Quantification and the Garden Path Effect
Reduction: The Case of the Universally Quantified NP

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ABSTRACT
This paper investigates the effect of quantification in sentence processing. Experimental results show that temporarily ambiguous sentences that include a universally quantified NP reduced the garden path effect in contrast to those that do not include it. This fact is accounted for by assuming that discourse representation structures are incrementally constructed, and that a tripartite structure introduced by the universal quantifier allows for temporal ambiguity while a single box associated with a bare NP forces one interpretation and to get the correct interpretation, the single box must be rewritten, which results in the garden path effect.

Keywords
temporarily ambiguous sentence, garden path effect, quantification, discourse representation theory, box merger

1. Introduction

Japanese has several types of temporarily ambiguous sentences (TASs) (Mazuka and Itoh 1995, Inoue 2006). The temporal ambiguity of the sentence pattern ‘NP-NOM [VP NP-ACC V] NP-DAT NP-ACC V’ as illustrated in (1) below has been extensively investigated in the field of psycholinguistic studies of Japanese sentence processing based on the notions of verb-predictability and the strength of co-occurrence (Den and Inoue 1997, Inoue and Den 1999).

Policeman-NOM thief-ACC caught man-DAT thank-ACC said
‘A policeman extended his thanks to the man who caught a thief.’

Old.man-NOM thief-ACC caught man-DAT thank-ACC said
‘An old man extended his thanks to the man who caught a thief.’
In (1a) the first NP *keekan-ga* ‘policeman-NOM’ tends to be construed as the subject of the following VP *doroboo-o tsukamaeta* ‘thief-ACC caught’ yielding the reading “a policeman caught a thief”, but this interpretation collapses when another NP *otoko-ni* ‘man-DAT’ shows up after the V *tsukamaeta* ‘caught’. To get the correct interpretation, the VP preceding *otoko-ni* ‘man-DAT’ must be construed as (part of) the relative clause modifying that NP, and the first NP must be construed as the subject of the sentence-final V *itta* ‘said’. This reinterpretation process is known as the garden path (GP) effect.

In (1b), on the other hand, the GP effect is reduced. Inoue (2006) reveals that the noun *keekan* ‘policeman’ and the verb phrase *doroboo-o tsukamaeta* ‘caught a thief’ in (1a) have a strong lexical relation while such a relation between *roojin* ‘old man’ and *doroboo-o tsukamaeta* ‘caught a thief’ in (1b) is weaker, which is established by Den and Inoue’s (1997) semantic-fit rating. Inoue concludes that when the first NP is interpreted as a typical subject of the following VP, the GP effect takes place, but when the first NP is not a typical subject of the following VP, it is retained in processing and hence the GP effect reduces.

However, the GP effect of TAS slightly reduces when only a bare NP *keekan* ‘policeman’ in (1a) is replaced with a universally quantified NP *subeteno keekan* ‘all policemen’ as in (2).\footnote{We do not use a sentence with the universally quantified subject *dono keekan-mo* ‘every policeman’ as in (i).}

\begin{equation}
(2) \quad \text{Subeteno keekan-ga} \quad [\text{VP} \quad \text{doroboo-o tsukamaeta} \quad \text{otoko-ni ree-o itta.} \\
\quad \quad \text{all policeman-NOM thief-ACC caught man-DAT thank-ACC said} \\
\quad \quad \text{‘All policemen extended their thanks to a/the man who caught a thief.’}
\end{equation}

This difference suggests that semantic representations play significant roles since the syntactic structure of (1) and (2) are the same,\footnote{Here we assume the very basic argumentation about syntactic structures; if two nominal expressions bear the same case marker and the same thematic role, they occupy the same syntactic position.} and that the quantificational structure introduced by the universal quantifier makes (2) easy to interpret.

In this paper, we claim that the relevant semantic representations are built independently of syntactic structures to some extent and we then propose algorithms for generating semantic representations which can account for the difference between (1a) and (2). The paper is organized as follows. Section 2 shows some basic facts and previous analyses of TASs. Section 3 introduces the theoretical background to our work. Sections 4 and 5 provide the formalization and the extension of our analysis. Section 6 summarizes our present study and future works.

\begin{equation}
(i) \quad \text{Dono keekan-mo} \quad [\text{VP} \quad \text{doroboo-o tsukamaeta} \quad \text{otoko-ni ree-o itta.} \\
\quad \quad \text{which policeman-also thief-ACC caught man-DAT thank-ACC said} \\
\quad \quad \text{‘Every policeman extended his thanks to a/the man who caught a thief.’}
\end{equation}

In (i) the subject does not bear the nominative case, so that it might be possible to claim that the syntactic position of such a quantified NP subject is different from the one of a nominative NP. See also footnote 2.
2. Tripartite Structure Concerning Quantification

2.1. Menéndez-Benito’s (2003) Analysis

In English, the sentences in (3) below are well known for the \( [VP \text{ raced past the barn}] \) can be construed either as the predicate of the subject \( \text{the horse} \) in (3a), \( \text{a horse} \) in (3b) or \( \text{horses} \) in (3c), or as the reduced relative clause modifying the subject.

