

# Processing Benefits from Similarity-Based Partial Reactivation: A Case Study of Subject-Predicate Dependency in Japanese

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## 1. Introduction

In real-time sentence comprehension, the parser incrementally constructs various structural dependencies from a string of successive inputs. Of such dependencies, the subject-predicate dependency is a representative one that we can easily find in a sentence. However, in multiple centre-embedded structures, subject-predicate dependency is hard to process (Chomsky and Miller, 1963):

(1) The rat [that the cat [that the dog bit] chased] ran away.

The source of such a difficulty can be explained by the Cue-based parsing theory, which involves a two-step process implemented by the interaction between the parser and the working memory: encoding and retrieval (Lewis, 1996; Lewis

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the local condition (4b) at the predicate (see also Nakatani & Gibson, 2000):

(3) Referential NP-Predicate

a. Distant Condition:

**店長が** [ウエイトレスが 店内で 常連客を 殴ったと] **信じなかった** ...

manager-NOM [waitress-NOM shop-at regular-customer-ACC hit-COMP] believe-NOT-PAST

‘The manager did not believe that the waitress hit the regular customer in the restaurant.’

b. Local Condition:

[ウエイトレスが 店内で 常連客を 殴ったと] **店長が** **信じなかった** ...

[waitress-NOM shop-at regular-customer-ACC hit-COMP] manager-NOM believe-NOT-PAST

(4) NP with NPI-Predicate

a. Distant Condition:

**店長しか** [ウエイトレスが 店内で 常連客を 殴ったと] **信じなかった** ...

manager-NPI [waitress-NOM shop-at regular-customer-ACC hit-COMP] believe-NOT-PAST

‘The manager did not believe that the waitress hit the regular customer at the restaurant.’

b. Local Condition:

[ウエイトレスが 店内で 常連客を 殴ったと] **店長しか** **信じなかった** ...

[waitress-NOM shop-at regular-customer-ACC hit-COMP] manager-NPI believe-NOT-PAST

Thus, the referential NP-predicate dependency is categorised as a distance-insensitive dependency, whereas the NPI-negation dependency is identified as a distance-sensitive dependency. Given the observation above, two questions arise to which the present study aims to provide alternative answers:

- (5) a. An empirical question: What type of subject-predicate dependencies show distance-(in)sensitive effects? (i.e., generalisation)
- b. A theoretical question: What underlying cognitive process induces distance-(in)sensitive effects? (i.e., processing algorithm)

This paper is organised as follows: Section 2 briefly reviews the previous proposal and presents our new proposal with regard to (5). In Section 3, to test our proposal, we conducted a self-paced reading experiment that uses the same distance manipulation as (3) and (4) but with different types of matrix subjects. Based on our experimental results, regarding (5a), we suggest that when matrix and embedded subjects are more similar, the (otherwise) distance-sensitive effects vanish. As for (5b), we argue that a partial feature match between these subjects makes the matrix subject (re)activate at the embedded verb position, which leads to the cancellation of distance effects. Section 4 concludes our study.

## 2. Previous and Current Proposals

### 2.1. Ono & Nakatani (2010)

Ono & Nakatani (2010) offer an original proposal with regard to the contrast between the distance-sensitive and -insensitive dependencies in Japanese. They conducted a self-paced reading experiment that manipulated the position of the Q-particle (Mid-Q vs. High-Q) and the distance between the *wh*-subject and its predicate (Distant vs. Local):

#### (6) a. Distant, Mid-Q

誰が [先生が 茶髪の 生意気な 学生を ひどく 叱った]と 信じているか...

who-NOM teacher-NOM dyed-hair-GEN impertinent student-ACC harshly scolded-C believe-Q

‘The parents asked who believes that the teacher harshly scolded the sassy student with dyed hair in the classroom.’

