Integration Costs in the Processing of Japanese Wh-interrogative Sentences

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Abstract

Locality effects in sentence comprehension are considered to reflect the magnitude of processing load closely related to working memory. Although locality effects are attested in head-initial languages such as English, they are often absent in head-final languages (Konieczny, 2000; Nakatani & Gibson, 2010; Vasishth & Lewis, 2006). We report the results of two self-paced reading experiments addressing the issues of locality effects as well as Miyamoto and Takahashi’s (2002) Typing Mismatch Effects, using Japanese wh-interrogative sentences. We found clear locality effects in the critical regions for the integration between wh-phrases and their theta-assigning verbs. This result necessitates a revision in the typology of locality-sensitive integrations. TMEs were also found, but only in the spillover regions. This delay probably reflected a mild processing failure suggested by Miyamoto and Takahashi. We also found a main effect of the complexity of the intervening phrases such that inserting a complement clause induced a greater load than inserting a series of arguments and adjuncts. This result cannot be accounted for by a simple time-based activation theory, but may be explained in terms of similarity interference (Van Dyke & Lewis, 2003).

1. Introduction

One of the ultimate goals of processing a sentence is to successfully establish the relationships between words. This process is often called integration in the literature (Gibson, 1998). A challenge for the parser is that many cases exist in which the grammatically associated words are not placed next to each other. In such cases, the parser must keep track of multiple grammatical dependencies simultaneously in the course of processing, which may sometimes cause processing difficulties. A reasonable hypothesis is that the processing difficulty emerges in accordance with various factors, such as the number of locally incomplete dependencies and the distance between the words that must be integrated. In this section, we review some previous studies and spell out the issues to be addressed in this study.
1.1. Locality Effects

Regarding the issue of integration distance, Phillips, Kazanina, and Abada (2005) asked the participants to rate the difficulty of the sentences as in (1), and observed that the sentences in (1b) involving long dependencies (between a wh-phrase and a verb, in this case) were rated lower than (1a), showing so-called locality effects\(^1\) (see also Gibson, 1998, 2000; Grodner & Gibson, 2005; Sprouse, Fukuda, Ono, & Kluender, 2011; Frazier & Clifton, 1989; Kluender & Kutas 1993; Fiebach, Shlesewsky, & Friederici, 2001).

(1) a. The detective hoped that the lieutenant knew *which accomplice* the shrewd witness would *recognize* in the lineup.

    b. The lieutenant knew *which accomplice* the detective hoped that the shrewd witness would *recognize* in the lineup.

Some researchers suggest that the locality-related processing cost be attributed to the difficulty of the NP retrieval process that is a necessary step for the integration between an argument and a verb (Gibson, 1998, 2000; Van Dyke & Lewis, 2003; Vasishth & Lewis, 2006). Thus, sentences with long dependencies are difficult to process because the parser has to store elements (i.e., NPs) in the working memory that has a limited capacity to hold items. The encoded information of NPs stored in the working memory will decay quite rapidly. When an NP is linearly far away from its predicate, such an NP is not highly activated in the working memory by the time the parser encounters the verb, making the memory retrieval more difficult.

1.2. Locality Effects in Head-final Languages

Interestingly, some studies dealing with head-final languages, such as Japanese, German, and Hindi, failed to observe a locality effect (Vasishth & Lewis, 2006; Konieczny, 2000; Nakatani & Gibson, 2008). For instance, Nakatani and Gibson (2008, 2010) manipulated the distance between the subject NP and the verb in the matrix clause by adding various phrases, such as a complement clause, as shown in (2). They did not observe any reading time increase at the matrix verb *hookokusita* ‘reported’ in their doubly-nested condition (2a) when compared with the non-nested condition (2b).