(3)  

a. \( \text{The horse} [VP \text{ raced past the barn}] \text{ fell.} \)

b. \( \text{A horse} [VP \text{ raced past the barn}] \text{ fell.} \)

c. \( \text{Horses} [VP \text{ raced past the barn}] \text{ fell.} \)

This ambiguity is not resolved until the sentence ends. The general tendency is that the VP is interpreted as the predicate of the subject, and therefore this interpretation collapses when the final verb \( \text{fell} \) shows up.

Since Bever (1970), TASs like (3a) have been discussed from various perspectives and there have been many proposals made in the literature. Syntax-driven models have been proposed by Frazier (1979), Frazier and Foder (1978), Frazier and Rayner (1982) and others. Crain and Steedman (1985) propose a discourse-based model, called the referential-support model, and experimental results supporting this model have been provided by Altmann and Steedman (1988), Spivey-Knowlton and Tanenhaus (1998), Clifton (1999) and others. The referential-support model pays attention to the semantics of the subject of TASs, uncovers the significant difference among \( \text{the horse} \) in (3a), \( \text{a horse} \) in (3b) and \( \text{horses} \) in (3c), and shows that sentences like (3a) differ in processing difficulty from sentences like (3b) and (3c) (See also Ni et al. (1996), Portner (1989), Sedivy (2002) and others). Since the sentences in (3) are structurally identical in terms of their surface syntax, in order to answer the question why these sentences differ in processing difficulty, it is necessary to take into account the effect of non-syntactic factors in parsing.

By investigating the contrast between (3a), on the one hand, and (3b), (3c), on the other, psycholinguists have been able to explore the interplay of syntax with both semantics and discourse in processing. Portner (1989) focuses on the processing of indefinite NPs as in (3b). He shows that when the generic interpretation is preferred, indefinite NPs like \( \text{a horse} \) facilitate the reduced relative clause interpretation. Recently, Menéndez-Benito (2003) reveals that the GP effect slightly reduces when a NP \( \text{the horse} \) in (3a) is replaced with a universally quantified NP \( \text{every horse} \) as in (4).

(4) \( \text{Every horse} [VP \text{ raced past the barn}] \text{ fell.} \)

Menéndez-Benito notes that the GP effect was observed in both (3a) and (4), and therefore the VP is initially interpreted as a predicate of the subject, but (4) has less of a GP effect than (3a) in the experiments she conducted. Following Portner (1989), she suggests that perceivers prefer
to place as much material as possible in the restrictive clause of a tripartite structure concerning quantification as (5).

(5) 

\[
\begin{array}{ccc}
\text{Quantifier} & \text{Restrictive Clause} & \text{Nuclear Scope} \\
\text{Every}_x & \text{horse}(x) & \text{raced-past-the-barn}(x) & \text{fell}(x)
\end{array}
\]

Portner’s (1989) proposal is framed within Heim’s (1982) theory of quantification, which claims that a sentence whose subject contains a quantifier will be represented by a tripartite structure as illustrated in (5) above. The point here is that every facilitates the reduced relative clause attachment.

2.2. Experimental Results from Kurafuji et al. (2007)

Kurafuji et al. (2007) investigate TASs of the sequence ‘NP-NOM [VP NP-ACC V] NP-DAT NP-ACC V’ in Japanese (e.g. (1a) and (2)), where the temporal ambiguity is caused by the interpretive indeterminacy of whether the VP functions as the predicate of the subject NP-NOM or the relative clause modifying the NP-DAT. Their experimental results are summarized in Table 1.3

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Regions</th>
<th>NP-NOM</th>
<th>NP-ACC</th>
<th>V₁</th>
<th>NP-DAT</th>
<th>NP-ACC</th>
<th>V₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1a) bare NP subj.</td>
<td></td>
<td>4</td>
<td>28</td>
<td>13</td>
<td>106</td>
<td>-56</td>
<td>-86</td>
</tr>
<tr>
<td>(2) universally quantified subj.</td>
<td></td>
<td>-11</td>
<td>46</td>
<td>-16</td>
<td>-59</td>
<td>-55</td>
<td>-91</td>
</tr>
</tbody>
</table>

Table 1: Mean Reading Times (ms)

Subject (F1) and item (F2) reading time means for each region are entered into separate one-factor analyses of variance (ANOVAs) for statistically evaluating the effect of the NP types. At the NP-DAT, the main effects are significant, F1(3, 120) = 6.54, p < .01; F2(3, 93) = 11.59, p < .01; Tukey’s HSD (honestly significant difference) tests show that there are significant differences between sentences of bare NP subject and sentences of universally quantified subject (106 ms vs. -59 ms), p₁ < .01; p₂ < .01. These results indicate that the bare NP induces the GP effect when the disambiguating NP-DAT shows up. In contrast, the universal quantifier subeteno ‘all’ reduces the GP effect. This is parallel with Menéndez-Benito’s (2003) results so that we may also pursue the idea that a tripartite structure associated with the universal quantifier is crucial in sentence processing.