#### b. Local, Mid-Q

[先生が 茶髪の 生意気な 学生を ひどく 叱った]と 誰が 信じているか...

teacher-NOM dyed-hair-GEN impertinent student-ACC harshly scolded-C who-NOM believe-Q

#### c. Distant, High-Q

誰が [先生が 茶髪の 生意気な 学生を ひどく 叱った]と 信じていると...

who-NOM teacher-NOM dyed-hair-GEN impertinent student-ACC harshly scolded-C believe-C

‘The parents told who believes that the teacher harshly scolded the impertinent student with dyed

hair in the classroom.’

d. Local, High-Q

[先生が 茶髪の 生意気な 学生を ひどく 叱った]と 誰が 信じていると…

teacher-NOM dyed-hair-GEN impertinent student-ACC harshly scolded-C who-NOM believe-C

‘The parents told who believes that the teacher harshly scolded the impertinent student with dyed hair in the classroom.’

Interrogative *wh*-phrases in Japanese must be licensed by a *c*-commanding *Q*-particle *ka*, either in the same clause or in a higher clause. The Japanese parser, however, has a strong preference for encountering a *Q*-particle in the earliest grammatical position after encountering a *wh*-phrase (Miyamoto & Takahashi, 2002). When the earliest position is filled with a declarative complementiser *to*, such as in (6c) and (6d), the *wh*-phrase cannot be licensed at this position (typically incurring the slowdown called Typing Mismatch Effect). (6a) and (6b) require the integration of the *wh*-phrase and the *Q*-particle at the embedded verb *believed-Q*, while (6c) and (6d) do not.

The results revealed robust distant effects in R8 (*sinziteiru-to/ka*, ‘believe-C/Q’). These effects clearly indicate that the integration between a *wh*-phrase and its predicates is distance-sensitive regardless of the *wh*-licensing process, which matches with the pattern of NPI-negation dependency but not with the referential NP-predicate dependency.<sup>1</sup>

Based on these results, Ono & Nakatani (2010) present the following proposal: the integration of a regular NP and a predicate is unmarked and is held active during the sentence processing. In contrast, the integration of NPIs or *wh*-words and predicates involves additional semantic computation. Because such scope-related processing could be temporarily deactivated in real-time sentence processing, distance-sensitive effects emerge in the case of the NPI-negation and

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<sup>1</sup> The Typing Mismatch Effect was not observed in R8, due to the delayed effect (see Ono & Nakatani, 2010; 2014 for details).

*wh*-predicate dependency.

This proposal can account for most of the existing data on Japanese distance-(in)sensitive phenomena. However, it is noteworthy that Nakatani (2009) reported that the integration of *dake-ga* (only-NOM) and its predicate failed to show distance-sensitive effects, though *dake* (only) may also involve scope interpretation:

(7) NP with only-Predicate

a. Distant Condition:

店長だけが[ウェイトレスが 店内で 常連客を 殴ったと] 信じなかった ...

manager-only-NOM [waitress-NOM shop-at regular-customer-ACC hit COMP] believe-NOT-PAST

‘Only the manager did not believe that the waitress had hit the regular customer at the shop.’

b. Local Condition:

[ウェイトレスが 店内で 常連客を 殴ったと] 店長だけが 信じなかった ...

[waitress-NOM shop-at regular-customer-ACC hit COMP] manager-only-NOM believe-NOT-PAST

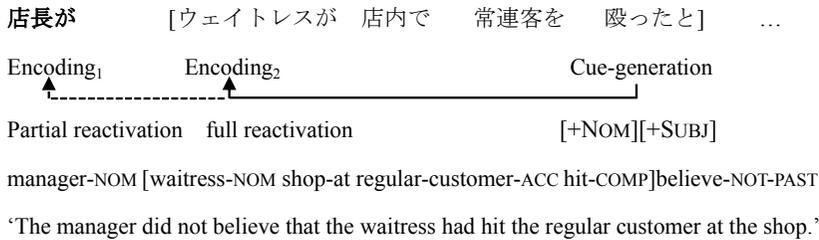
Given this observation, scope-related processing does not seem to be the only factor that involves distance-sensitive effects. In the following section, we present an alternative account that focuses on the role of grammatical and semantic similarities between matrix and embedded subjects.

