval in memory (Lewis et al., 2005, 2006). When a new linguistic input, such as a subject, arrives, its lexical and semantic information is encoded in the working memory, and it is stored there until a predicate arrives. In the retrieval process, retrieval cues are generated when the predicate arrives, and the stored information is retrieved using those cues. It has been also suggested that when syntactic and semantic similarities of the items to the target item is increased, an interference occurs, resulting in increased processing difficulties. This similarity-based interference could occur in both encoding and retrieval processes.

Previous studies on English language subject-predicate dependency processing in nested structures have found locality effects. In Japanese, however, not all subject-predicate dependencies are sensitive to the distances between the subject and its predicate. For example, Nakatani (2009, 2014) examined the processing difficulty in the sentences which include two clauses, comparing nested structures and non-nested structures in Japanese. Note that the experimental sentences contained the same words and expressed the same events, but only the structure was different across the conditions, thus any processing difficulty (i.e., locality effects) found in the experiments can be associated with its structure. They found that when the matrix subject contained a negative polarity item (NPI) in the nested structures, the linear distance between the matrix subject with the NPI and its predicate with negation increased the cost of the association; however, when the matrix subject was a referential noun phrase (NP), no locality effects were observed. In the case, where there is no locality effect observed, it has been assumed that both the matrix subject and the embedded subject become reactivated when the embedded predicate is processed due to the similarity-based interference, which decreases the processing cost at the matrix predicate as the matrix subject has been reactivated prior to the matrix verb position. While both distance-sensitive and distance-insensitive cases have been observed in previous Japanese language studies, it remains unclear as to the type of subject-predicate dependencies that are subject to locality effects. Therefore, to go some way to clarifying these effects, the present study used different matrix subjects to examine the locality effects.

In particular, this study firstly focused on an NPI with wh-phrase, "*dare-mo*" ("wh + *mo*" '*nobody'*) in a subject-predicate dependencies. As mentioned, NPI phrases such as "NP-*shika*" 'NP-only' have been found to show locality effects (e.g., Nakatani, 2009). Other studies also have shown that when a wh-phrase *dare-ga* 'who-nominative case marker (NOM)' and *sinjiteiru-ka* 'believe-Q particle' or *sinjiteiru-to* 'believe-complementizer (COMP)' are intervened

by an embedded clause, processing difficulty was increased, compared with when they were adjacent to each other (i.e., showing locality effects) (e.g., Ono & Nakatani, 2010, 2014). While NPIs need to be licensed by negation and wh + Q-particle also needs a grammatical licensing, the licensing may not be the only cause of increased processing costs from the integration since the locality effect was found even in the *sinjiteiru-to* 'believe- COMP' case. Therefore, the first experiment investigated whether NPI licensing mattered or whether wh-phrase itself caused the locality effect regardless of the presence of the grammatical licensing.

2. Experiment 1

In Experiment 1, an NPI with the wh-phrase, "*dare-mo*" ("wh + *mo*" '*nobody'*) was used as the matrix subject in a long-distance dependency. To investigate whether the presence of the NPI affects the sensitivity to the distance, a self-paced reading experiment was conducted using sentences that included "*dare-mo*" ("wh + *mo*" '*nobody'*), or "*dare-mo-ga*" ("wh + *mo* + NOM '*ga*' " '*everyone'*) as matrix subjects. Note that "*dare-mo-ga*" phrase has no restrictions for upcoming predicates, which means either negative predicate or affirmative predicate can be the matrix predicate.

2.1 Stimuli

The sentences shown in (2) were used in Experiment 1.

(2) a. Distant/NPI Condition:

daremo *sono-uweitoresu-ga* *tennai-de*
wh+*'mo'* [the waitress-NOM restaurant- LOCATIVE (LOC)
jourenkyaku-o *nagu-tta-to* *sinji-nakatta-node* ...
regular customer-ACCUSATIVE (ACC) hit-past-COMP] believe-not-past-because ...
'No one believed that the waitress hit the regular customer at the restaurant, so...'

b. Distant/Non-NPI Condition:

daremo-ga *sono-uweitoresu-ga* *tennai-de*
wh+*'mo'*-NOM [the waitress-NOM restaurant-LOC
jourenkyaku-o *nagu-tta-to* *sinji-nakatta-node* ...
regular customer-ACC hit-past-COMP] believe-not-past-because ...
'Everyone did not believe that the waitress hit the regular customer at the restaurant, so...' / 'Not everyone believed that...'

c. Local/NPI Condition:

sono-uweitoresu-ga *tennai-de* *jourenkyaku-o*

[the waitress-NOM restaurant-LOC regular customer-ACC

nagu-tta-to ***daremo*** *sinji-nakatta-node* ...

hit-past-COMP] **wh+*'mo'*** believe-not-past-because ...