3 For detailed experimental settings, see Kurafuji et al. (2007).
Menéndez-Benito (2003) uses the semantic notion of tripartite structure, but in languages like English, the tripartite structure roughly corresponds to the syntactic structure of the sentences in (3a) and (4), as shown in (5), and therefore it is not clear whether the contrast between (3a) and (4) is syntactic or semantic. Kurafuji et al. (2007), on the other hand, conducted a psycholinguistic experiment in which sentences like (1a) and (2) were displayed on a CRT monitor in a phrase-by-phrase fashion and the reading times for each phrase were recorded. The results of the experiment suggest that semantic representations such as (5) can be obtained directly from the sequence of phrases without building syntactic structures.4

3. Inter- and Intra-sentential Box Merger of DRS

In a situation like the experimental setting of Kurafuji et al. (2007), the semantic representations of TASs are built in a left-to-right fashion. To account for the GP effect reduction in a TAS which begins with a universally quantified NP, we propose an incremental sentence processing algorithm under the framework of Discourse Representation Theory (DRT). The DRT that we follow here is the standard one as proposed in Kamp and Reyle (1993) with one crucial difference. The standard DRT assumes that a discourse representation structure (DRS) is constructed based on a syntactic structure, which means they are built after syntactic parsing. In our model DRSs are constructed phrase-by-phrase, independently of syntactic parsing.

Let us begin with the standard definition of DRS and the box merger operation.

\[ \text{Box Merger} \]
\[ <D_1, C_1> \otimes <D_2, C_2> = <D_1 \cup D_2, C_1 \cup C_2> \]

A DRS K is a pair of a set of discourse referents D and a set of conditions C, represented as K = <D, C>. This pair is also called a box. A box combines with the preceding one by the inter-sentential merger operator \( \otimes \), which takes the union of the sets of discourse referents and the union of the sets of conditions as given in (6) above (Bos et al. 1994).

With this operation, a discourse representation proceeds, as shown in (7), where u and v are discourse referents and ‘u = John’, ‘u came in’, ‘v = Mary’ and ‘v left’ are conditions.

4 Kurafuji et al. (2007) examined the effect of NP types on the degree of GP effect. According to them, the sentence beginning with demonstrative NP sono keekan-ga ‘that policeman-NOM’ also has less of a GP effect than (2), but the status of the sentence with existentially quantified NP aru keekan-ga ‘a certain policeman-NOM’ is not clear since there was no significant difference of reading time between such a sentence and the other types of sentences.
We assume that all lexical items are translated into a box notation. For example, the name John is translated into \([u : u = \text{John}]\) and the adjective rich is translated into \([ : \lambda x[\text{rich}(x)]\)\. These two boxes are then combined by the box merging operation.

In addition to the inter-sentential merging operation in (7), we introduced the intra-sentential merging operation in (8), whose definition is the same as that of (6) but with a different range of application. The inter-sentential merger \(\otimes\) applies across sentence boundaries, while the intra-sentential merger \(\otimes\) applies only within a sentence, and applies incrementally from left-to-right. The \(\lambda\)-formula in conditions is combined with the discourse referent \(u\) by \(\lambda\)-reduction.\(^5\)

We also use a bracket notation as in (9) below as well as the box notation of (8).

The treatment of tense and aspect is ignored throughout this paper.

4. Incremental Building of DRSs

4.1. The GP Effect

\(^5\) It should be noted that in (8) merging of \([u : u = \text{John}]\) of type \(e\) to \([ : \lambda x[\text{rich}(x)]\) of type \(< e, t >\) happens to obey the restriction of types, but the intra-sentential box merging operation we propose here is not type-sensitive (of course \(\lambda\)-abstraction applies type-theoretically).
The lexical items and their box-translations relevant to our discussion are given in Table 2.

<table>
<thead>
<tr>
<th>Lexical Item</th>
<th>Box-Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>keekan</td>
<td>[u: policeman(u)]</td>
</tr>
<tr>
<td>dorobo</td>
<td>[u: thief(u)]</td>
</tr>
<tr>
<td>otoko</td>
<td>[u: man(u)]</td>
</tr>
<tr>
<td>ree</td>
<td>[u: thanks(u)]</td>
</tr>
<tr>
<td>tsukamaeta</td>
<td>[e: λyλx[catching(e) ∧ AG(x, e) ∧ TH(y, e)]]</td>
</tr>
<tr>
<td>itta</td>
<td>[e: λzλyλx[saying(e) ∧ AG(x, e) ∧ TH(y, e) ∧ GOAL(z, e)]]</td>
</tr>
<tr>
<td>subeteno</td>
<td>[ : [ :) ⇒ ALL [ :] ]</td>
</tr>
</tbody>
</table>

Table 2: A Small Fragment of Japanese

Here we assume that verbs introduce an event argument e, and every NP introduces a discourse referent as in [u : P(u)]. The grammatical role or semantic information indicated by case-markers is important in sentence processing, but we put this aside at the moment.