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\(^1\) The term “locality effects” is also used in the literature on syntax, where the term refers to the effects observed when a dependency involves the so-called “island” structure. In the psycholinguistics literature, the term refers to the difficulty associated with the linear distance of the dependency, not necessarily involving the island structure.
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(2) a. Doubly-nested: [NP1 [NP2 [NP3 V3-c] V2-c V1]
   [syoki-ga] [daigisi-ga] [syusyoo-ga]
   [secretary-NOM] [congressman-NOM] [prime.minister-NOM]
   utatanesita to] koogisita to] hookokusita].
   dozed-C] protested-C reported
   “The secretary reported that the congressman had protested that
   the prime minister had dozed.”

   b. Non-nested: [NP3 V3-c] [NP2 V2-c] [NP1 V1]
   [syusyoo-ga] utatanesita to] [daigisi-ga]
   [prime.minister-NOM] dozed-C] [congressman-NOM]
   koogisita to] [syoki-ga hookokusita].
   protested-C] [secretary-NOM reported]

By contrast, Nakatani (2009) observed a slowdown at the verb when the
subject NP was a negative polarity item (NPI) NP-sika ‘only NP,’
suggesting that the syntactic and/or semantic type of NP has some impact
on the reading time of the verb that participates in the dependency
formation. The fact that a Japanese NPI NP-sika exhibits locality effects
clearly indicates that there are cases in which head-final languages exhibit
locality effects. It could be that even in head-final languages, the scope-
bearing elements, such as an NPI, show locality effects, even though the
elements that do not participate in the scope interaction are not distance-
sensitive. To test this hypothesis, other types of scope-related dependencies
must be examined. In this paper, we report the results from two self-paced
reading experiments testing the effects of the integration distance between a
wh-phrase and its verb and its licenser, Q-particle ka.

1.3. Typing Mismatch Effects

An interesting property of Japanese wh-Q dependencies that is not
present in the processing of NPI-dependencies is the flexibility of the
attachment of the Q-particle: It may be attached to a higher clause than the
one containing the wh-phrase. This means that the Q-particle may or may
not be attached to the verb that assigns a theta-role to the wh-phrase. This
could cause a different type of difficulty that is not found in the NPI-
processing, because the Q-particle may not be found in the closest possible
position. Miyamoto and Takahashi (2002) investigated the parser’s bias on
the dependency between a wh-phrase and the verb with a Q-particle. They
used sentences as shown in (3), and they observed a reading time slowdown
at the embedded verb in (3b), where the embedded verb appeared with a
declarative-complementizer to.
(3) a. senmu-wa [kakarityoo-ga dono pasokon-o tukatteiru-ka]
supervisor-TOP [director- NOM which PC-ACC use-Q]
iimasita.
said
“The supervisor said which PC the manager uses.”

b. senmu-wa [kakarityoo-ga dono pasokon-o tukatteiru-to]
supervisor-TOP [director-NOM which PC-ACC use-C]
iimasita-ka?
said-Q
“Which PC did the supervisor say that the manager uses?”

According to their claim, the parser expects to find a verb with a Q-particle
at the embedded clause in (3) because it sees the wh-phrase dono pasokon-o
‘which PC-ACC’ in the embedded clause, and the embedded verb is the
earliest position where the licensing Q-particle can appear. In (3b), the
parser’s expectation of seeing a Q-particle was not fulfilled, resulting in a
slower reading time, which Miyamoto and Takahashi (2002) called a
Typing Mismatch Effect (TME). They also suggested that part of the extra
cost signified as a TME stems from the parser’s effort to reanalyze the
scope of the wh-phrase from the embedded to the higher clause.

What is not known, however, is the influence of the locality factor on
TMEs. Will a greater distance between the wh-phrase and its theta-assigner
lead to a greater magnitude of TME? We also address this issue in this
study.

Note that testing locality effects with wh-interrogative sentences in
Japanese as depicted above has a great benefit that is not available in the
processing of head-initial languages. When a wh-phrase in Japanese is
integrated with the verb with a Q-particle, the integration seems to involve
at least two separate processes. First, the wh-phrase and the verb will
establish a thematic dependency. Second, there is a dependency between the
wh-phrase and the Q-particle, which will determine the scope of the wh-
phrase. It seems necessary to separate those two dependencies because, as
illustrated in (3b), the verb that has a thematic relation with the wh-phrase
may not bear a Q-particle. Therefore, in (3a), although a Q-particle at the
embedded verb should satisfy the parser’s preference to have a Q-particle in
the same clause, the parser has to establish two separate dependency
relations at a particular verb position, which could incur some processing
cost. Although such cost was not reported in Miyamoto and Takahashi’s
study, it is hasty to conclude that no such cost exists because Miyamoto and
Takahashi’s materials were fairly simple, which might have been the reason
why no cost was observed for wh-Q integration.
1.4. Wh-Q integration, thematic integration, locality effects, and TMEs