## 2.2. The Similarity-Based Partial Reactivation Hypothesis

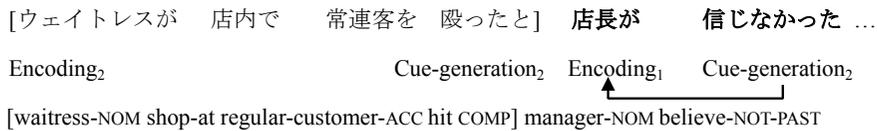
We argue that, in the case that similarities between the matrix and the embedded subjects increase, the matrix subject (“*the manager*” in (8) below) is reactivated at the embedded verb position because of the partial overlapping of

encoded features: <sup>2</sup>

(8) a. Distant Condition:



b. Local Condition:



If the matrix subject works as a distractor upon retrieving an embedded subject, such similarity-based interference is expected to again increase the activation level of the matrix subject to some extent. When the parser retrieves a grammatically appropriate matrix subject at the matrix verb position, the higher activation would make such processes less costly. If this is the case, there may be little difference in the activation level of the matrix subject between the distant condition and the following local condition:

Our hypothesis successfully accounts for the observation of Nakatani (2009) noted above. In the case of a regular NP or *dake*-NOM and a predicate dependency, the matrix and embedded subjects both have lexical nouns and nominative Case. Hence, the similarity-based reactivation may boost the

<sup>2</sup> Although what kind of information is encoded is a topic that needs to be examined empirically, we assume that the parser encodes Case information during Japanese sentence processing. This is because the repetition of nominative NPs in Japanese causes a severe processing difficulty when their grammatical functions hold constant (Uehara, 1997; Uehara & Bradley, 2002).

activation level of decayed encoded information, which results in a distance-*insensitive* phenomenon. However, because the NPI *sika* does not have an overt Case, such reactivation is less robust. This leads to distance-sensitive effects.

One may think that this account assumes the following two mechanisms arbitrarily. However, existing evidence motivates these mechanisms, as introduced in the next section.

- (9) a. The matrix subject is partially reactivated at the embedded verb position, even though it is grammatically irrelevant for associating the embedded subject and predicate.
- b. The reactivation of some encoded features at the sentence-intermediate position facilitates the subsequent association of the reactivated item with its cue-generating item.

### 2.2.1. The Interference Effect

Under the current hypothesis, we assume that a matrix subject becomes reactivated upon encountering an embedded verb. The evidence for this follows from the fact that a matrix subject participates in the retrieval process of an embedded subject in nested constructions.

In Japanese, the parser utilises Case information to incrementally determine the relation between arguments. According to Kamide & Mitchell (1999) and Miyamoto (2002), the Japanese parser inserts a left clause boundary between NP-TOP and NP-NOM upon encountering this sequence.

- (10) NP<sub>1</sub>-TOP [ NP<sub>2</sub>-NOM ....

Ono, Obata & Yusa (2013) hypothesised that the Japanese parser actively predicts NP<sub>1</sub>-TOP as a matrix subject of the predicate that takes a complement CP including NP<sub>2</sub>-NOM, even though alternative continuations are possible (e.g.,

adjunct clauses).

- (11) NP-TOP [CP NP-NOM .... V] V]  
matrix S embedded S CP-taking V

To test whether the parser actually commits to this analysis, Ono et al. (2013) conducted a self-paced reading experiment that utilised similarity-based interference effects and crossed clause order (centre-embedded vs. preposed) and verb types (NP-taking verb vs. NP and CP-taking verbs).

**(12) a. Centre-Embedded, NPCP-Verb condition**

店員は [常連客が 雑貨屋の 店頭で 商品の 値下げを 要望したと] 控室で 話した。  
clerk-TOP [regulars-NOM goods.shop-GEN front-at goods-GEN discount-ACC demanded-C] lobby-in  
was.talking

**b. Preposed, NPCP-Verb condition**

[常連客が 雑貨屋の 店頭で 商品の 値下げを 要望したと] 店員は 控室で 話した。  
[regulars-NOM goods.shop-GEN front-at goods-GEN discount-ACC demanded-C] clerk-TOP  
lobby-in was.talking  
‘A shop clerk was saying at the backroom that frequent shoppers demanded some discount of the goods in front of the variety goods shop.’

