Locality and incrementality in the human linguistic computation: 
A view from processing of the aggressively non-D-linked wh-phrases in Japanese* 

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Abstract 
One central property of the human sentence processor (i.e., the parser) is incrementality; the parser processes input in a piecemeal fashion. This system has interfaces with many other cognitive systems; a working memory system is known to influence the parser’s performance. This study aims to make clear the relation between incrementality and the memory resource. There have been many studies in the literature where incrementality and pressure from the memory resource go hand in hand, but the cases where incrementality counteracts the bias from the requirement of the memory resource are yet to be investigated in detail. We chose sentences with the aggressively non-D-linked wh-phrases as a test case, and conducted two sentence-fragment completion experiments and one self-paced reading experiment, and found that the constraint from the memory resource is extremely strong.

1 Introduction 
Human language processing is known to be quite rapid, accurate and incremental (i.e., without any delay), despite the fact that it is a very complex system that interfaces with other cognitive systems, and the nature of incremental processing is one of the highly debated issues in this field (Frazier & Fodor, 1978). On the other hand, in which aspects the human sentence processing is in fact incremental, and why the parser employs incremental processing are yet to be investigated in greater detail. For instance, it has been claimed that aspects of sentence processing such as phrase structure building (Frazier & Fodor, 1978), dependency formation (Stowe, 1986), and thematic role assignment (Pritchett, 1992) are incremental. On the other hand, native speakers of any language certainly process a much wider range of linguistic information, and it is to be made clear whether they are incrementally processed as well. Furthermore, some claims have been advocated that certain types of information are underspecified during sentence processing (Construal hypothesis: Frazier & Clifton, 1996) or that the

* This research was supported by Japan Society for the Promotion of Science Grant-in-Aid for Scientific Research (to HS, #20320060; to HO, #21320083), Japanese Ministry of Education, Culture, Sports Science & Technology Grant-in-Aid for Scientific Research on Priority Areas: System Study on Higher-Order Brain Functions (to HS, #20020020), and Grant-in-Aid for Young Scientists (to HO, #21720152). We would like to thank Rosalynn Chiu for assistance in conducting the experiments, and the audience at KLS 2009 and an anonymous reviewer for helpful discussions and comments on this work. All remaining shortcomings are ours.
parser can avoid making a strong commitment for their decisions (Information-Paced Parsing: Inoue & Fodor, 1995); all of those indicate some kind of non-incremental processing in a limited domain.

As for the nature of incremental processing by the parser, it has been suggested that incrementality is derived from the efficiency consideration for the working memory system (Gibson, 1998). Given the limited capacity of working memory system, it seems reasonable to assume that the parser carries out the linguistic computation as it encounters the input since that is the way by which the parser can achieve the goal most efficiently. However, it has been observed that incremental processing in certain cases forces the parser to build a structure that would incur more memory resources eventually (Kamide & Mitchell, 1999). Such a finding seems to blur the link between the memory constraint and incrementality, at least in terms of structure building.

Building upon the findings on structure building by Kamide & Mitchell (1999), it is important to examine other cases that exhibit an interaction between the memory constraint and incrementality. In this paper, we analyze a certain kind of wh-questions that allow us to look into the complex nature of incrementality. As we will discuss in detail below, with those wh-questions, the incremental parser is led to choose the analysis that satisfies a well-known locality bias, although it requires heavier working memory load in the end. Examining such a paradigm would make clear the relation between incrementality and the working memory constraint.

1.1 Wh-dependency and its locality bias

Previous studies on Japanese sentence processing have demonstrated that there is a locality bias in the comprehension of wh-questions: after encountering a wh-phrase, such as nani ‘what’, readers expect to encounter a licensing question particle ka (Q-particle) at the first grammatically available verb position. Miyamoto & Takahashi (2002) found that the reading time of the embedded verb region katta-to ‘bought-C’ in (2) is longer than that of katta-ka ‘bought-Q’ in (1), arguing that the reading time slowdown, which is dubbed as Typing Mismatch Effects (TME), reflects the unfilled expectation by the reader to encounter a Q-particle at that particular verb position (also see Aoshima, et al., 2004; Ono, 2006; Ono, et al., 2006).