On the basis of the above considerations on the locality effects and TME in Japanese, we can cross these two factors (the locality factor × the typing mismatch factor) to test (i) whether Japanese wh-phrases, which are A'-elements, show a locality effect relative to the position of the Q-particle; (ii) whether they show locality effects relative to the position of their theta-assigners; and (iii) whether TME, if any, is affected by the locality factor. Sample materials are provided below, where the Local conditions (4c,d) are scrambled versions of (4a,b) and semantically identical, respectively:

(4) a. Distant/Match:

\[
\text{dare-ga} \quad \text{[sensee-ga tyapatu-no namaikina gakusee-o who-NOM]} \text{[teacher-NOM dyed.hair-GEN sassy student-ACC} \\
\text{hidoku sikatta-to]} \text{ sinziteiru-ka kyoositu-de hogosya-wa harshly scolded-c] believe-Q classroom-at parents-TOP kikimasita.}
\]

as

“The parents asked who believed that the teacher had harshly scolded the sassy student with dyed hair.”

b. Distant/Mismatch:

\[
\text{dare-ga} \quad \text{[sensee-ga tyapatu-no namaikina gakusee-o who-NOM]} \text{[teacher-NOM dyed.hair-GEN sassy student-ACC} \\
\text{hidoku sikatta-to]} \text{ sinziteiru-to kyoositu-de hogosya-wa harshly scolded-c] believe-C classroom-at parents-TOP iimasita-ka?
\]

said-Q

“Who did the parents say believed that the teacher had harshly scolded the sassy student with dyed hair?”

c. Local/Match:

\[
\text{[sensee-ga tyapatu-no namaikina gakusee-o} \\
\text{[teacher-NOM dyed.hair-GEN sassy student-ACC} \\
\text{hidoku sikatta-to]} \text{ dare-ga sinziteiru-ka kyoositu-de harshly scolded-c] who-NOM believe-Q classroom-at hogosya-wa kikimasita. parents-TOP heard}
\]

d. Local/Mismatch:

\[
\text{[sensee-ga tyapatu-no namaikina gakusee-o} \\
\text{[teacher-NOM dyed.hair-GEN sassy student-ACC} \\
\text{hidoku sikatta-to]} \text{ dare-ga sinziteiru-to kyoositu-de harshly scolded-c] who-NOM believe-C classroom-at}
\]
In the four conditions provided above, the subject wh-phrase dare ‘who’ is either distant from its theta-assigner sinziteiru ‘believe’ (the Distant conditions: (4a,b)) or adjacent to it (the Local conditions (4c,d)). The Q-particle for dare ‘who’ is either attached to the closest possible predicate sinziteiru ‘believe’ (the Match conditions (4a,c)) or attached to the matrix clause (the Mismatch conditions (4b,d)). The latter conditions are expected to cause a TME. Overall, the Match/Local condition (4b) is predicted to be the easiest to process, and the Mismatch/Distant condition (4c) should be the hardest, if both TME and locality factors are in effect.

If a difference between the Mismatch conditions is found, it can be interpreted as a locality effect either on TME, or on the wh’s thematic integration, or both. If a difference between the Match conditions is found, it can be interpreted as a locality effect either on the wh-Q integration or on the wh’s thematic integration, or both.

The final region may show similar locality effects between the Mismatch conditions because these conditions involve wh-Q integration in this final region. Alternatively, no such effect may be found if a locality effect is assumed to be found between the point of integration and the final point where the target of the retrieval (in this case, dare) was activated prior to the final region (i.e., the region containing the wh’s theta-assigner, sinziteiru) (Vasishth & Lewis, 2006).