**c. Centre-Embedded, NP-Verb condition**

店員は [常連客が 満員の 店内で 新年の 福袋を 開封したと] 控室で 話した。  
clerk-TOP [regulars-NOM full.people-GEN shop-in<sub>4</sub> new.year-GEN lucky.bag-ACC opened-C]  
lobby-in was.talking

**d. Preposed, NP-Verb condition**

[常連客が 満員の 店内で 新年の 福袋を 開封したと] 店員は 控室で 話した。  
[regulars-NOM full.people-GEN shop-in new.year-GEN lucky.bag-ACC opened-C]  
clerk-TOP lobby-in was.talking  
‘A shop clerk was saying at the backroom that frequent shoppers opened the New Year’s lucky bag in the store being full of people.’

In the embedded verb position, the parser performs a cue-generation for retrieving an embedded subject from the working memory. If the parser actively encodes the NP-TOP as *a matrix subject of the verb that takes a complement CP*, the interference effect would appear in the embedded verb of (12a) because CP-taking verbs trigger a search for a subject whose predicates take a complement CP. Hence, the reading times of (12a) in the embedded verb position would be longer than (12b). However, the reading time of a verb is generally sped up in nested constructions (Nakatani & Gibson, 2010). To assess the speed-up effect, (12c) and (12d) were added because no relevant interference effects are expected.

The results revealed that the reading time of (12c) in the embedded verb position is significantly faster than (12d) due to the expected speed-up effects. On the contrary, there is no significant difference between (12a) and (12b), which indicates that the speed-up effect in (12a) was cancelled by the interference slow-down effect.

For the relevance of our proposal, these results demonstrate that the Japanese parser cannot completely ignore a grammatically irrelevant matrix subject when searching for an appropriate embedded subject. Rather, a matrix subject is temporarily accessed and acts as a distractor for memory retrieval.

Vasishth & Lewis (2006) argued that if an NP is accessed prior to the verb, the activation level of the NP increases and the NP can be retrieved more easily later. Given this suggestion, distance-(in)sensitive phenomena may involve the presence/absence of a partial reactivation in the embedded predicate position.

### **2.2.2. Prediction**

Now that the existing evidence motivates the two assumptions of our account, let us turn to an experimental verification of our account. As introduced above, Nakatani (2009) observed distance-insensitive effects in the integration of *dake*-NOM and a predicate, unlike in the integration of NPI and a negation. If our account is empirically accurate, we should observe distance-*sensitive* effects by

decreasing the similarities between matrix and embedded subjects. Concretely, distance-sensitive effects would remerge when the nominative Case does not attach to the *dake*, as in (13), because the decreased similarity between these two subjects leads to a lesser reactivation level of the matrix subject at the embedded verb. Consequently, the retrieval of the matrix subject may not be facilitated.<sup>3</sup>

In the next section, we report the results of a self-paced reading experiment conducted to replicate previous findings and test our prediction.

(13) NP with only-Predicate

a. Distant Condition:

店長だけ [ウエイトレスが 店内で 常連客を 殴ったと] 信じなかった ...  
 manager-only [waitress-NOM shop-at regular-customer-ACC hit COMP] believe-NOT-PAST  
 ‘Only The manager did not believe that the waitress had hit the regular customer at the shop.’

b. Local Condition:

[ウエイトレスが 店内で 常連客を 殴ったと] 店長だけ 信じなかった ...  
 [waitress-NOM shop-at regular-customer-ACC hit COMP] manager-only believe-NOT-PAST

### 3. Experiment

#### 3.1. Method

##### 3.1.1. Participants

Thirty undergraduate and graduate students from Kyushu University participated in the experiment (19 female, mean age=21.6, SD=1.6). All participants were native speakers of Japanese and gave informed consent for

<sup>3</sup> Unlike NP-*dake-ga* or NP-*ga*, NP-*dake* can be temporarily interpreted as an object because it does not have an overt Case and subjects can be dropped in Japanese. Here, we assume that NP-*dake* is interpreted as a subject no later than at the embedded subject (waitress-NOM). We also assume that overt morphological marking plays a crucial role in encoding and expectation for upcoming constituents, although NP-*dake* may possibly have a covert Case (cf. Molinaro et al., 2011).

participation.