(1) Taro-wa [ Hanako-ga nani-o katta-ka] iimasita ‘Taro said what Hanako bought.’
T-TOP H-NOM what-ACC bought-Q said

(2) Taro-wa [ Hanako-ga nani-o katta-to] iimasita-ka ‘What did Taro say that Hanako bought?’
T-TOP H-NOM what-ACC bought-C Q said

The locality effect limned above has several crucial aspects. First, it involves a grammatical constraint; a wh-phrase nani must be grammatically licensed by the Q-particle ka. Second, the parser recognizes the existence of the wh-dependency first by encountering the licensee of the dependency, namely the wh-phrase. Below, we attempted to elucidate the nature of TME by dealing with the second aspect.
1.2 Aggressively-non-D-linked Wh-phrase

The current study examines a case where the preference by the parser illustrated in the last section has to be sacrificed in order to satisfy the grammatical constraint of the wh-dependency. It is of interest to see in what way the parser satisfies the two different kinds of constraints that go opposite directions. Taking studies such as Miyamoto & Takahashi (2002) and Aoshima et al. (2004) as a starting point, we used a paradigm in which a Q-particle has already been predicted before the parser encounters a wh-phrase. A wh-question with an adverb ittai ‘the hell’ (ittai-wh-question; Pesetsky, 1987; Huang & Ochi, 2004; Ono, 2008) is able to provide a great test case.

An adverb ittai is a kind of polarity item that must be licensed in wh-questions. A relevant property of ittai for our purpose is that it can be separated from its wh-associate as shown in (4), but (5) shows that such a non-local relationship between ittai and its wh-associate is only possible to the extent that the position of ittai is no higher than a clause with a Q-particle (Huang & Ochi, 2004).

(4) Ittai Taro-wa [Hanako-ga nani-o katta-to] omoimasita-ka
the.hell T-TOP H-NOM what-ACC bought-C thought-Q
‘The hell did Taro think that Hanako bought?’

(5) *Ittai Taro-wa [Hanako-ga nani-o katta-ka] sitteimasu
the.hell T-TOP H-NOM what-ACC bought-Q know
‘Taro knows what the hell Hanako bought.’

Let us consider how the parser might process an ittai-wh-question in (4). Since ittai grammatically requires a Q-particle usually in the same clause, the incremental parser would posit a Q-particle (and probably it expects an upcoming wh-phrase) as soon as it encounters ittai. As the parser recognizes the presence of the embedded clause (i.e., encountering NP-NOM following NP-TOP), the Q-particle will be posited at the matrix verb position. When the parser further encounters a wh-phrase in the embedded clause, the parser can do either one of the following options. It may be that the parser considers the matrix Q-particle as a relevant licensing particle, and does not posit any Q-particle at the embedded verb position. This option seems efficient for the parser in the sense that the dependency required for the embedded wh-phrase piggybacks on the already established dependency of ittai in the matrix clause. However, this option sacrifices the locality bias. Alternatively, the parser nonetheless posits a Q-particle at the embedded verb position by “ignoring” the previously posited matrix Q-particle that is potentially a licensor for the wh-phrase. In this option, the parser might expect to encounter a sentence such as (6), where there are two separate wh-dependencies: one in the embedded, and the other in the matrix clause. Note that in this case, ittai belongs to the matrix wh-dependency.

(6) Ittai Taro-wa [Hanako-ga nani-o katta-ka] dare-ni tazunemasita-ka
the.hell T-TOP H-NOM what-ACC bought-Q who-to asked-Q
‘Who the hell did Taro ask what Hanako bought?’