1.5. Locality Factor and Syntactic Movement

Finally, it is worth mentioning that there is another good reason to investigate the processing of Japanese wh-interrogative sentences. Recently, Bartek, Lewis, Vasishth and Smith (2011) investigated the locality effects in English by comparing the data collected from the self-paced reading task and the eye-tracking task. They provided an extensive review of Grodner and Gibson (2005) that also investigated the major source of locality effects. They manipulated the dependency length by adding a relative clause modifier (the part indicated by a parenthesis in the example below). One major finding of Grodner and Gibson (2005) is that locality effects were found at the verb supervised in sentences such as (5a) where the embedded subject the nurse was modified with a relative clause, but no locality effects were found in sentences such as (5b) where the subject the nurse is in the matrix clause.

(5) a. The administrator [who the nurse (who was from the clinic) supervised __ ] scolded the medic while . . .
b. The nurse (who was from the clinic) supervised the administrator . . .

Bartek, et al. (2011) suggested that the results found in Grodner and Gibson (2005) can be interpreted in a few different ways. For instance, Grodner and Gibson’s results may indicate that a locality effect emerged only when there is an overt movement of the phrase. In other words, the reading time of the verb supervised was slow in (5a) with a relative clause modifier because the phrase the administrator was moved from the object position of the verb. Alternatively, it seems possible to assume that locality effects in (5a) were due to the existence of an A'-dependency between the phrase the administrator and the verb supervised. Using the wh-phrase in Japanese, we can provide very useful data to tease apart those two possibilities. Recall that the Japanese wh-phrase does not have to undergo movement (therefore it can remain in situ). If a locality effect shows up in Japanese, it would support the idea that the A'-dependency (and not the movement per se) is responsible for the locality effect, at least partially.

2. Experiment 1

A self-paced reading experiment was conducted to address the issues discussed above, as summarized in the following: (i) whether a Japanese wh-phrase shows a locality effect relative to the position of the Q-particle; (ii) whether it shows a locality effect relative to the position of the theta-assigner; and (iii) whether TME, if any, is affected by the locality factor.

2.1. Method
2.1.1. Participants

Experiment 1 was conducted twice (the first run in January, 2010, and the second run in July, 2010) at Konan University using exactly the same materials and method, with different subjects. A total of 109 native speakers of Japanese (53 for the first run; 56 for the second; mostly undergraduate students at Konan) participated. They were each paid 1000 yen for participation in the experiment, which took about 20–30 minutes per session.

2.1.2. Materials

A sample set of the four target conditions crossing the two factors (the locality factor × the typing mismatch (TM) factor) is provided in (4) above. Bound morphemes such as case-markers and complementizers were grouped with preceding words such as nouns and verbs. The syntactic

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2 Some part of the results have been presented as Ono & Nakatani (2010), as an interim technical report.
frames of these conditions are summarized in the following:

(4’) a. Distant/Match:  
   \[ wh\text{-NOM} [ CC ] V\text{-Q} N\text{-LOC} N\text{-TOP} V \]

b. Distant/Mismatch:  
   \[ wh\text{-NOM} [ CC ] V\text{-C} N\text{-LOC} N\text{-TOP} V\text{-Q} \]

c. Local/Match:  
   \[ [ CC ] wh\text{-NOM} V\text{-Q} N\text{-LOC} N\text{-TOP} V \]

d. Local/Mismatch:  
   \[ [ CC ] wh\text{-NOM} V\text{-C} N\text{-LOC} N\text{-TOP} V\text{-Q} \]

(A complement clause (CC) comprised six words in each condition.)

We prepared 24 items, each with four variants as depicted above. The four variants of each item comprised the same words, except that the final region contained different verbs for the Match and Mismatch conditions because very few verbs select interrogative as well as declarative CCs. The critical region was the region containing the \( wh \)-phrase’s theta-assigner, which was Region 8. The spillover region (Region 9: a locative phrase) was of interest to us as well. The final region (Region 11) was also of interest, although the results from this region must be interpreted with care because the verb choice was not controlled.

