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

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Abstract. This paper investigates the effect of quantification in sentence processing. The experimental results show that temporarily ambiguous sentences that begin with the universally quantified NPs reduced the garden path effect in contrast to the ones that begin with bare NPs. This fact is accounted for by assuming that discourse representation structures are incrementally constructed, and a tripartite structure introduced by the universal quantifier gives a *room* 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, DRT, box merger

1 Introduction

Japanese has several types of *temporarily ambiguous sentences* (TASs) (Inoue, 2006). This paper focuses on the pattern 'NP-NOM [$_{VP}$ NP-ACC V] NP-DAT NP-ACC V' as exemplified in (1).

(1) *Keekan*-ga   [$_{VP}$ hanni-o   tsukamaeta] otoko-ni ree-o   itta.
    police.officer-NOM   criminal-ACC caught   man-DAT thank-ACC said
    'A police officer extended his thanks to a/the man who caught a criminal.'

The first NP *keekan-ga* 'police.officer-NOM' tends to be construed as the subject of the following VP, yielding the reading "a police officer caught a criminal" but this interpretation crashes 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.

However, the GP effect of TAS slightly reduces when only a bare NP *keekan* 'police.officer' in (1) is replaced with a universally quantified NP *subeteno keekan* 'all police officers' as in (2).

(2) *Subeteno keekan*-ga   [$_{VP}$ hanni-o   tsukamaeta] otoko-ni ree-o   itta.
    all   police.officer-NOM   criminal-ACC caught   man-DAT thank-ACC said
    'All police officers extended their thanks to a/the man who caught a criminal.'

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This difference suggests that semantic representations play significant roles since the syntactic structure of (1) and (2) are all the same,[1] and that the quantificational structure introduced by the universal quantifier makes (2) easy to interpret.

In this paper, we claim the relevant semantic representations are built independently of syntactic structures to some extent and then propose algorithms of generating semantic representations which can account for the difference between (1) and (2). The paper is organized as follows. Section 2 shows some basic facts and previous analyses of TASs. Section 3 introduces some theoretical settings. Section 4 and Section 5 provide a formalization and a summary of our analysis presented in this paper.

2 Tripartite Structure Concerning Quantification

Since Bever (1970), TASs like (3) have been discussed from various perspectives and there have been many proposals made in the literature (e.g. syntax-driven model (Frazier, 1979), discourse-based referential-support model (Crain and Steedman, 1985) among others).

(3) *The horse* [VP raced past the barn] fell.

(3) is well known for the [VP raced past the barn] can be construed either as the predicate of the subject *the horse* or as the reduced relative clause modifying the subject, and 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 crashes when the final verb *fell* shows up.

Menéndez-Benito (2003) reveals that the GP effect slightly reduces when a NP *the horse* in (3) is replaced with a universally quantified NP *every horse* as in (4).

(4) *Every horse* [VP raced past the barn] fell.

According to her, the GP effect was observed in both (3) and (4), and therefore the VP is initially interpreted as a predicate of the subject, but (4) has less GP effect than (3) 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 in (5).

(5)

Quantifier	Restrictive Clause	Nuclear Scope
$Every_x$	$horse(x)$ & $raced\text{-}past\text{-}the\text{-}barn(x)$	$fell(x)$
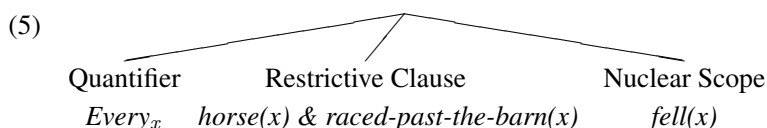
Kurafuji *et al.* (2007) investigates TASs of the sequence 'NP-NOM [VP NP-ACC V] NP-DAT V' in Japanese (e.g. (1) and (2)), where the temporal ambiguity is caused by the interpretive indeterminacy of whether the VP functions as the predicate of the subject NP-NOM or the relative clause modifying the NP-DAT. The GP effect takes place when the NP-DAT shows up after the VP. Their experimental results also reveal that sentences with a universally quantified NP subject have less GP effect than those with a bare NP subject do. This result is parallel with Menéndez-Benito's,[2] so that we may also pursue the idea that tripartite structure associated with the universal quantifier is very crucial in sentence processing.

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[1] Here we assum 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.

[2] We do not use a sentence with the universally quantified subject *dono keekan-mo* 'every police officer' as in (i).

(i) *Dono keekan*-mo   [VP hanni-o   tsukamaeta] otoko-ni ree-o   itta.
     which police.officer-also   criminal-ACC caught   man-DAT thank-ACC said
     'Every police officer extended his thanks to a/the man who caught a criminal.'

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 1.