This option also seems efficient in the sense that the locality bias for the embedded wh-phrase is maximally satisfied. On the other hand, the parser posits a structure with two separate dependencies, which is quite costly from the point of view of computing dependencies. In this paper we will report
results from one self-paced reading experiment and two sentence fragment completion experiments. The results would provide an insight into the nature of the human sentence processing, especially in terms of a complex interaction between grammar and the working memory system.

2 Experiment 1

Experiment 1, a sentence fragment completion experiment, was conducted in order to investigate whether and how the presence of ittai would influence the way the embedded wh-phrase is licensed; in particular, we are interested in finding out whether the locality bias could be observed with ittai.

Twenty-eight students at Kansai Gaidai University participated in the study. Experimental materials consisted of 15 sets of sentence fragments with 3 conditions each, as shown in (7).

(7) a. *Wh-Locative condition (WhLoc)*
    dokono kyoositu-de kyooyu-wa zyosyu-ga dareno ronbun-o  □□□□□
    which classroom-at professor-TOP assistant-NOM whose paper-ACC

b. *Non-Wh-Locative condition (NWhLoc)*
    sono kyoositu-de kyooyu-wa zyosyu-ga dareno ronbun-o  □□□□□
    that classroom-at professor-TOP assistant-NOM whose paper-ACC

c. *Ittai condition (Ittai)*
    ittai kyooyu-wa zyosyu-ga dareno ronbun-o  □□□□□
    the.hell professor-TOP assistant-NOM whose paper-ACC

WhLoc condition (7a) has a wh-locative expression at the beginning of the fragment while NWhLoc condition (7b) has a non-wh-locative expression. In the Ittai condition (7c), ittai is placed at the beginning of the fragment. Target items require supplying at least two verbs to be completed as a grammatical sentence, since there is no single predicate that takes all of the NPs as arguments. We would like to investigate where the participants posit a Q-particle, especially in the Ittai condition; if an embedded Q-particle is posited, it would suggest that the participants choose to make the dependency between the wh-phrase and the Q-particle as short as possible. On the other hand, if a Q-particle is added to the matrix verb, it would suggest that the grammatical requirement for the embedded wh-phrase piggybacks on the ittai dependency. The 15 sets of items were distributed among 3 lists in a Latin Square design. Each participant saw exactly one of the lists intermixed with 30 unrelated fillers in a random order.

2.1 Results

From 28 participants, 420 sentence fragments were completed in total. Among those, 30 completions (7.1%) were eliminated as uncodable. Most of them were incomplete sentences. Remaining 390 completions were further coded by the placement of the Q-particle. Table 1 illustrates its distribution in each condition, and a chi-square test of independence showed that the relation among the conditions had an impact on the distribution of the Q-particle ($\chi^2(4) = 52.6, p < .01$).

The NWhLoc condition revealed an extremely strong tendency that a question particle was placed in the embedded clause. Second, in the WhLoc condition, a similar bias was found. Although the
strength of the bias was not as strong as in the NWhLoc condition, there were quite a few cases where a Q-particle was supplied in the embedded clause. One noticeable pattern only found in this condition is that there were some completions with both an embedded and a matrix Q-particle. Third and finally, a bias for putting an embedded Q-particle was also found in the Ittai condition. On the other hand, the overall pattern for this condition was different from the other two conditions, in that there were some completions with matrix Q-particles.

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<td>count</td>
<td>%</td>
</tr>
<tr>
<td>Emb. Q</td>
<td>84</td>
<td>69 %</td>
<td>*134</td>
<td>98 %</td>
<td>102</td>
<td>77 %</td>
</tr>
<tr>
<td>Mat. Q</td>
<td>18</td>
<td>15 %</td>
<td>1</td>
<td>1 %</td>
<td>*24</td>
<td>18 %</td>
</tr>
<tr>
<td>Both Q</td>
<td>*20</td>
<td>16 %</td>
<td>1</td>
<td>1 %</td>
<td>6</td>
<td>5 %</td>
</tr>
<tr>
<td>Total</td>
<td>122</td>
<td>136</td>
<td>132</td>
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Note: The “*” sign denotes that the number of occurrence is significantly larger than expected. The totals do not match up neatly across the conditions, due to the number of occurrences of uncodable sentence fragments.