With these settings, let us firstly consider why the GP effect takes place in sentences as (1a) but not in sentences as (2). Let us consider the former sentences, repeated as (10).

(10) *Keekan-ga* [VP doroobo-o tsukamaeta ] otoko-ni ree-o itta.

policeman-NOM thief-ACC caught man-DAT thank-ACC said

‘A policeman extended his thanks to a/the man who caught a thief.’

(11) a. [u: policeman(u)]

b. [v: thief(v)]

c. [u: policeman(u)] ⊗ [v: thief(v)] = [u, v: policeman(u), thief(v)]

d. [u, v: policeman(u), thief(v)] ⊗ [e: λyλx[catching(e) ∧ AG(x, e) ∧ TH(y, e)]] = [e, u, v: policeman(u), thief(v), λyλx[catching(e) ∧ AG(x, e) ∧ TH(y, e)]]

In sentence (10), when the first bare NP is given, a discourse referent and its condition are introduced in a single box as in (11a). The second NP also gives another discourse referent and its condition in another box, as in (11b), and then the two boxes intra-sententially merge, as in (11c). The verb *tsukamaeta* ‘caught’ also introduces another box with an event argument e, and merges with the preceding box as in (11d). Here we propose that the DRS construction algorithm is subject to the following preference rule as a parsing strategy.
The \( \lambda \)-reduction with a discourse referent in the local box is preferred to the same operation with one in a non-local box. It is worth noting that since rule (12) is a preference rule, it can be violated if required by another principle. In (11d), the box has two discourse referents of individual type, \( u \) and \( v \), and rule (12) requires that these discourse referents serve as arguments of \textit{tsukamaeta} ‘caught’, yielding (13) below.

\[
DRS(13) \text{ means “a policeman caught a thief”.
}
\]

Here we assume that the lexical relation between NPs and \( V \) and the information carried by case-markers determine which discourse referent bears the AG(ent) role and which bears the TH(eme) role. For example, the nominative NP tends to bear the AG and the accusative NP tends to bear the TH, and so on. We also assume that after all \( \lambda \)-operators are replaced, the conjunctions \( \land \) are deleted in representations.

Now what happens when the third NP \textit{otoko-ni} ‘man-DAT’ shows up? This NP introduces a new discourse referent in a single box, which intra-sententially merges with box (13), as (14).

\[
DRS(14) \text{ itself has nothing wrong in principle but it is not favored in processing. One of the possibilities for making (14) intelligible is to yield the reading “a policeman caught a thief and there is a man”. However, to get such an interpretation, man(r) should be associated with an event argument, and the discourse referent r must be linked to a theme role, as in TH(r, e’), where e’ is an event argument different from e. In other words, man(r) itself is a well-formed condition, but without an event argument it is not a well-formed event-semantic proposition.}
\]

Another possibility is to regard (14) as an intermediate stage of a DRS of a sequence of sentences as in (15) below, where the dative NP is considered to be the first phrase in the second sentence.

\[
\text{(15) } \# \textit{Keekan-ga} \text{ doroboo-o tsukamaeta. Otoko-ni . . .}
\]

\[
\text{policeman-NOM thief-ACC caught man-DAT}
\]

‘A policeman caught a/the thief. To a/the man, . . .’
However, the sequence of sentences in (15) sounds quite strange. To improve the sequence, a connective such as sospite ‘and’ should be inserted between the two sentences, maybe for the indication of a sentence boundary to introduce the inter-sentential merging operator $\otimes$. So the possibility of interpreting (14) as a sequence of sentences should also be rejected.

The last possibility is to interpret (14) as part of an incomplete sentence. This is in fact the correct way to go, since the reading that we want is the one in which the dative NP is interpreted as the agent of tsukamaeta ‘caught’. But here is the problem. In (13) the agent slot of tsukamaeta ‘caught’ has already been filled in by u associated with keekan-ga ‘policeman-NOM’, so that there is no thematic role for otoko-ni ‘man-DAT’ to be part of the sentence, DRS (13) must be reconstructed, going back to the prior stage (11d). This is the cause of the GP effect.