'No one believed that the waitress hit the regular customer at the restaurant, so...'

d. Local/Non-NPI Condition:

sono-uweitoresu-ga *tennai-de* *jourenkyaku-o*

[the waitress-NOM restaurant-LOC regular customer-ACC

nagu-tta-to ***daremo-ga*** *sinji-nakatta-node* ...

hit-past-COMP] **wh+*'mo'*-NOM** believe-not-past-because ...

'Everyone did not believe that the waitress hit the regular customer at the restaurant, so...' / 'Not everyone believed that...'

The experimental sentences included either "*dare-mo*" ("wh + *mo*" '*nobody'*) as in NPI conditions, or "*dare-mo-ga*" ("wh + *mo* + NOM" '*everyone'*) as in non-NPI conditions. In Japanese, both phrases are quantifiers and contain the wh-phrase "*dare*" 'who'. Also, "wh + *mo*" is an NPI, whereas "wh + *mo* + NOM" is not an NPI. The distance between the matrix subject and the matrix predicate was manipulated by changing the structure of the sentence. In distant conditions, an embedded clause intervened the matrix subject, which was an NPI or non-NPI phrase, and the matrix predicate. In local conditions, the embedded clause was fronted and the matrix subject and matrix predicate were next to each other. The critical region is the matrix predicate region ("*sinji-nakatta-node"* 'believe-not-past-because') which is underlined in the examples above.

Twenty-four sets of target sentences and 72 filler sentences were used in the experiment. The filler sentences had similar sentence constructions to the target sentences; for example, "*dare-mo-ga*" ('wh + *mo* + NOM') with an affirmative predicate; and also contained irrelevant sentences; for example, '*The view from the top of the mountain that the hiker enjoyed yesterday was very beautiful.*' or '*The actor bought the actress a red bag*.' Each experimental sentence was followed by a comprehension question; for example, '*Did the waitress hit the regular customer?*' for the example (2): to make sure the participants understood the presented sentences.

Predictions

If the presence of NPI affects the distance sensitivity, the reading time (RT) in the distant/NPI condition should be longer than that in the local/NPI condition reflecting the processing load at the matrix verb position where the integration between the matrix NPI subject and the matrix predicate occurs, but, in non-NPI conditions, there should be no RT difference. However, if the wh-phrase influences the locality effect regardless of the NPI licensing, the RTs at the matrix predicate in the distant conditions should be longer than in the local conditions in both the NPI and non-NPI conditions.

2.2 Procedure

Linger software developed by Doug Rohde was used in the experiment. The sentence was presented in a phrase-by-phrase noncumulative moving window self-paced reading paradigm (Just, Carpenter & Woolley, 1982). In each trial, the dashes showed up on the screen. Each sentence began with a '+' mark to signal where the sentence started. The participants were asked to press the space bar to see each phrase. When the space bar was pressed, each phrase showed up on the screen. The boundary between each phrase was shown as spaces in (2). In the comprehension task, the participants received feedback when they gave an incorrect answer. Prior to the main experiment, participants received five practice trials to become familiar with the experiment's procedure. The self-paced reading experiment took approximately 15-20 minutes, including the practice part.

2.3 Participants

Thirty-six native Japanese speakers from the university of Tokyo community participated in the experiment. Participants were paid 500 Japanese yen for their completion of the task.

2.4 Statistical analysis

The trials including reading time data of less than 80ms or more than 6,000ms were excluded. However, we did not exclude the trials with incorrect answers in the comprehension task because non-NPI conditions have an ambiguity in the meaning of the sentence, so it might affect the response of the comprehension questions (There were no participants who scored below 75% in the accuracy rate). Statistical analyses of linear mixed-effects models (Baayen, et al., 2008) were conducted with R (R Core Team, 2019) by submitting reading time data to *lmer* function in the *lme4* package (Bates, et al., 2015). The models include DISTANCE (Distant/Local) and SUBJECT-TYPE (NPI/Non-NPI) as fixed factors. Both participants and sets of experimental sentences were treated as random factors. The dependent variable was the row RT data of each