### 3.1.2. Martials

A sample set of stimuli is shown in Table 1, where two factors are crossed: two levels of DISTANCE  $\times$  three levels of NP TYPE of the matrix subject. We used 72 sets of six sentences, which were distributed into six lists so that the participants each encountered an item of the same set. Additionally, 72 filler sentences were included in each list. The lists were counterbalanced among the participants.

The critical region is Region 8, where the integration of the matrix subject and its predicate takes place (*omot-ta-node*, ‘think-PAST-because’). Our account predicts that the DAKE distant condition would produce a slower reading time compared to its local counterpart in Region 8 due to the lack of a partial reactivation of the matrix subject in Region 7 (*tukut-ta-to*, ‘make-PAST-COMP). In contrast, NOM and DAKE-NOM should not induce distance-sensitive effects, owing to their benefit from the reactivation process.

Table 1. A Sample of stimuli

Sentence Type	R1	R2	R3	R4	R5	R6	R7	R8
NOM, Distant	oba-ga aunt-NOM	[mei-ga niece-NOM	sakuban last night	hitoride by oneself	ringo-no apple-GEN	keeki-o cake-ACC	tukut-ta-to] make-PAST-COMP	omot-ta-node think-PAST-because
NOM, Local	[mei-ga	sakuban	hitoride	ringo-no	keeki-o	tukut-ta-to]	oba-ga	omot-ta-node
DAKE-NOM, Distant	oba-DAKE-ga	[mei-ga	sakuban	hitoride	ringo-no	keeki-o	tukut-ta-to]	omot-ta-node
DAKE-NOM, Local	[mei-ga	sakuban	hitoride	ringo-no	keeki-o	tukut-ta-to]	oba-DAKE-ga	omot-ta-node
DAKE, Distant	[oba-DAKE	mei-ga	sakuban	hitoride	ringo-no	keeki-o	tukut-ta-to]	omot-ta-node
DAKE, Local	[mei-ga	sakuban	hitoride	ringo-no	keeki-o	tukut-ta-to]	oba-DAKE	omot-ta-node
	Because (only) aunt thought that (her) niece baked an apple pie by herself last night, ...							

### 3.1.3. Procedure

The self-paced reading task was conducted with Linger software (developed by Doug Rohde, MIT). Each trial started with a series of dashes, and then each sentence was presented in a word-by-word, non-cumulative, moving-window manner. Participants were instructed to read at a natural speed. To ensure that our participants were paying enough attention to the reading task, a yes-no comprehension question was given in each trial, and feedback was provided when the answer was incorrect. Prior to the experiment, 10 practice trials were given to familiarise the participants with the self-paced reading task. The experiment took approximately 30 minutes.

### 3.1.4. Analysis

We analysed only the trials in which the comprehension question was answered correctly. Reading time data that exceeded 2000 ms or 2.5 standard deviations from the individual participant's mean at each region were discarded (17.6 %). The participant mean (F1) and item mean (F2) of the remaining reading time data for each region were submitted to a repeated measures  $2 \times 3$  ANOVA with the factors DISTANCE (distant vs. local) and NP TYPE (NOM vs. DAKE-NOM vs. DAKE). In the region of interest, planned comparisons within each NP type were also conducted.

### 3.2. Results

The mean accuracy of the comprehension questions was 88.1 % (NOM, Distant: 90.2 %, NOM, Local: 87 %, DAKE-NOM, Distant: 88 %, DAKE-NOM, Local: 86 %, DAKE, Distant: 88 %, DAKE, Local: 90 %). There were no significant main effects or interaction of NP TYPE and DISTANCE (all  $ps > 0.10$ ).