The important point here is that in (11d), where the box translation of tsukamaeta ‘caught’ is merged, the $\lambda$-operators in $\lambda y \lambda x [\text{catching}(e) \wedge \text{AG}(x, e) \wedge \text{TH}(y, e)]$ are replaced with the discourse referents u and v. One might ask what is wrong if $\lambda$-reduction does not apply at the stage (11d), and waits for another discourse referent (in this case r associated with otoko-ni ‘man-DAT’, and after its arrival does the $\lambda$-operator bind x with its new discourse referent r, as in (16).

If this option were taken, the GP effect would not be observed. However, experimental result from Kurafuji et al. (2007) show that the GP effect actually took place, which means that keekan-ga ‘policeman-NOM’ and doroboo-o ‘thief-ACC’ are interpreted as arguments of tsukamaeta ‘caught’. In order to account for the GP effect in the present approach, we propose another processing strategy, given in (17).

\begin{enumerate}
\item [16] [e, u, v: policeman(u), thief(v), $\lambda y \lambda x [\text{catching}(e) \wedge \text{AG}(x, e) \wedge \text{TH}(y, e)]$]
\[\otimes [r: \text{man}(r)]\]
\[\Rightarrow [e, u, v, r: \text{policeman}(u), \text{thief}(v), \lambda y [\text{catching}(e) \wedge \text{AG}(r, e) \wedge \text{TH}(y, e)], \text{man}(r)]\]
\[\Rightarrow [e, u, v, r: \text{policeman}(u), \text{thief}(v), \text{catching}(e), \text{AG}(r, e), \text{TH}(v, e), \text{man}(r)]\]
\end{enumerate}

Now let us see how the rest of sentence (10) is processed and the DRS is constructed.
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After the GP effect took place at the merging point of *otoko-ni* ‘man-DAT’, the parser traces back to (11d), repeated as (18a), where the $\lambda$-reduction has not applied yet. Then the discourse referent associated with *otoko-ni* ‘man-DAT’ is introduced; it bears the agent role of *tsukamaeta* ‘caught’ as (18b). The boxes associated with *ree-o* ‘thanks-ACC’ and *itta* ‘said’ intrasententially merge with DRSs in (18b) and (18c), respectively, resulting in (18d), the literal translation of which is “a policeman said thanks to the man who caught a thief”.

4.2. The Case of the Universally Quantified Subject

Next, let us consider the incremental derivation of sentence (2), repeated as (19).

(19) *Subeteno keekan-ga* [VP doroboo-o tsukamaeta] *otoko-ni ree-o itta.*

‘All policemen extended their thanks to the man who caught a thief.’

The universal quantifier (Q) *subeteno* ‘all’ is translated into the complex DRS as shown in (20).

(20)

\[
\begin{array}{c}
\text{\[u: policeman(u)\]} \\
\Rightarrow \text{ALL} \end{array}
\]

At the next step, the box \[\{u: policeman(u)\}\] introduced by *keeken-ga* ‘policeman-NOM’ intrasententially merges with (20), which has three possible merging boxes; the main box, the left sub-box, and the right sub-box. Here we assume that the internal structure of a quantified NP gives the information of the merging operation, as shown in (21).
According to rule (21), in the sequence ‘[Q subeteno] [NP keekan]-ga’, the box introduced by keekan ‘policeman’ is merged with the left sub-box, yielding (22).

(22) correctly represents the fact that the NP following Q serves as a restrictive clause for that Q. At this point, one might claim that the DRS for the universal quantifier should be something like \([ : [u : P(u)] \Rightarrow \text{ALL} [ : Q(u)] \] \), where both sub-boxes contain the variable \(u\) in their conditions. Given the usual translation of a universal quantifier \(\lambda Q \forall x[P(x) \rightarrow Q(x)]\), in which the antecedent and the consequent clauses share the same variable \(x\), it seems reasonable to assume that the two subordinate boxes in (20) share the same variable in their conditions when a universal quantifier is translated into its box notation.

However, we do not take this position. In our approach such a co-occurrence of \(u\)’s is underspecified in the lexicon and the desirable result comes from something else such as the requirement of the ban on vacuous quantification, which requires that both the restrictive clause and the nuclear scope contain the same variable bound by the quantifier. We assume that there is a more limited version of this requirement in Japanese semantic processing, as given in (23).

(23) The Ban on Vacuous Quantification (a version of Japanese semantic processing)
A variable introduced in the left sub-box by the tripartite structure rule must also appear in the right sub-box.

In (22) the variable introduced in the left sub-box by the tripartite structure rule in (21) is \(u\), and the ban on vacuous quantification (23) requires that \(u\) should appear in the right sub-box. This requirement is satisfied if a \(\lambda\)-operator introduced in the right sub-box is replaced with \(u\). A concrete example will be given below.

Let us go back to the derivation of the DRS of sentence (19).