region. Final models were selected by backward stepwise method. After the final models were selected, the data points above 2.5 standard deviation from the residual between the estimated data points and the actual reading times, were excluded, and then the very final models were calculated (Baayen, 2008). *P*-values were calculated by submitting the final model to the lmer function of the *lmerTest* (Kuznetsova, et al., 2017). The negative value of the coefficient of DISTANCE indicates that the distant condition was read slower than the local condition, and the positive value indicates the opposite pattern. The negative value of the coefficient of SUBJECT-TYPE indicates that the NPI condition was read faster than the non-NPI condition, and the positive value indicates the opposite pattern.

2.5 Results & Discussion

Comprehension accuracy

The overall mean accuracy for the target sentence comprehension questions was 93.86 % (SD = 5.22). The mean accuracy for the distant/NPI condition was 94.44%, 94.44% for the distant/non-NPI condition, 92.59% for the local/NPI condition, and 93.98% for the local/non-NPI condition.

Reading time data

Only the regions of interest are reported here. As shown in Table 1, the statistical analysis showed that the main effects of DISTANCE and SUBJECT-TYPE were significant. However, the interaction between DISTANCE and SUBJECT-TYPE was not significant. The RTs in the distant condition were slower than that in the local condition in both the NPI ("wh + *mo*") and the non-NPI ("wh + *mo* + NOM") conditions at the matrix predicate region (Figure 1), that is, locality effects were found in both conditions. The results suggested that when the dependency element has a wh-element, the integrative process of a dependency is sensitive to distance.

Table 1. Parameters of the fixed effects from the LME model at the matrix predicate region

	β	SD	*df*	*t*	*p*	
(Intercept)	628.70	59.01	35.45	10.65	< 0.001	***
DISTANCE	-123.75	42.93	30.54	-2.88	0.007	**
SUBJECT-TYPE	-54.27	20.29	736.32	-2.67	0.008	**
DISTANCE × SUBJECT-TYPE	35.01	40.60	736.17	0.86	0.389	

The spill-over region (the region immediately following the matrix predicate) was also analyzed as observable effects sometimes appear in these following regions. The main effect of DISTANCE was marginally significant (β = -17.62, SD = 10.55, df = 727.88, t = -1.67, p = 0.095),

but the main effect of SUBJECT-TYPE was not significant (β = -18.38, SD = 13.27, df = 18.24, t = -1.39, p = 0.182). It was found that the interaction of DISTANCE and SUBJECT-TYPE was significant (β = 67.32, SD = 21.10, df = 728.33, t = 3.19, p = 0.002), which indicated that in the non-NPI condition, the distant condition was slower than the local condition (Figure 2).

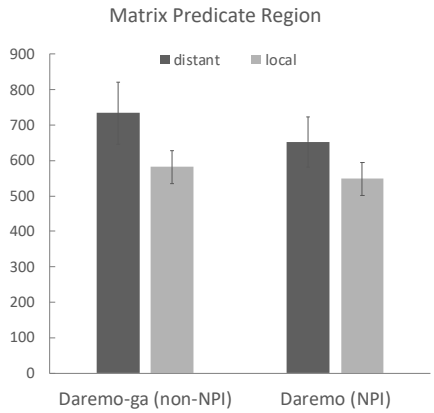

Figure 1. Estimated RTs at the matrix predicate

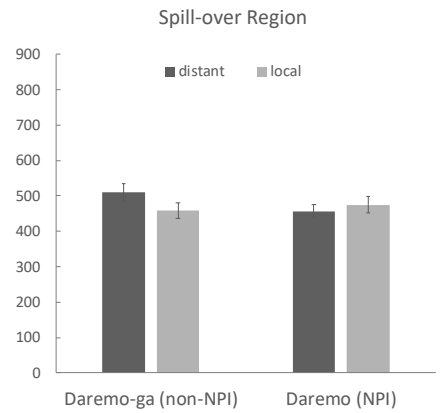

Figure 2. Estimated RTs at spill-over region

Even though an NPI phrase "wh + *mo*" needs to be licensed in the same clause and the "wh + *mo* + NOM" phrase does not require such licensing, locality effects were found in both conditions, which led to a question regarding the wh-phrase. Therefore, the following experiments investigated whether the locality effects found in Experiment 1 were general characteristics of wh-containing subjects.