2.1.3. Procedure

The experiment was conducted with Linger (v.2.88), a sentence processing experimental presentation program written by Douglas Rohde, using Apple Mac mini computers on Mac OS X and 17-inch TFT displays. The program presented one sentence at a time on the computer monitor, left to right, word by word in a noncumulative, moving-window manner as a participant pushed the space bar (Just, Carpenter & Woolley, 1982). The 24 sets (items) of four target conditions were distributed in a Latin Square design, resulting in four lists. Fifty-four filler items were added to each list. The 78 sentences in a list were presented in a different pseudo-random order for each participant, such that no two target items were presented consecutively. The participants were asked to read the sentences as naturally as possible. The experiment was preceded by brief instructions and 10 practice items. Each stimulus was immediately followed by a yes-no question regarding the content of the sentence that was presented, with feedback for wrong answers, to ensure that participants kept track of the meaning of each sentence.

2.2. Results

To make sure that only the data from serious participants were included, the data from the participants whose mean accuracy rates for the comprehension questions were less than 70% (which amounted to 39 participants) were eliminated from the analysis. We also excluded the data.
from one participant whose mean reading time (RT) of all items (except the practice items) was beyond 2.5 standard deviations from the mean RT of all the participants (excluding the aforementioned 39 participants). The data from the other 69 participants were analyzed. Of all the trials from the 69 participants, those containing data points smaller than 200 milliseconds (ms) and greater than 5000ms were eliminated because such extremely quick and slow responses in certain regions might have had an effect on the neighboring regions in unpredictable ways. All the wrongly answered trials were also excluded.

The mean RTs of Regions 8–11 for the four target conditions are summarized in Figure 1.

In Region 8 (the critical region), ANOVAs revealed a main effect of the locality factor (F1(1,68)=39.2, p<.001; F2(1,23)=66.3, p<.001) such that the Distant conditions were read slower, whereas no TME was found (Fs<0.1, ps>.9); no interaction was found either (Fs<0.1, ps>.9).

Conversely, in Region 9 (the spillover region), a main effect of the TM factor was found (F1(1,68)=6.7, p<.05; F2(1,23)=4.9, p<.05) such that the Mismatch conditions were read slower, whereas no locality effect was found (Fs<2, ps>.1); there was an interaction between the two factors (F1(1,68)=4.7, p<.05; F2(1,23)=6.9, p<.05) such that the Local/Match condition (4c) was read faster than the other three.

In the final region (Region 11), a significant effect of the TM factor was found (F1(1,68)=6.8, p<.05; F2(1,23)=7.3, p<.05) such that the Mismatch conditions were read slower; no other effects were found.
2.3. Discussion

There are several major findings in this experiment. First of all, strong locality effects were found in the critical verb region. This clearly supports the hypothesis that even in head-final languages, the processing of A’-elements are distance-sensitive. Note that locality effects were found in both Match and Mismatch conditions. In Match conditions, the reading time slowdown was observed when a complement clause was placed between the wh-phrase and the verb. Similar to the sentences involving an NPI NP-sika found in Nakatani (2009), the sentences involving an A'-dependency between a scope-bearing wh-phrase and the verb showed locality effects. However, it was unclear if the found locality effect was caused by the wh-Q integration distance, or the wh’s thematic integration distance. In the Match conditions, both types of integration were expected in this region, and thus, we were unable to tease apart these two possibilities. It is noteworthy that a locality effect was found even in the Mismatch conditions, where the integration was only thematic (i.e., no wh-Q integration was involved). This effect is not likely to be induced by the TM factor because no TME was found in this region. Thus, the reasonable conclusion that can be drawn from this finding is that the wh’s thematic integration is distance-sensitive. This conclusion requires us to revise the hypothesis that the thematic integration in general is not distance-sensitive.

As for the dependency between a wh-phrase and Q-particle, we found an effect of Q-integration in the final region (although the data in this region must be treated with care because the verbs were not constant across the conditions). We can interpret the slowdown observed in the Mismatch conditions as suggesting that the integration between the wh-phrase and the Q-particle is costly. In this region, the parser needs to calculate the dependency between the wh-phrase and the Q-particle to finally determine the scope of the wh-phrase. One may notice that no locality effects were found in this region. However, the lack of locality effects of the wh-phrase was not unexpected once we assume that the parser has made access to the wh-phrase at the embedded verb position in both the Distant and Local conditions. Regardless of the position of the Q-particle, the thematic integration had to be done in the embedded verb. Therefore, it seems plausible to assume that the activation level of the wh-phrase was not different between the Distant and Local conditions. In fact, this kind of lack of locality effects support Vasishth and Lewis’s (2006) assumption that the integration locality is quantified in terms of the distance between the point of integration and the last activation point of the word to be retrieved.