(24) a. \([ u : \text{policeman}(u) ] \Rightarrow \text{ALL} \)
    \[ [ e, v : \text{thief}(v), \lambda y x [ \text{catching}(e) \wedge \text{AG}(x, e) \wedge \text{TH}(y, e) ] ] \]

b. \([ u : \text{policeman}(u) ] \Rightarrow \text{ALL} \)
    \[ [ e, v : \text{thief}(v), \lambda x [ \text{catching}(e) \wedge \text{AG}(x, e) \wedge \text{TH}(v, e) ] ] \]
In (24a) *doroboo-o* ‘thief-ACC’ and *tsukamaeta* ‘caught’ merge with the right box, following the tripartite structure rule in (21), then in (24b) $\lambda y$ is replaced with $v$, following the locality preference of $\lambda$-reduction in (12).

At this point, it is important to consider how a sentence like (25) is interpreted.

(25) Subeteno keekan-ga doroboo-o tsukamaeta.
    'All policeman-NOM thief-ACC caught
    'All policemen caught a thief.'

In Japanese linguistic literature (e.g. Kuroda (1965), Hoji (1985) and others), it is claimed that in a structure ‘Q NP-NOM Q NP-ACC Ψ’, the Q NP-NOM takes wide scope over the Q NP-ACC. In (25), the object is a bare NP and the wide scope reading of the object bare NP is easy to obtain as well as the wide scope reading of the Q NP subject. Likewise, sentences like (19) are ambiguous between the wide scope reading of the Q NP subject and that of the dative bare NP. The question, then, is what interpretation the participants in experiments by Kurafuji et al. (2007) actually obtained.

In DRT, the scope ambiguity between a universally quantified NP and an existentially quantified NP is unambiguously represented, depending on where the discourse referent associated with the existentially quantified NP is introduced. In a DRT with event semantics like ours, the place of the event argument also disambiguates the interpretations. In what follows, just for the sake of presentation, we assume that the participants in their experiment interpreted sentences like (25) as “There is a thief such that all policemen caught her/him together”, since this kind of interpretation seems the easiest to obtain.

Interpretations such as “all policemen caught a thief together” can be represented by assuming that the discourse referent denoting an event of the sub-box is projected to the main box, as schematized in (26).\(^7\)

\[
\begin{align*}
\text{main box} & : \ldots \text{[sub box e : ]} \ldots \\
\rightarrow & \text{project e [main box e : ]} \cdot \text{[sub box : ]} \ldots
\end{align*}
\]

Let us go back to DRS (24b). In (27a), the discourse referent in the sub-box e is projected to the main box following the operation in (26). DRS (27a) has a variable x bound by the $\lambda$-operator, and how to treat this variable is important in the derivation. If the sentence ends at this point, this variable is replaced with u in the left box as in (27b).

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\(^6\) Other interpretations can be captured in our approach, so the choice of this particular interpretation does not have any significance.

\(^7\) This kind of projection is not ad hoc since the treatment of proper nouns requires this type of operation anyway.
Quantification and the Garden Path Effect Reduction

This operation does not obey the locality preference of $\lambda$-reduction in (12). As mentioned earlier, this preference rule is violable if the violation is forced by a principle that must be obeyed. In this case, the ban on vacuous quantification in (23) forces the violation of the locality preference of $\lambda$-reduction. By replacing the $\lambda$-operator in the right box with $u$ in the left box, the variable introduced in the left sub-box, namely $u$, appears in the right sub-box, so the ban on vacuous quantification is satisfied. Thus, the resulting DRS (27b) represents "all policemen caught a thief (together)".

Now let us consider the case where another NP merges with (27a).

As shown in (28a), the box $[\ r : \text{man}(r)]$ associated with $\text{otoko-ni} \ '\text{man-DAT}'$ introduces a new discourse referent $r$ in the right box, and the variable $x$ is replaced with $r$ following the locality preference of $\lambda$-reduction in (12).

Again, the important point here is the treatment of the agent variable of $\text{tsukamaeta} \ '\text{caught}'$. Unlike the case illustrated by sentence (10) discussed in Section 4.1, the $u$ associated with $\text{keekan} \ '\text{policeman}'$ is not in the right box, so that it is not the primary option for the replacement of $x$. On the other hand, the $r$ introduced by $\text{otoko} \ '\text{man}'$ is in the same box as the agent variable is, so the locality preference in (12) chooses $r$ as the agent of the verb.

Then $\text{ree-o} \ '\text{thanks-ACC}'$ and $\text{itta} \ '\text{said}'$ merge with DRSs in (28a) and (28b), respectively. As discussed above, the $\lambda x$ of $\text{itta} \ '\text{said}'$ is replaced with $u$ in the left box to satisfy the ban on vacuous quantification. The final DRS (28c) represents the correct truth conditions of sentence (19).
5. Yet Another Quantification Effect

5.1. The Case of the Universally Quantified Object

The present approach can also account for a sentence with the universally quantified object such as (29).