2.2 Discussion

The strong preference for an embedded wh-phrase to be matched up with an embedded Q-particle, which was observed in the NWhLoc condition, was expected from previous studies. We take this pattern as a baseline in discussing results from other conditions. In the WhLoc condition, the number of completions with two Q-particles (embedded and matrix) is larger than that in the NWhLoc condition: obviously due to an extra wh-phrase at the beginning of the fragment. The particular pattern illustrates that the embedded wh-phrase was licensed by an embedded Q-particle, and the sentence-initial wh-phrase was licensed by a matrix Q-particle. In other words, two wh-phrases form separate wh-dependencies. In contrast, a large number of completions with an embedded Q-particle show that the embedded Q-particle licensed both wh-phrases. It should mean that the participants took the sentence-initial locative wh-phrase as being dislocated from the embedded clause. In fact, this reasoning can be also applied to the pattern found in the Ittai condition. The preference for the embedded Q-particle illustrates that the participants consider ittai to have been dislocated from the embedded clause. Nonetheless, the finding that the Q-particle was placed only at the embedded clause in the Ittai condition is quite surprising. The discussion with regard to (5) indicates that the scrambling of ittai from the embedded clause to the matrix clause should be grammatically unavailable. This

1 As for the cases that were categorized as ‘Matrix Q’, there were a few instances, in the WhLoc condition, where the sentence ends without the Q-particle *ka, but with a modal marker -daroo. We counted that marker as a licensing particle, since the number of such a case was rather small in this condition, and it seems that the decision does not alter the overall picture of the WhLoc condition. In the Ittai condition, it was also quite rare (only two instances) to observe a case where the Q-particle *ka was omitted. Note also that in most of the cases where the Q-particle appeared in the matrix clause, it appeared as -no-daroo-ka. We are grateful to an anonymous reviewer for pointing out the relevant issues on the licensing particle.
raises some concern that the materials used in the experiment were too hard to complete as sentences with appropriate wh-dependencies. In order to examine these points in detail, the second sentence completion experiment was prepared.

3 Experiment 2

Experiment 2, an off-line sentence completion task, was conducted in order to investigate to what extent the native speakers of Japanese consider that \textit{ittai} is related to wh-dependencies. Also, we examine the distribution of wh-phrase generated by the participants depending on the position of \textit{ittai}. Finally, it is of importance to investigate how the distribution of the Q-particle changes with respect to the positions of the wh-phrase. Forty students at Kansai Gaidai University, all native speakers of Japanese, participated in the study. None of them participated in Experiment 1. Experimental materials consisted of 16 sets of sentence fragments with 4 conditions each, as shown in (8).

\begin{enumerate}
\item \textit{Ittai-Low condition}: kyoozyu-wa zyosyu-ga ittai _______
\item \textit{Ittai-Mid condition}: kyoozyu-wa ittai zyosyu-ga _______
\item \textit{Ittai-High condition}: ittai kyoozyu-wa zyosyu-ga _______
\item \textit{No-Ittai condition}: kyoozyu-wa zyosyu-ga kekkyoku _______
\end{enumerate}

The differences among the conditions are (a) whether the sentence fragment contains \textit{ittai} or not, and (b) if it contains \textit{ittai}, where it occurs. The adverb was placed in three different positions: Low (after NP-NOM), Mid (between NP-TOP and NP-NOM), and High (at the beginning of the fragment). As in Experiment 1, each sentence fragment requires at least two predicates, and Q-particles when necessary. The 16 sets of items were distributed among 4 lists in a Latin Square design. Each participant saw exactly one of the lists intermixed with 30 unrelated fillers in a random order.