The mean reading times per region are shown in Figure 1. The region of interest is Region 8, containing *omot-ta-node* ('think-PAST-because'), where the local or distant subject is integrated with a predicate. In this region, the distance-(in)sensitive effect is expected to emerge. Figure 2 provides the DISTANCE effects for each NP TYPE in R8. The main effect of DISTANCE was significant in both participant- and item-analyses (DISTANCE:  $F_1(1, 29)=5.36$ ,

$p=.02$ ;  $F_2(1, 71)=4.30$ ,  $p=.04$ ). Neither the main effect of NP TYPE or interaction reached a significant level. To test our hypothesis, planned pair-wise comparisons were conducted within each NP TYPE. The results indicated that the DAKE conditions showed significant DISTANCE effects in the participant-analysis and marginal effects in the item-analysis (DAKE:  $F_1(1, 29)=4.15$ ,  $p=.05$ ;  $F_2(1, 71)=2.72$ ,  $p=0.10$ ). In contrast, the NOM and DAKE-NOM conditions did not show any statistically reliable effects (NOM:  $F_1(1, 29)= 1.05$ ,  $p=.31$ ;  $F_2(1, 71)=1.19$ ,  $p=0.27$ , DAKE-NOM:  $F_1(1, 29)=2.55$ ,  $p=0.12$ ;  $F_2(1, 71)=1.14$ ,  $p=0.28$ ). In the spill-over region, there was no difference between conditions. <sup>4</sup>

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<sup>4</sup> The results of other regions were as follows: In Region 1, there was no significant effect other than the word differences. In the distant conditions of Region 2, the NOM condition was read slower than the DAKE and DAKE-NOM conditions. This pattern was similar to the one of the sequence of NP-NOM and NP-NOM being harder to process than that of NP-TOP and NP-NOM (Uehara, 1997; Uehara & Bradley, 2002). In Region 3, some spurious effect was observed: in the comparison of the local conditions, the DAKE condition was read faster than the NOM and DAKE-NOM conditions. The DAKE-NOM distant condition produced a faster reading time than the NOM and DAKE distant conditions. Since the earlier parts of a sentence are likely to be subject to an artefact and this effect occurred well ahead of the region of interest, this effect was not supposed to undermine the results of Region 8. Importantly, the spurious effect disappeared in Regions 4, 5, 6 and 7, in which there were not significant effects. In Region 10, we did not find a reliable difference between conditions.

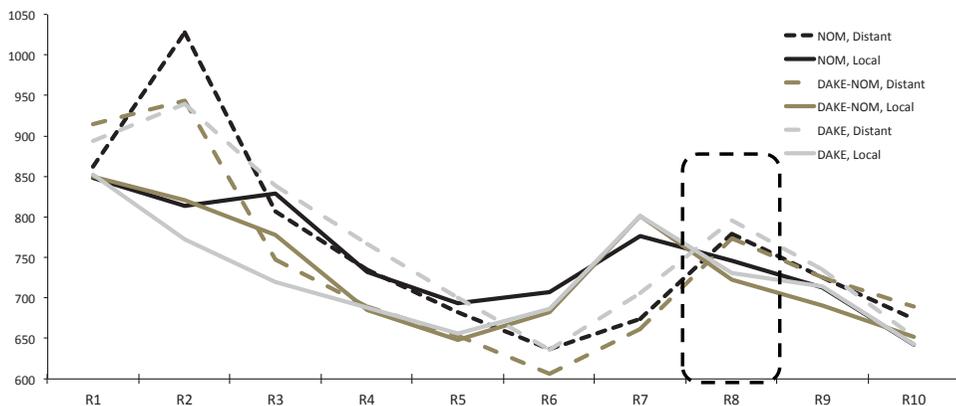


Figure 1. Reading Time per region

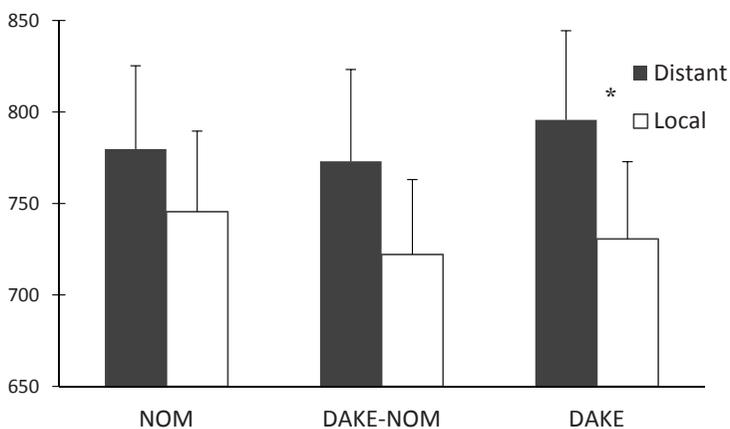


Figure 2. Reading times at R8: *omot-ta-node* ('think-PAST-because')  
Error bars indicate standard errors (ms).