Third, while we found a strong locality effect in the critical verb region, a TME was not found until the following spillover region. This finding regarding the timing of the two types of effect may reflect some difference in how these two types of processing are handled by the parser. Locality
effects may simply reflect the difficulty in the integration process itself. By contrast, a TME is probably induced by the need for reanalysis, as Miyamoto and Takahashi (2002) suggests. Because the need for reanalysis is preceded by a mild processing failure, its remedial process inducing the mismatch effects may only be found in the spillover region.

Finally, it is slightly peculiar to see that there was no TME in the Distant conditions in this spillover region. Recall that in Region 9 there was a clear TME in the Local conditions. One possible account for the lack of a TME in the Distant conditions is that although there was in fact a TME, the contrast between the Match and Mismatch conditions was masked due to a spillover from the large locality effect in the previous region. Alternatively, the sum of the large distance effect and TME might have resulted in a ceiling effect in the Distant/Mismatch effect. Note that Miyamoto and Takahashi’s materials (3) were structurally much simpler than ours (4). Then, a question arises as to whether manipulating the complexity of the intervening phrases would lead to clearer TME patterns. Experiment 2 was conducted to test locality effects and TMEs with Wh-interrogative sentences, manipulating the complexity of the intervening elements.

3. Experiment 2

Experiment 2 was prepared to examine whether a TME can be observed when we decrease the difficulty associated with the integration cost discussed in the previous section. In this experiment, we crossed two factors: (i) the intervening-category factor (the intervening elements between a Wh-phrase and its theta-assigner being either clausal (CC) or non-clausal (NP)), and (ii) the TM factor (Match vs. Mismatch). In addition, the intervening CCs were shorter, comparable with Miyamoto and Takahashi’s (2002) items in terms of complexity. We also used *dono NP* ‘which NP’ instead of *dare* ‘who.’ The use of a so-called D-linked Wh-phrase *dono NP* ‘which NP’ (Pesetsky, 1987) might help the parser to process the Wh-dependency. It is known in the literature of syntactic island constraints that the referentiality of the Wh-phrase is linked to the ease of extraction out of syntactic islands (Szabolcsi, 2006). For instance, in (6a), it is possible to extract a Wh-phrase *which politician* out of an adjunct, while such an extraction is not possible with a Wh-phrase *how much water* in (6b).

(6) a. Which politician did you go to England [after meeting __ ] ?
    b. *How much water did you make the pasta [after boiling __ ] ?

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3 Some part of the results have been presented as Ono & Nakatani (2011) in the form of a poster.
This contrast can be captured in terms of the referentiality of the extracted wh-phrase. On the basis of this, it was expected that the locality-sensitive processing cost could be reduced with the use of a D-linked wh-phrase.

3.1. Method
3.1.1. Participants
Fifty-five native speakers of Japanese, mostly undergraduate students at Konan University, participated. None of them participated in Experiment 1. They were each paid 1000 yen for participation in the experiment, which took about 20–30 minutes per session.

3.1.2. Materials
A sample set of the four target conditions crossing the two factors (the intervening-category factor × the TM factor) is provided below:

(7) a. CC/Match: \textbf{wh-NOM [ CC ] said-Q NP-TOP V}
\textit{dono syain-ga} \quad [kakarityoo-ga atarasii pasokon-o]
\textbf{which employee-NOM} \quad [director-NOM new \quad PC-ACC]
tukatteiru-to\textbf{] itta-ka} \quad \textit{butyoo-wa sitteiru.}
\text{use-C]} \quad \textbf{said-Q} \quad \text{manager-TOP know}
“The manager knows which employee said that the director was using a new PC.”