3.1 Results

From 40 participants, 640 sentence fragments were completed in total. Among those, 34 completions (5.3\%) were eliminated as uncodable. Most of them were incomplete sentences. Remaining 606 completions were further coded by the combination of the placement of the wh-phrase and the Q-particle. Since a wh-phrase was rarely provided in the No-Ittai condition, the data are not reported below. We further focus on some completion patterns that are relevant to the interests of our study. Table 2 illustrates the distribution of the wh-phrase and the Q-particle in each condition, and a chi-square test of independence was performed for the remaining 3 conditions and distributions except for the category “others”; it showed that the relation among the conditions has an impact for the distribution of the wh-phrase and the Q-particle ($\chi^2(4) = 60.1, p < .01$).

In the Ittai-Low condition, there was a strong preference for putting a wh-phrase right after \textit{ittai} and the Q-particle in the embedded clause. The preference was so strong that most of the completions
showed this pattern. Furthermore, the Ittai-Mid condition illustrated the same pattern. Although there were a lot of completions with the embedded wh-phrase and Q-particle, we found some cases where a wh-phrase and a Q-particle were both provided in the matrix clause.²

<table>
<thead>
<tr>
<th>Table 2: Experiment 2, distribution of the wh-phrase and the Q-particle.</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Ittai-Low</td>
</tr>
<tr>
<td>count</td>
</tr>
<tr>
<td>Emb.Wh+Emb.Q</td>
</tr>
<tr>
<td>Emb.Wh+Mat.Q</td>
</tr>
<tr>
<td>Mat.Wh+Mat.Q</td>
</tr>
<tr>
<td>Others</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Note: The "*" sign denotes that the number of occurrence is significantly larger than expected, and a "^" mark significantly smaller than expected. The totals do not match up neatly among the conditions, due to the numbers of occurrence of the uncodable sentence fragments. The ratio shown with the number of percent does not include the number of occurrences from the category "other".

3.2 Discussion

One thing that is quite clear from this experiment is that the native speakers of Japanese clearly recognized a central property of ittai that it must be associated with the wh-dependency. When ittai appeared in sentence fragments, the participants provided a wh-phrase and a Q-particle. Given that, in the No-Ittai condition, there were only a few completions with a wh-dependency, it is quite noteworthy that ittai strongly triggered the presence of wh-dependency.

Now, the patterns that were obtained from the Ittai-Low condition and the Ittai-Mid condition were extremely similar. In both conditions, almost all of the sentence fragments were completed with an embedded wh-phrase and an embedded Q-particle. As for the Ittai-Low condition, ittai was clearly a constituent of the embedded clause, and it triggered the presence of an embedded wh-phrase. The fact that such an embedded wh-phrase is matched with the embedded Q-particle is a replication from Experiment 1; the participants preferred to make the length of a wh-dependency as short as possible. Second, the placement of ittai in Ittai-Mid condition was ambiguous; the adverb could either be a constituent of the embedded clause or that of the matrix clause. The results in this experiment suggest that the adverb in such a position was taken as a constituent of the embedded clause (cf. Kamide & Mitchell, 1999), assimilating to the pattern from Ittai-Low condition.

Finally, the Ittai-High condition produced a result different from the other two conditions. Although most of the completions fell into the category where both wh-phrase and the Q-particle were provided in the embedded clause, there were some cases in which the Q-particle was placed in the matrix clause. The produced sentences with the embedded wh-phrase and the matrix Q-particle are of interest to our current concern. One crucial point is that a wh-phrase was placed most preferably in the embedded

² Being similar to the result in Experiment 1, there were a few cases where the Q-particle was not provided, but a modal marker -daroo showed up at the matrix clause. As we noted in Experiment 1, we classified those as ‘Matrix Q’.
clause. This seems to indicate that the native speakers of Japanese wanted to establish a link between ittai and a wh-phrase as soon as possible. It is of course grammatically possible to put a wh-phrase in the matrix clause, but such a choice forces the participants to wait until they constructed the embedded clause completely, rendering a production that requires a lot of memory resource. As for the placement of the Q-particle, assuming that in general it is preferable to have a wh-dependency as short as possible, the result suggests that the presence of ittai created a force to choose a long wh-dependency. This option is in fact expected given the discussion of Huang and Ochi (2004), and as we have seen in Experiment 1, it should be unacceptable to have the embedded wh-phrase and the embedded Q-particle when ittai is in the matrix clause. The result in which there was a large number of completions with the embedded wh-phrase and the embedded Q-particle seems to suggest that establishing a longer dependency requires a large amount of memory resource and sometimes the non-preferred option is avoided even when the grammar indicates otherwise.