Menéndez-Benito (2003) uses the semantic notion of tripartite structure in her account, but in languages like English, the tripartite structure roughly corresponds to the syntactic structure of the sentences in (3) and (4), as shown in (5), and therefore it is not clear whether the contrast between (3) and (4) is syntactic or semantic. Kurafuji *et al.* (2007), on the other hand, conducted a psycholinguistics experiment in which the sentences like (1) 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 experiment suggest that semantic representations such as (5) can be obtained directly from the sequence of phrases without building syntactic structures.[3]

3 Inter- and Intra-sentential Box Merger of DRT

In a situation like Kurafuji *et al.*'s (2007) experimental setting, 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 *discourse representation structure* (DRS) is constructed based on syntactic structure, which means they are built after syntactic parsing. In our model, in contrast, DRSs are constructed phrase-by-phrase, independently of syntactic parsing.

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

(6) 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]

(7) John came in. (And) Mary left.

u
u = John
u came in

$\otimes$

v
v = Mary
v left

=

u v
u = John
u came in
v = Mary
v left

(Inter-sentential Merging)

We assume that all lexical items are translated into a box notation. For example, the name *John* is translated into [u : u = John] and the adjective *rich* is translated into [: λx[rich(x)]]. These two boxes are then combined by the intra-sentential merging.

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[3] Kurafuji *et al.* (2007) examined the effect of NP types on the degree of GP effect. According to them, the sentence begins with demonstrative NP *sono keekan-ga* 'that police.officer-NOM' also has less GP effect than (2), but the status of the sentence with existentially quantified NP *aru keekan-ga* 'a certain police.officer-NOM' is not clear since there was no significant diffrence of reading time between such a sentence and the other types of sentences.

[4] We also use a box notation with brackets as in [u: u = John, u came in] as well as a representation like (7). The treatment of tense and aspect is ignored throughout the paper.

(8) John is rich.

$$\boxed{\begin{array}{c} u \\ \hline u = \text{John} \end{array}} \quad \otimes \quad \boxed{\begin{array}{c} \\ \hline \lambda x[\text{rich}(x)] \end{array}} \quad = \quad \boxed{\begin{array}{c} u \\ \hline u = \text{John} \\ \lambda x[\text{rich}(x)] \end{array}} \qquad \text{(Intra-sentential Merging)}$$

$$\Rightarrow \quad \boxed{\begin{array}{c} u \\ \hline u = \text{John} \\ \lambda x[\text{rich}(x)] \end{array}} \qquad (\lambda\text{-Reduction})$$

In addition to the inter-sentential merger operation in (6), we newly introduce *the intra-sentential merger operator* $\otimes$, whose definition is the same as the one in (6), but the range of application is different. The inter-sentential merging $\otimes$ applies across a sentence boundary, while the intra-sentential merging $\otimes$ applies only in a sentence. The latter applies incrementally from left-to-right.

The λ-formula in conditions is combined with the discourse referent u by λ-reduction.[5]

4 Incremental Building of DRSs

4.1 The GP Effect

The lexical items and their box-translations relevant to our discussion are given in table 1.

Table 1: A Small Fragment of Japanese

Lexical Item	Box-Translation
keekan	[u : police-officer(u)]
hannin	[u : criminal(u)]
otoko	[u : man(u)]
ree	[u : thanks(u)]
tsukamaeta	[e : $\lambda y \lambda x$[catching(e) $\wedge$ agent(x, e) $\wedge$ theme(y, e)]]
itta	[e : $\lambda z \lambda y \lambda x$[saying(e) $\wedge$ agent(x, e) $\wedge$ theme(y, e) $\wedge$ goal(z, e)]]
subeteno	[: [:] $\Rightarrow_{\text{ALL}}$ [:]]

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 it aside at this moment.

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

(9) *Keekan*-ga   [$_{\text{VP}}$ hanni-o   tsukamaeta] otoko-ni ree-o   itta.
     police.officer-NOM   criminal-ACC caught   man-DAT thank-ACC said
     'A police officer extended his thanks to a/the man who caught a criminal.'

(10)   a.   [u: police-officer(u)]

      b.   [v: criminal(v)]

      c.   [u: police-officer(u)] $\otimes$ [v: criminal(v)] = [u, v: police-officer(u), criminal(v)]

      d.   [u, v: police-officer(u), criminal(v)] $\otimes$
                             [e : $\lambda y \lambda x$ [catching(e) $\wedge$ agent(x, e) $\wedge$ theme(y, e)]] =
         [e, u, v: police-officer(u), criminal(v), $\lambda y \lambda x$[catching(e) $\wedge$ agent(x, e) $\wedge$ theme(y, e)]]

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[5] It should be noted that in (8) merging of [u : u = 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 λ-abstraction applies type-theoretically).