b. CC/Mismatch: \textbf{wh-NOM [ CC ] V-C NP-TOP V-Q}
\textit{dono syain-ga} \quad [kakarityoo-ga atarasii pasokon-o]
\textbf{which employee-NOM} \quad [director-NOM new \quad PC-ACC]
tukatteiru-to\textbf{] itta-to} \quad \textit{butyoo-wa \textbf{omotteiruno-ka}?
\text{use-C]} \quad \textbf{said-C} \quad \text{manager-TOP think-Q}
“Which employee does the manager think said that the director was using a new PC.”

c. NP/Match: \textbf{wh-NOM [ NP+ ] said-Q NP-TOP V}
\textit{dono syain-ga} \quad [kakarityoo-no hakarai-de atarasii
\textbf{which employee-NOM} \quad [director-NOM help-with new
pasokon-o] \quad \textbf{tukatteiru-ka} \quad \textit{butyoo-wa sitteiru.}
\text{PC-ACC]} \quad \textbf{use-Q} \quad \text{manager-TOP know}
“The manager knows which employee is using a new PC owing to the director’s arrangement.”

d. NP/Mismatch: \textbf{wh-NOM [ NP+ ] V-C NP-TOP V-Q}
\textit{dono syain-ga} \quad [kakarityoo-no hakarai-de atarasii
\textbf{which employee-NOM} \quad [director-NOM help-with new
pasokon-o] \quad \textbf{tukatteiru-to} \quad \textit{butyoo-wa \textbf{omotteiruno-ka}?
\text{PC-ACC]} \quad \textbf{use-C} \quad \text{manager-TOP think-Q}
“Which employee does the manager think is using a new PC owing to the director’s arrangement?”

Note that the Complement Clause (CC) conditions (7a,b) were similar to the Distant conditions in the previous experiment, except that the intervening CCs were simplified: the number of words included in each CC was four in Experiment 2, whereas it was six in the previous one. The NP conditions (7c,d) included a series of NPs (with an AP and a PP) instead of a CC. The number of the intervening words was identical across all conditions. We prepared 20 items, each with the four conditions. Again, the critical region was the region containing the verb that assigns a theta-role to the \( Wh \)-phrase, Region 6. The spillover region (Region 7) and the final region (Region 8) were also of interest.

3.1.3. Procedure

The procedure of Experiment 2 was exactly the same as Experiment 1, except that the number of fillers was 70.

3.2. Results

The data trimming was done in the same manner as in the previous experiment: We eliminated the data from the eight participants whose mean comprehension accuracy rates were less than 70%, as well as those from two slow participants whose mean RTs were beyond 2.5 SDs from the mean of the RTs of the 47 participants; all the wrongly answered trials were excluded, as well as those with extremely fast (<200ms) or slow (>5000ms) data points. The data from another participant was excluded because he/she answered incorrectly on every trial of the NP/Match condition (7c). Eventually, the data from the remaining 44 participants were analyzed.

The mean RTs of Regions 6–8 for the four target conditions are summarized in Figure 2. In Region 6 (the critical region), ANOVAs revealed a main effect of the intervening-category factor (\( F(1,43)=23.9, p<.001; F(2,19)=16.1, p<.001 \)) such that the CC conditions were read slower, whereas the effect of the TM factor was, again, not found in this region (\( F_s<0.5, ps>.6 \)); no interaction was found either (\( F_s<0.1, ps>.8 \)).

In the spillover region (Region 7), a main effect of the intervening-category factor was found (\( F(1,43)=9.9, p<.005; F(2,19)=9.0, p<.01 \)) such that the CC conditions were read slower; the effect of the TM factor was at best marginal in this region (\( F(1,43)=4.4, p<.05; F(2,19)=2.3, p>.1 \)); pairwise comparisons between the CC conditions and between the NP conditions did not show significant differences (\( F_s<4; ps>.1 \)); the difference between the Mismatch conditions turned out to be significant in the participants analysis only (\( F(1,43)=6.98, p<.05; F(2,19)=2.4, p>.1 \));
there was no interaction between the two factors ($F_s<1.1$, $p_s>.3$).

In the final region (Region 8), the TM factor was found with a main effect ($F_1(1,43)=12.4$, $p<.005$; $F_2(1,19)=12.4$, $p<.005$) such that the Mismatch conditions were read slower, replicating our previous finding; no other effects were found.