(29) *Keekan-ga* \[\text{VP subeteno doroboo-o tsukamaeta} otoko-o syochoo-ni syookaishita.}\]

\[\text{policeman-NOM all thief-ACC caught man-ACC chief-DAT introduced}\]

‘A policeman introduced to his chief a/the man who caught all thieves.’

The universal quantifier (Q) subeteno ‘all’ in the sequence ‘[(Q subeteno) [NP doroboo]-o’’, is translated into the complex DRS, the box introduced by doroboo ‘thief’ is merged with the left sub-box by (21i), then the box introduced by keekan ‘policeman’ is merged with the right sub-box by (21ii), yielding (30).

![Diagram](image)

The sentence is parsed and the DRS is constructed phrase-by-phrase, the resulting DRS in (31) below can be obtained directly from the sequence of phrases without building a syntactic structure.

(31) \[\begin{array}{l}
\text{[e, e': [v: thief(v)] } \Rightarrow \text{ ALL)}
\\
\text{[u, r, s: policeman(u), catching(e), AG(r, e), TH(v, e), man(r), thank(s),}
\\
saying(e'), AG(u, e'), TH(s, e'), GOAL(r, e')]}\end{array}\]

This analysis also reveals that sentences with a universally quantified object have less of a GP effect than those with a bare NP subject and object as in (32) do.

(32) *Keekan-ga* \[\text{[VP doroboo-o tsukamaeta] otoko-o syochoo-ni syookaishita.}\]

\[\text{policeman-NOM thief-ACC caught man-ACC chief-DAT introduced}\]

‘A policeman introduced to his chief a/the man who caught a thief.’

However, the GP effect of the sequence ‘NP-NOM [VP NP-ACC V] NP-ACC NP-DAT V’ does not reduce when both subject and object are universally quantified, as in (33b).
   all policeman-NOM thief-ACC caught man-ACC chief-DAT introduced
   ‘All policemen introduced to their chiefs a/the man who caught a thief.’

   b. Subeteno keekan-ga [VP subeteno doroboo-o tsukamaeta] otoko-o syoochoo-ni
   all policeman-NOM all thief-ACC caught man-ACC chief-DAT
   introduced
   ‘All policemen introduced to his chiefs a/the man who caught all thieves.’

<table>
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<tr>
<th>Conditions</th>
<th>Regions</th>
<th>NP-NOM</th>
<th>VP NP-ACC₁</th>
<th>VP-ACC₂</th>
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<th>Ṽ₂</th>
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<tr>
<td>(32) bare NP subj., bare NP obj.</td>
<td>134</td>
<td>44</td>
<td>-33</td>
<td>215</td>
<td>-48</td>
<td>-173</td>
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<tr>
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</table>

Table 3: Mean Reading Times (ms)

Table 3 lists experimental results from Inoue et al. (2008) which show the average ratings for the four conditions exemplified in (29), (32), (33a) and (33b). Subject (F1) and item (F2) reading time means for each region are entered into two-factor ANOVAs for evaluating statistically the effect of the subject and object quantification; each of them is not significant, \( F1s < 1; F2s < 1 \). but their interaction is significant, \( F1(1, 51) = 23.66, p < .01; F2(1, 31) = 15.66, p < .01 \). The simple main effects are significant as (32) > (29), (32) > (33a), (33b) > (29) and (33b) > (33a) \( (p1 < .05) \). This result indicates that not only a sentence with a bare NP subject and a bare NP object as in (32) but also sentences with a universally quantified subject and a universally quantified object as in (33b) are read more slowly than the sentences whose subject or object is universally quantified as in (29) and (33a). The present approach cannot account for the GP effect of sentences such as (33b).

5.2. Quantification and the GP Effect Induction

To account for the GP effect in sentences where both the subject and the object are universally quantified, we propose another processing strategy, given in (34).

(34) The Fewer Boxes Strategy

Make a box as simple as possible, where a box is a box which does not contain other boxes.
The conceptual basis of (34) is from limitations in the capacity of human sentence processing. If there are several semantic parsing possibilities in a sentence, we prefer to choose the simplest one. The simplest is the best in most but not all cases. The preference rules of the Locality Preference of λ-Reduction in (12) and the Early Completion Strategy in (17) share the same background, and therefore it is natural to assume strategy (34) in our approach.