In summary, the results in Experiment 2 confirmed that the native speakers of Japanese fully recognized that ittai must be associated with a wh-phrase, but as for the relationship between the position of ittai and the associated wh-dependency, the participants decided to have the short wh-dependency, contrary to what has been suggested by the grammar. It was assumed that such an option is preferred due to the demand from the memory resource; the calculation of the link between the adverb ittai and the wh-dependency in addition to the calculation of the wh-dependency itself required a lot of computational resource. Now, the above consideration calls for further scrutiny; although we attempted to account for the current results in terms of the memory resources, the sentence fragment completion task used in Experiments 1 and 2 allowed the participants to take a certain amount of time, and when they complete sentences in principle it is certainly possible to go back, reconsider the produced sentences, and fix if they wanted to. In order to investigate the locus of difficulty and how they process sentences with ittai and a wh-phrase, we further conducted a self-paced reading task which is more appropriate to examine the time-course of processing such sentences.

4 Experiment 3

We conducted a self-paced reading experiment to investigate the influence of ittai on the locality bias in the wh-dependency. A self-paced reading task was adopted in order to figure out the time-course of the processing of wh-dependency with ittai, and in particular, we would like to compare our results against that in Miyamoto & Takahashi (2002). Forty-seven students at Hiroshima University, all native speakers of Japanese, participated in the study. Experimental materials consisted of 24 sets of sentence fragments with 4 conditions each, as shown in Table 3.

Each sentence in experimental materials starts with either ittai or other frequency adverbs that are not associated with the wh-dependency (region 1). The embedded verb appears either with a declarative complementizer to or a Q-particle ka (region 5). In all conditions, sentences continue with a locative expression (region 6) and another wh-phrase (region 7), which is necessary to make all
sentences end as grammatical. The 24 sets of items were distributed among 4 lists in a Latin Square design. Each participant saw exactly one of the lists intermixed with 60 fillers in a random order. The 4 conditions were organized in a $2 \times 2$ factorial design that manipulated the factors Adverb-type (ittai vs. non-ittai) and Complementizer-type (-ka or just -to at the embedded clause verb). Participants were timed in a self-paced non-cumulative moving-window reading task. Each experimental trial was followed by a yes-no comprehension question about the content of the sentence.

Table 3: Target Materials in Experiment 3

<table>
<thead>
<tr>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
<th>Region 4</th>
<th>Region 5</th>
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</thead>
<tbody>
<tr>
<td>Ittai / Q</td>
<td>ittai</td>
<td>kyoozyu-wa</td>
<td>zyosyu-ga</td>
<td>dono ronbun-o</td>
</tr>
<tr>
<td>Ittai / DC</td>
<td>ittai</td>
<td>kyoozyu-wa</td>
<td>zyosyu-ga</td>
<td>dono ronbun-o</td>
</tr>
<tr>
<td>Non-Ittai / Q</td>
<td>itumo</td>
<td>kyoozyu-wa</td>
<td>zyosyu-ga</td>
<td>dono ronbun-o</td>
</tr>
<tr>
<td>Non-Ittai / DC</td>
<td>itumo</td>
<td>kyoozyu-wa</td>
<td>zyosyu-ga</td>
<td>dono ronbun-o</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Region 6</th>
<th>Region 7</th>
<th>Region 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>kenkyuusitu-de</td>
<td>dare-ni</td>
<td>setumeisimasu-ka</td>
</tr>
<tr>
<td>office-at</td>
<td>who-to</td>
<td>explain-Q</td>
</tr>
</tbody>
</table>

4.1 Results

Results from two participants were eliminated due to their low accuracy rates (less than 70%). The average accuracy rate for the remaining participants was 88.5%. For the remaining data, the reading times longer than 2900ms were cut off, affecting 2.0% of the total data points. Results of the reading times are shown in Table 4; region 5 and 6 are critical regions in the current experiment.