3. Experiment 2

Experiment 2, which was also a self-paced reading experiment, investigated whether the subject-predicate dependency processing of wh "*dare*" and a NOM "*ga*" in the matrix subject ("wh + mo + NOM") differed from the processing of a non-wh subject ("referential NP + NOM").

3.1 Stimuli

An example set of the sentences in Experiment 2 is given in (3).

(3) a. Distant/Wh Condition:

daremo-ga	*sono-uweitoresu-ga*	*tennai-de*
wh+'*mo*'-NOM	[the waitress-NOM	restaurant-LOC
jourenkyaku-o	*nagu-tta-to*	*sinji-nakatta-node* ...
regular customer-ACC	hit-past-COMP]	believe-not-past-because ...

'Everyone did not believe that the waitress hit the regular customer at the restaurant, so...' / 'Not everyone believed that...'

b. Distant/Non-Wh Condition (referential NP):

kokku-ga *sono-uweitoresu-ga* *tennai-de*
chef-NOM [the waitress-NOM restaurant-LOC
jourenkyaku-o *nagu-tta-to* *sinji-nakatta-node* ...
regular customer-ACC hit-past-COMP] believe-not-past-because ...

'The chef did not believe that the waitress hit the regular customer at the restaurant, so...'

c. Local/Wh Condition:

sono-uweitoresu-ga *tennai-de* *jourenkyaku-o*
[the waitress-NOM restaurant-LOC regular customer-ACC
nagu-tta-to ***daremo-ga*** *sinji-nakatta-node* ...
hit-past-COMP] **wh+*'mo'*-NOM** believe-not-past-because ...

'Everyone did not believe that the waitress hit the regular customer at the restaurant, so...' / 'Not everyone believed that...'

d. Local/Non-Wh Condition (referential NP):

sono-uweitoresu-ga *tennai-de* *jourenkyaku-o*
[the waitress-NOM restaurant-LOC regular customer-ACC
nagu-tta-to ***kokku-ga*** *sinji-nakatta-node* ...
hit-past-COMP] **chef-NOM** believe-not-past-because ...

'The chef did not believe that the waitress hit the regular customer at the restaurant, so...'

Experiment 2, for which there were 24 sets of target sentences and 72 filler sentences, used the same wh conditions sentences as the non-NPI conditions in Experiment 1; however, the "referential NP + NOM" was used as the matrix subject in the non-wh conditions to test the effect of the presence of the wh-element on the locality effect in nested structures.

Predictions

If the wh-phrase ("*daremo-ga*") increases the processing costs in the nested structures, the RT in the distant condition should be slower than in the local condition only for the wh

conditions, but there should be no RT differences in the non-wh conditions in which the matrix subject was a referential NP.

3.2 Procedure

The Experiment 2 procedure was the same as in Experiment 1.

3.3 Participants

Thirty-seven native Japanese speakers participated in Experiment 2, who were recruited from the same community as in Experiment 1; however, Experiment 1 participants were excluded. Participants were paid 500 Japanese yen for the task.

3.4 Statistical analysis

The statistical analysis in Experiment 2 was conducted in the same way as in Experiment 1. The models include DISTANCE (Distant/Local) and SUBJECT-TYPE (Wh/Non-WH) as fixed factors. The negative value of the coefficient of DISTANCE indicates that the distant condition was read slower than the local condition, and the positive value indicates the opposite pattern. The negative value of the coefficient of SUBJECT-TYPE indicates that the wh condition was slower than the non-wh condition, and the positive value indicates the opposite pattern.

3.5 Results & Discussion

Comprehension accuracy

The overall mean accuracy for the target sentence comprehension questions was 87.84 % (SD = 6.08). The mean accuracy for the distant/wh condition was 88.74%, 83.78% for the distant/non-wh condition, 91.44% for the local/wh condition, and 87.39% for the local/non-wh condition.

Reading time data

The statistical analysis revealed that only the main effect of DISTANCE was significant; that is, the RTs in the distant conditions were longer than in the local conditions for both the wh and non-wh conditions at the matrix predicate region, which indicated that there were locality effects as shown in Table 2 and Figure 3.

In the spill-over region, the main effect of DISTANCE was marginally significant (β = -24.55, SD = 13.32, df = 797.26, t = -1.84, p = 0.066) and the main effect of SUBJECT-TYPE was significant (β = 38.38, SD = 13.32, df = 796.17, t = 2.88, p = 0.004), as shown in Figure 4.