![Figure 2. Mean RTs (ms) of Regions 6–8 for the four conditions.](image)

### 3.3. Discussion

The results clearly indicated that the integration cost found at the verb was influenced by the complexity of the materials between the $wh$-phrase and its theta-assigning verb. The integration cost was larger when a complement clause appeared between the $wh$-phrase and the verb. This finding suggests that locality effects are sensitive not only to the linear distance between the two elements, but also to the syntactic and/or semantic complexity of the elements constituting the distance. Although we have to be careful in drawing a strong conclusion only from the results of the current experiment because different verbs were compared in the critical region, it could be relevant to look at the issues from a perspective of the similarity-based interference (Vasishth & Lewis, 2006; Lewis, Vasishth, & Van Dyke, 2006, among others). From this perspective, the CC conditions were more difficult because the embedded nominative NPs interfered with the target of the retrieval $dono$ NP, which was also nominative.

As for the TM factor, we did not observe a TME at the critical verb region, similar to Experiment 1. The effect was observed in the spillover region, although the effects were statistically reliable only within the participants analysis. The expected increase in the magnitude of a TME was not found, but this could be due to the fact that the number of participants...
was small (the number of participants in Experiment 1 was twice as large as that of Experiment 2). Numerically, we see that the RT difference between the Match/Mismatch conditions in the spillover region increased as the complexity of intervening elements decreased: The RT difference was 22.9ms between the Distant/Match and Distant/Mismatch conditions in Experiment 1 (six intervening words); it was 52.4ms between the Match and Mismatch conditions in Experiment 2 (four intervening words); it was 116.9ms between the Local/Match and Local/Mismatch conditions in Experiment 1 (no intervening words). A mild effect of the intervening-category factor was observed in the TME conditions, indicating that TME might be distance-sensitive.

Finally in the final region, we found an effect which was quite similar to the one in Experiment 1. The slower reading times in the Mismatched conditions indicate the existence of the integration cost between the *wh*-phrase and the Q-particle.

4. General Discussion and Conclusion

As we have illustrated in the Introduction, locality effects often provide informative clues to the problems of the relationship between sentence processing and working memory. The two experiments presented in this paper aimed to provide new empirical data regarding locality effects in Japanese. Major findings from these experiments are summarized in the following.

First, clear locality effects were found in the critical verb regions. In Experiment 1, locality effects were observed even when the *wh*-phrase was not paired up with the Q-particle. Given that no TME was observed in this region, it is safe to conclude that the *wh*’s thematic integration was sensitive to locality. Thus, we have concluded that the integration between a *wh*-phrase and its theta-assigner is distance-sensitive, while it remains unclear whether the *wh*-Q integration is sensitive to locality. Recall that Nakatani (2009) observed locality effects with a Japanese NPI *NP-sika* ‘only NP.’ Therefore, it seems plausible that the A'-dependency in general, which typically involves a scope-related element, should show locality effects.

However, this finding is also somewhat surprising, given the assumption that thematic integrations are generally cost-free and distance-insensitive. A question arises as to why the thematic integration involving a *wh*-phrase is treated differently from the regular thematic integration. It could be the case that a *wh*-phrase, which is an A'-element, is registered to a processing (or memory) thread different from the thematic processing thread. Thus, unlike regular NPs, the retrieval of a *wh*-phrase is distance-sensitive because the parser has to seek it crossing multiple threads (or memory space).
Another major focus in this paper was to examine the nature of TME. In our experiments, the TM factor was crossed against the locality factor, in order to investigate whether the locality manipulation has some impact on the size of a TME. One important finding is that the region where a TME was found was different from the one where locality effects were observed, suggesting that those two effects stem from different types of processing. That is to say, the former effect might simply reflect a retrieval difficulty, whereas the latter is induced by a mild garden-path effect followed by a structural reanalysis, leading to the delay in the emergence of the effect. A mild locality effect on TME was found in Experiment 2, although further research is required to draw a decisive conclusion.

Taken together, we have provided new evidence in regard to locality effects in a head-final language, Japanese, suggesting that integration of \textit{wh} phrases (and possibly A' elements in general) are distance-sensitive. The current data also clarified the nature of TME in comparison with regular retrieval processes.

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**Reference**