Table 4: Region by region reading time (ms) in Experiment 3.

<table>
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<th>2</th>
<th>3</th>
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<tbody>
<tr>
<td>Ittai / Q</td>
<td>614(24)</td>
<td>954(37)</td>
<td>997(42)</td>
<td>775(33)</td>
<td>732(31)</td>
<td>583(18)</td>
<td>460(14)</td>
<td>685(32)</td>
</tr>
<tr>
<td>Ittai / DC</td>
<td>617(24)</td>
<td>963(41)</td>
<td>956(40)</td>
<td>798(32)</td>
<td>702(26)</td>
<td>643(26)</td>
<td>470(14)</td>
<td>674(29)</td>
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<tr>
<td>Non-Ittai / Q</td>
<td>690(28)</td>
<td>959(37)</td>
<td>893(34)</td>
<td>774(31)</td>
<td>707(27)</td>
<td>614(24)</td>
<td>467(14)</td>
<td>717(30)</td>
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<tr>
<td>Non-Ittai / DC</td>
<td>689(28)</td>
<td>958(38)</td>
<td>964(41)</td>
<td>757(32)</td>
<td>718(29)</td>
<td>657(26)</td>
<td>480(14)</td>
<td>707(31)</td>
</tr>
</tbody>
</table>

Note: the numbers in parenthesis represent standard error (SE).

The reading times were analyzed, region by region, by repeated measures ANOVAs with two factors: Adverb-type and Complementizer-type. In region 1, in which an adverb (ittai or non-ittai adverb) appears, there was a significant main effect of Adverb-type ($F_1(1,44) = 17.5, p < .01; F_2(1,23) = 10.9, p < .01$), indicating that the Ittai conditions were read faster than the Non-Ittai conditions. No main effect of Complementizer-type or interaction was found. There was no significant main effect or interaction from region 2 to 4. In region 5, one of the crucial regions, in which an embedded verb appears with either the declarative complementizer to or the question licensing particle ka, there was no significant main effect ($F_s < 1$), and there was no significant interaction, either ($F_1 < 1; F_2(1,23) = 1.9, p = .18$). In region 6, which is the region right after the embedded verb, there was a significant main effect of Complementizer-type ($F_1(1,44) = 4.9, p < .04; F_2(1,23) = 5.1, p < .04$), indicating that the Q-particle conditions were read faster than the declarative complementizer conditions, but there
was no main effect of Adverb-type \( (F_1(1,44) = 1.6, p = .21; F_2(1,23) = 2.0, p = .17) \), or interaction \( (Fs < 1) \). No significant main effects or interactions were found in region 7 and 8.

4.2 Discussion

The fact that there was no main effect in region 5, but a main effect of Complementizer-type was found in region 6 seems to be a spill-over effect, which is often observed in self-paced reading experiments. We assume that the difference in region 6 in fact arises from region 5, note that the material in region 6 is invariant across conditions. Given that, the lack of interaction suggests that the observed effect of complementizer-type was not different between the two Adverb-type conditions. Assuming that the slowdown observed in the Non-Ittai / Declarative complementizer condition is TME, it is fair to say that a slowdown in the Ittai / Declarative complementizer condition was also TME, and sentences in both conditions have been processed in a similar way.