However, the interaction was not significant (β = -38.47, SD = 26.63, *df* = 796.67, *t* = -1.44, *p* = 0.015).

Table 2. Parameters of the fixed effects from the LME model at the matrix predicate region

	β	SD	*df*	*t*	*p*	
(Intercept)	747.21	59.63	35.85	12.53	< 0.001	***
DISTANCE	-62.97	24.86	792.50	-2.53	0.012	*
SUBJECT-TYPE	27.62	24.86	793.28	1.11	0.267	
DISTANCE × SUBJECT-TYPE	17.54	49.73	792.96	0.35	0.724	

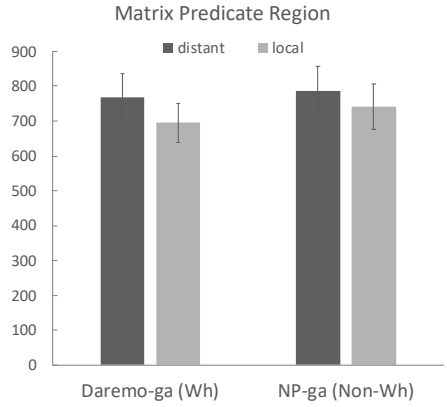

Figure 3. Estimated RTs at the matrix predicate

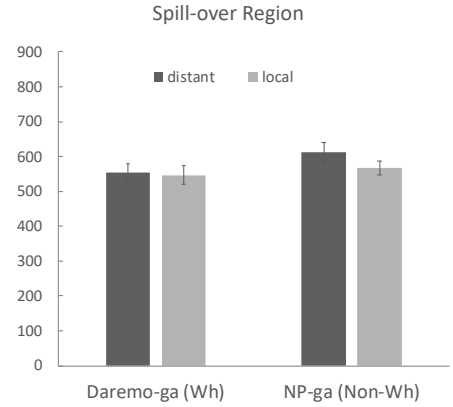

Figure 4. Estimated RTs at spill-over region

Experiment 2 indicated that there were processing difficulties in the nested structures regardless of whether the subject was a wh or a non-wh phrase. The locality effects found in the non-wh (referential NP) condition was inconsistent with the results in previous studies in which the referential NP was not found to cause locality effects in nested structures. The critical region, the matrix predicate, contained negation, and it might have caused extra processing costs, resulting in the locality effects. As the wh-phrase "wh + *mo* + NOM" was not an NPI, the predicate could be either an affirmative predicate or a negative predicate. If readers have a specific expectation of upcoming predicate type following the "wh + *mo* + NOM", it might have affected the processing. For example, if the structure "wh + *mo* + NOM" with an affirmative predicate was more expected than the "wh + *mo* + NOM" with a negative predicate, the expectation mismatch could cause a processing difficulty when readers encountered the negative predicate. In addition, a sentence that had a negative matrix predicate with "wh + *mo* + NOM" subject have un ambiguity in the meaning of the sentence; for example, 'Everyone did not believe that…'/ 'Not everyone believed that…'. This ambiguity of the sentence meaning may

have affected the processing in the experiment. Even though those concerns are applicable to Experiment 1, as the matrix predicate, which was the critical region, was negative in Experiment 2 and it may have caused the extra processing difficulties, a further experiment was conducted to confirm that this effect was found in the subject-predicate dependencies regardless of the predicate type.

4. Experiment 3

In Experiment 3, the matrix predicate was changed to an affirmative predicate to test the possibility that the predicate type had affected the results in Experiment 2.

4.1 Stimuli

Experiment 3 used the sentences like (4) in the self-paced reading study.

(4) a. Distant/Wh Condition:

daremo-ga *sono-uweitoresu-ga* *tennai-de*
wh+*'mo'*-NOM [the waitress-NOM restaurant-LOC
jourenkyaku-o *nagu-tta-to* *sinjita-node* ...
regular customer-ACC hit-past-COMP] believe-past-because ...
'Everyone believed that the waitress hit the regular customer at the restaurant, so...'

b. Distant/Non-Wh Condition (referential NP):

kokku-ga *sono-uweitoresu-ga* *tennai-de*
chef-NOM [the waitress-NOM restaurant-LOC
jourenkyaku-o *nagu-tta-to* *sinjita-node* ...
regular customer-ACC hit-past-COMP] believe-past-because ...
'The chef believed that the waitress hit the regular customer at the restaurant, so...'