Let us consider the incremental derivation of sentences as (33b) whose subject and object are universally quantified. Here we describe the box introduction of the universally quantified expressions more precisely as follows.\(^8\)

\[(35)\]
\[
\begin{align*}
\text{a. } & \textit{subeteno keekan-ga} \\
& \textit{all } \text{policeman-NOM} \\
& [U: \text{policeman}(U), [u: u \in U]] \Rightarrow \textit{all } [\vdash \vdash] \\
& \text{‘all policemen’}
\end{align*}
\]
\[
\begin{align*}
\text{b. } & \textit{subeteno doroboo-o} \\
& \textit{all } \text{thief-ACC} \\
& [V: \text{thief}(V), [v: v \in V]] \Rightarrow \textit{all } [\vdash \vdash] \\
& \text{‘all thieves’}
\end{align*}
\]

In sentences such as (33b), when the universally quantified subject and object are given, the box introduced by the object is embedded as a sub-box of the box introduced by the subject, yielding a complex box as in (36a).

\[(36)\]
\[
\begin{align*}
\text{a. } & \textit{Subeteno keekan-ga } \quad \textit{subeteno doroboo-o } \\
& \textit{all } \text{policeman-NOM all } \text{thief-ACC} \\
& \text{‘All policemen… all thieves…’} \\
& [U: \text{policeman}(U), [u: u \in U]] \Rightarrow \textit{all } [V: \text{thief}(V), [v: v \in V]] \Rightarrow \textit{all } [\vdash \vdash] \\
\text{b. } & [U, V: \text{policeman}(U), \text{thief}(V)]
\end{align*}
\]

Regarding the quantifier scope, the DRS in (36a) is equivalent to the simpler DRS in (36b), the latter, simpler DRS is preferred by strategy (34) in the derivation as shown below.

---

\(^8\) This reformulation does not affect the heart of the quantification and the GP effect reduction of both universally quantified subject sentences as (33a) and universally quantified object sentences as (29).
The DRS of sentences as (33b) is obtained by the locality preference of $\lambda$-reduction in (12) and the early completion strategy in (17), and the derivation proceeds from (37a) to (37c), but the parser eventually traces back to (37a) after the GP effect took place at the point of merging of *otoko-ni* ‘man-DAT’ because of the absence of bound variables.\footnote{See Section 4.1.}

6. Concluding Remarks

This paper investigated Japanese TASs of the form ‘NP-NOM [VP NP-ACC V] NP-DAT NP-ACC V’. Such sentences with a bare NP subject and with a universally quantified subject show differences in reading time based on psycholinguistic experiments (Kurafuji et al. 2007). To account for this, we developed a new incremental DRS building algorithm using the framework of DRT (Kamp and Reyle 1993), in which each lexical item is translated into a box-notation and such a box intra-sententially merges with another box from left to right.

When the subject is a bare NP, a single box is introduced, and boxes introduced by the second NP and the verb are combined with this single box, constituting a new single box. If the argument structure of the verb is saturated in this single box, there is no scope for a new intra-sententially merged discourse referent. This is the cause of the GP effect. When the subject has a quantifier like *subeteno* ‘all’, on the other hand, a complex DRS is introduced, which provides scope for a new discourse referent, and thus the GP effect does not take place. This mechanism also accounts for the GP effect reduction of sentences with universally quantified object and the GP effect induction of the sentence with both universally quantified subject and universally quantified object.

We proposed three parsing strategies; the locality preference of $\lambda$-reduction, the early completion strategy and the fewer boxes strategy. They are connected to the same conceptual basis where human parser works as simply as possible.

The effects of the first two strategies are similar to the effect of the minimal attachment (Frazier and Fodor 1978). However, a syntactic approach with the minimal attachment cannot
account for the fact that the universal quantifier reduces the GP effect. So our incremental DRT approach is different from a syntactic approach though they assume the similar strategies.

Our approach can be applied to some cases that we did not address in the paper. One is concerned with the interpretation of the Japanese topic marker wa. Inoue (1991) reported with a different experimental setting that the GP effect reduces when wa is used in the initial NP instead of the nominative case marker ga. If our account is on the right track, the fact suggests that the topic-marked NP introduces a tripartite structure as \([u: P(u)] \Rightarrow \text{TOPIC} [u: Q(u)]\), which says, approximately, “for the topic \(u\), if \(u\) has the property \(P\), it also has the property \(Q\)”. The functional similarity between conditionals and topic expressions has been pointed out in the literature (e.g. Haiman (1978) and others). Our approach thus supports such an idea with the experimental results.

We did not go into detail on other quantified NPs with an existential quantifier like aru keekan ‘a policeman’ or numeral quantifier like san-nin-no keekan ‘three policemen’. The status of sentences beginning with the former is not clear since there was no significant difference of reading time between such a sentence and the sentence with a universal quantifier. Regarding the sentence with the latter, we have not conducted any experiments. We will leave the analyses of and experiments with these quantifiers for future work.

Acknowledgments

We are indebted to three anonymous PACLIC reviewers, Michinao F. Matsui, Robert Logie, Maria del Pilar Valverde Ibáñez and Mark Steedman for their invaluable comments on an earlier version of this paper. All remaining inadequacies are our own. This research is partially supported by Osaka Gakuin University and Grant-in-Aid for Scientific Research (C), 18530578, 21500152 and 24500189 of the Japan Society for the Promotion of Science (JSPS).

7. References