The results in this experiment were quite unexpected, assuming that the presence of ittai at the beginning of the sentence would influence the way in which the wh-dependency is grammatically established. It seems that the locality bias of the wh-phrase is so strong that the grammatical requirement triggered by ittai was in a sense “ignored” in order to satisfy the need to establish the short wh-dependency. Recall that we have observed in Experiments 1 and 2 that the sentence-initial ittai have a certain influence on the processing of the wh-dependency. In contrast, in Experiment 3, we did not find the effect of ittai. It seems that the force from the constraint from the memory resource stood out much strongly due to the task in this experiment.

5 General discussion and conclusion

In this paper, we started the discussion by asking the question regarding the relation between incrementality and the constraint of the memory resource. We then aimed to provide some insight into the problem by investigating a structure where the incremental processing counteracts the constraint of the memory resource. Specifically, we chose a dependency formation with ittai where satisfying the usual locality bias triggered by a wh-phrase would increase the total cost of processing the whole sentences memory-wise. From the two experiments using the sentence fragment completion task, we observed that the locality bias was very strong, and the embedded wh-phrase triggered postulation of the Q-particle in the same clause. It is nonetheless certain that the presence of the sentence-initial ittai altered the overall pattern, but the effects were in general weak. Such a finding seems to be peculiar, especially looking from the grammatical point of view. The participants generated sentences that are claimed to be unacceptable in the syntactic literature; the findings in our experiments seem to indicate that the grammatical dependency involving ittai is quite hard to process / produce.

We also investigated the paradigm by a self-paced reading task. The task allows us to examine the time-course of the sentence processing, and we found that TME was observed in conditions with ittai. The results suggest that the preference found in the sentence fragment completion task was also
present, and even with *ittai*, the parser expected to find the embedded verb with the Q-particle. In other words, the presence of *ittai* had no effect on the parser. In summary, our results seem to highlight the strength of the requirement from the memory resource, but the complex nature of the parser certainly calls for further investigation.

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言語処理における局所性と漸増性：
日本語の「いったい」を伴う疑問詞の処理を通じて

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人間の文解析機構の重要な性質の 1 つは漸増性である。つまり解析器は入力を少しずつ処理するということが知られている。また、この解析機構は他の認知システムとのインターフェースを持ち、その 1 つ作動記憶は、解析器がどのように文を解析、また産出するかに大きな影響を与えると考えられている。本研究では、文解析機構の漸増性と作動記憶の要求の関係を明らかにすることを目的としている。これまで多くの研究が漸増性と作動記憶の要求が一致する構造を対象に進められてきたのに対して、漸増性が作動記憶の要求と対立するケースについてはまだ詳しい研究が進んでいない。Kamide & Mitchell (1999) では解析器が漸増的に処理を進めた結果、全体としては作動記憶に負荷のかかる構造を構築してしまうことを示している。本研究では、類似する状況を生み出す可能性のある wh-依存関係に焦点を当て、漸増性の本質に迫ることを目的とした。

特に、「いったい」を伴う疑問詞の処理を題材とし、文完成課題を用いた実験 2 つと自己ベース読文課題を用いた実験を 1 つ実施した。

実験 1（文完成課題）では、文頭に置かれた「いったい」が埋め込み節の疑問詞の認可にどう影響するかを調査した。他の条件と比較して、「いったい」の条件では Miyamoto & Takahashi (2002) 等の多くの先行研究で観察されている wh-疑問文の適好性が幾分弱まるという効果が観察された。そのため効果は弱いものだった。実験 2（文完成課題）では同様の観察が得られた。実験 3（自己ベース読文課題）では、上述述べた適好性をリアルタイムで観察することを目的としたが、「いったい」の効果は観察されなかった。これらの結果から、作動記憶の要求が非常に強力であり、総合的な処理負荷の計算がされていないことが示唆される。
Proceedings of the Thirty-Fourth Meeting of The Kansai Linguistic Society 2010
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ワークショップ

複雑述語の形式・機能とダイナミズム—日本語・琉球語・韓国語をもとに—
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第 34 回 関西言語学会プログラム (神戸松蔭女子学院大学 2009 年 6 月 6 日・7 日)
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