c. Local/Wh Condition:

sono-uweitoresu-ga *tennai-de* *jourenkyaku-o*
[the waitress-NOM restaurant-LOC regular customer-ACC
nagu-tta-to ***daremo-ga*** *sinjita-node* ...
hit-past-COMP] **Wh+*'mo'*-NOM** believe-past-because ...
'Everyone believed that the waitress hit the regular customer at the restaurant, so...'

d. Local/Non-Wh Condition:

sono-uweitoresu-ga *tennai-de* *jourenkyaku-o*

[the waitress-NOM restaurant-LOC regular customer-ACC

nagu-tta-to ***kokku-ga*** *sinjita-node* ...

hit-past-COMP] **chef-NOM** believe-past-because ...

'The chef believed that the waitress hit the regular customer at the restaurant, so...'

In the wh conditions, "wh + *mo* + NOM" '*everyone*' was used as the matrix subject, whereas in the non-wh conditions, a referential NP + NOM was used as the matrix subject. The matrix predicate was affirmative, contrary to Experiment 2, where the matrix predicate was negative. There were 24 sets of the target sentences, and 72 filler sentences in this experiment.

Predictions

If the wh-phrase ("*daremo-ga*") increases the processing cost in the nested structures regardless of the predicate type, and the distance between the matrix subject and the matrix predicate increases the processing costs, locality effects should be observed in the wh condition at the matrix predicate region; that is the RTs in the distant conditions would be longer than in the local conditions.

4.2 Procedure

The procedure in Experiment 3 was the same as in Experiments 1 and 2.

4.3 Participants

Thirty-six native Japanese speakers participated in Experiment 3, who were recruited from the same community as in Experiments 1 and 2; however, the participants in the previous experiments were excluded. Participants were paid 500 Japanese yen for their participation.

4.4 Statistical analysis

The statistical analysis was conducted in the same way as in Experiment 2.

4.5 Results & Discussion

Comprehension accuracy

The overall mean accuracy for the target sentence comprehension questions was 86.00% (SD = 7.87). The mean accuracy for the distant/wh condition was 89.35%, 82.87% for the

distant/non-wh condition, 89.35% for the local/wh condition, and 82.41% for the local/non-wh condition.

Reading time data

As shown in Table 3 and Figure 5, the statistical analysis revealed that only the main effect of DISTANCE was significant, indicating that there were locality effects in both the wh conditions and the non-wh (referential NP) conditions at the matrix predicate even when the matrix predicate was affirmative.

Table 3. Parameters of the fixed effects from the LME model at the matrix predicate region

	β	SD	*df*	*t*	*p*	
(Intercept)	611.51	31.81	39.02	19.22	< 0.001	***
DISTANCE	-87.95	24.93	35.48	-3.53	0.001	**
SUBJECT-TYPE	0.27	21.61	744.08	0.01	0.990	
DISTANCE × SUBJECT-TYPE	-15.92	43.36	758.46	-0.37	0.714	

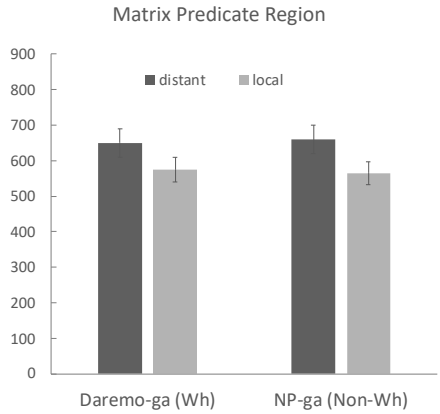

Figure 5. Estimated RTs at the matrix predicate

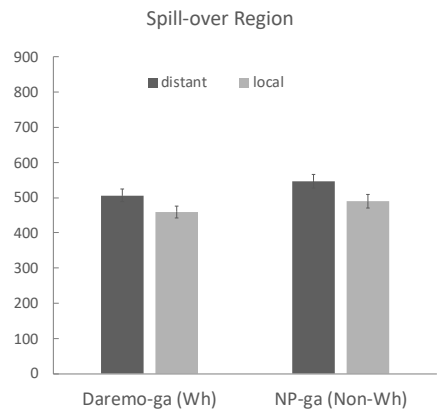

Figure 6. Estimated RTs at spill-over region

At the spill-over region, the main effects of DISTANCE and SUBJECT-TYPE were significant (β = -51.75, SD = 11.63, *df* =798.97, *t* = -4.45, $p < 0.0001$; β = 36.40, SD = 11.62, *df* =781.43, *t* = 3.14, $p = 0.002$). The distant conditions were read slower than in the local conditions (Figure 6). However, the interaction was not significant (β = -9.88, SD = 23.25, *df* =797.90, *t* = -0.43, $p = 0.671$).