### 3.3 Discussion

First, the results of our experiment showed no reliable distance effects in the NP-NOM and NP-DAKE-NOM conditions, although the distance conditions were read more slowly than the local conditions. This result is consistent with previous findings (Nakatani, 2009, 2014). According to our account, when the similarities between these subjects increase, the grammatically unavailable matrix subject is reactivated to a certain degree, due to encoded feature overlapping, in the process of searching for an appropriate embedded subject. Although the encoded information fades away over time, such a process reactivates the encoded

information associated with the matrix subject. Consequently, the memory retrieval of the matrix subject is facilitated.

A different pattern was obtained in the DAKE conditions, which also contain *dake* (only) similar to the NP-DAKE-NOM conditions. The only difference between these two conditions is whether the nominative Case is attached to the matrix subject. In other words, the difference is determined by whether the matrix subject has the same Case marker as the embedded subject. We interpreted this result as evidence indicating that the distance-sensitive effects remerge by decreasing such similarities. Therefore, our hypothesis can account for our results and others' previous results.

One may think that, if matrix subjects can be reactivated due to similarity-based reactivation, the distant NOM and DAKE-NOM conditions should show similarity-based interference effects, while the distant DAKE condition should not show interference effects at the embedded verb position (i.e., R7, *tukut-ta-to*, 'make-PAST-COMP'). However, we did not find such effects in R7. We will need to examine why the similarity-based interference effects were not observed in our experiment in the future.

To our knowledge, it is not obvious how Ono & Nakatani (2010)'s proposal can account for the non-locality effect in DAKE-NOM conditions, as noted in Section 2. Furthermore, additional mechanisms are needed to explain the locality difference between DAKE-NOM and DAKE sentences, because both sentences should require additional semantic computation.

We raised two questions regarding distance-sensitive phenomena in a Japanese subject-predicate dependency:

- (14) a. An empirical question: What type of subject-predicate dependencies show distance-(in)sensitive effects? (i.e., generalisation)
- b. A theoretical question: What underlying cognitive process induces distance-(in)sensitive effects? (i.e., processing algorithm)

Our answer to question (14a) is that larger degrees of difference between the matrix subject and embedded subject lead to a larger distance-sensitive effect. As for (14b), if the similarity of these arguments, such as Case and NP type, increases, then similarity-based reactivation occurs that can cancel (or attenuate) distance-related memory retrieval difficulties.

In the present study, we examined a rather limited dataset of the Japanese subject-predicate dependency. Our hypothesis definitely needs to be evaluated in the context of new empirical evidence. For example, one may expect that, in the case that the intervening constituent is NP or PP instead of CP, distance-sensitive effects would appear even in a typically distance-*insensitive* subject-predicate dependency in our experimental configuration because NP and PP do not contain a predicate, which generates cues and potentially reactivates the matrix subject. Thus, future studies will require a more systematic investigation that manipulates syntactic configurations and NP types.

#### **4. Conclusion**

The results of our self-paced reading experiment demonstrated that the integration of *dake* (only) and its predicate shows distance-sensitive effects, while that of *dake*-NOM and predicate dependency does not. These results favour our account in which the matrix subject is temporarily accessed in the retrieval of an embedded subject when the two subjects have features in common. We propose that the memory retrieval of the matrix subject obtains benefits from the partial reactivation process, and the locality effect is thus cancelled.

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## 主語名詞句の再活性化が日本語文処理における 距離の効果に及ぼす影響

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本研究では、主節主語の種類と主語-動詞間の距離を操作した読文実験を実施した。その結果、NP だけ-動詞の統合では距離の効果が見られたが、NP だけが-動詞の統合では距離の効果が見られなかった。この結果は、主節主語と埋め込み節主語の類似性が高い場合、埋め込み節主語-動詞の統合の際に、主節主語が一時的にアクセスされ、主節主語の活性化度を高めているために距離の効果が見られなくなるという仮説を支持するものである。