Even when the matrix predicate was affirmative, locality effects were observed in Experiment 3. The locality effect in Experiment 2 was also replicated for referential NP condition.

5. General discussion

Three self-paced reading experiments were conducted to investigate whether the integration of a matrix subject and a matrix predicate in nested structures was sensitive to distance. Experiment 1 found that greater processing difficulties occurred in the integration in nested structures when the matrix subject was an NPI and contained a wh-phrase. Experiments 2 and 3 found that there were locality effects in nested structures, regardless of the presence of the wh-phrase or regardless of the predicate types. These results provide new empirical data for locality effects in nested structures in Japanese.

The locality effect in the NPI case was consistent with the results in the previous studies, where a different NPI phrase was used in the experiments (Nakatani, 2009, 2014). The non-NPI matrix subject with a wh-element also showed the locality effects in our experiments. Ono & Nakatani (2010) showed that a wh-phrase and a verb with Q-particle dependency was also distance-sensitive. The wh and Q-particle relation is a dependency where one of the elements needs the other one to complete a dependency similar to NPIs. In this study, we found the locality effects even when the wh-element of the matrix subject was in the subject–predicate dependency which does not need the polarity licensing or have the relation such as the wh and Q-particle.

The different result between the NPI subjects and the non-NPI subjects was found in the spill-over region in Experiment 1. There was the prolonged locality effect only in the non-NPI condition. This might be because the negative predicate was more expected in the NPI conditions since NPIs are always followed by a negative predicate, and it reduced the processing cost after the integration, whereas in the non-NPI conditions, either negative or affirmative predicate could follow, thus the upcoming predicate type was less predicted, resulting the spill-over integration costs.

As both "wh + *mo"* and "wh + *mo* + NOM" are quantifiers, another possibility is that when the matrix subject in a nested structure contains a quantifier, the processing costs may be higher in the integrative processing; this possibility could be tested using other quantifiers.

Also, there was a concern that the ambiguity of the sentence meaning can affect the processing in the non-NPI condition. However, similar results were found for both Experiments 2 and 3 for the wh conditions, which tended to imply that sentence meaning ambiguity was less influential on the processing in this study.

As shown in Experiments 2 and 3, when the matrix subject contained a wh-element, the distance between the matrix subject and matrix predicate affected the processing cost, as reflected in the RTs. This suggested that when the additional information, such as wh-element or

NPI, is added to the matrix subject in the nested structures, the locality effect is observed in general. Cue-based Theory explains the processing (costs) associated with the encoding, storage, and retrieval stages. Given that the matrix subject was encoded with the information that the word has, additional information such as the presence of the wh-element or NPI could be encoded differently in memory, with the generated retrieval cues at the predicates being searched for in a different way to the referential NPs.

The results for the referential NP cases in Experiments 2 and 3 were not consistent with the previous studies (e.g., Nakatani, 2009). This apparent inconsistency may have come from the fact that our stimuli contained the demonstrative "*sono*" 'the' in the embedded subject phrases but not in the matrix subject phrase, whereas there was no such demonstrative attached to either matrix or embedded subjects in the previous studies. It is possible that the embedded subject (demonstrative + referential NP) was encoded differently from the matrix subject (bare referential NP) because of the presence of the demonstrative, and the matrix subject was not similar enough to the embedded subject to be reactivated at the embedded predicate. The less reactivation of the matrix subject at the embedded predicate could require more processing costs to retrieve the matrix subject at the matrix predicate in the nested structures. This possibility could be further investigated in future research.

6. Conclusion

In this study, three self-paced reading experiments were conducted to determine the degree to which encoding information affects the processing costs for subject-predicate dependencies in nested structures. In Experiment 1, it was found that a greater processing difficulty occurred in nested structures at the integration when the matrix subject was an NPI and contained a wh-element. Experiments 2 and 3 found that there were also locality effects in nested structures regardless of the presence of wh-phrase or predicate types.

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