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In the sentence (9), when the first bare NP is given, a discourse referent and its condition are introduced in a single box as in (10a). The second NP also gives another discourse referent and its condition in another box, as in (10b), and then the two boxes intra-sententially merge, as in (10c). The verb *tsukamaeta* 'caught' also introduces another box with an event argument e, and merges to the preceding box as in (10d). Here we propose that the DRS construction algorithm is subject to the following preference rule as a parsing strategy.

(11)   The Locality Preference of λ-Reduction
       Reduce λ-operators in conditions in box K with
        (i) the discourse referents in K, or
       (ii) discourse referents in boxes accessible from them, if there is no discourse referent available in the box.

(11) says that the λ-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 (11) is a preference rule, it can be violated if a requirement by another principle forces it to be. In (10d), the box has two discourse referents of individual type, u and v, and the rule (11) requires that these discourse referents serve as arguments of *tsukamaeta* 'caught', yielding (12) below.

(12)   [e, u, v: police-officer(u), criminal(v), catching(e), agent(u, e), theme(v, e)]

DRS (12) means "a police officer caught a criminal."

Here we assume that the lexical relation between NPs and V and the information of case-markers determine which discourse referent bears the AGENT role and which bears the THEME role. For example, the nominative NP tends to bear the agent role and the accusative NP tends to bear the theme role, and so on. We also assume that after all λ-operators are replaced, the conjunction '$\wedge$' are deleted in representations.

Now what happens when the third NP *otoko-ni* 'man-DAT' shows up? This NP introduces a new discourse referent in a single box, which intra-senentially merges to box (12), as in (13).

(13)   [e, u, v: police-officer(u), criminal(v), catching(e), agent(u, e), theme(v, e)] $\otimes$ [r: man(r)]
       = [e, u, v, r: police-officer(u), criminal(v), catching(e), agent(u, e), theme(v, e), man(r)]

The DRS (13) itself has nothing wrong in principle but it is not favored in processing. One of the possibilities for making (13) intelligible is to yield the reading "a police officer caught a criminal 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 theme(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 it as an intermediate stage of a DRS of a sequence of sentences as in (14) below, where the dative NP is considered to be the first phrase in the second sentence.

(14)   # *Keekan*-ga   hanni-o   tsukamaeta.   Otoko-ni . . .
          police.officer-NOM criminal-ACC caught   man-DAT
          'A police officer caught a/the criminal.   To a/the man, . . .'

However the sequence of sentences in (14) itself sounds quite strange. To improve the sequence, a connective such as *soshite* '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 (13) as a sequence of sentences should also be rejected.

The last possibility is to interpret (13) 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

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as the agent of *tsukamaeta* 'caught'. But here is the problem. In (12) the agent slot of *tsukamaeta* 'caught' has already been filled in by u associated with *keekan-ga* 'police.officer-NOM', so that there is no thematic role for *otoko-ni* 'man-DAT'. In order for *otoko-ni* 'man-DAT' to be part of a sentence, the DRS (12) must be reconstructed, going back to the prior stage (10d). This is the cause of the GP effect.

The important point here is that in (10d), where the box translation of *tsukamaeta* 'caught' is merged, the λ-operators in $\lambda y\lambda x[\text{catching}(e) \wedge \text{agent}(x, e) \wedge \text{theme}(y, e)]$ are replaced with the discourse referents u and v. One might ask what is wrong if λ-reduction does not apply at the stage (10d), and waits for another discourse referent (in this case r associated with *otoko-ni* 'man-DAT'), and after its arrival does the λ-operator bind x with its new discourse referent r, as in (15).

(15) $[e, u, v: \text{police-officer}(u), \text{criminal}(v), \lambda y\lambda x[\text{catching}(e) \wedge \text{agent}(x, e) \wedge \text{theme}(y, e)]\,]$
        $\underline{\otimes}\,[r: \text{man}(r)]$
        $\Rightarrow [e, u, v, r: \text{police-officer}(u), \text{criminal}(v), \lambda y[\text{catching}(e) \wedge \text{agent}(r, e) \wedge \text{theme}(y, e)],$
        $\qquad\qquad \text{man}(r)]$
        $\Rightarrow [e, u, v, r: \text{police-officer}(u), \text{criminal}(v), \text{catching}(e), \text{agent}(r, e), \text{theme}(v, e), \text{man}(r)]$

If this option were taken, the GP effect would not be observed. However, Kurafuji *et al.*'s (2007) experimental result shows that the GP effect actually took place, which means that *keekan-ga* 'police. officer-NOM' and *hannin-o* 'criminal-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 (16).

(16)   The Early Completion Strategy
        Make a DRS complete as early as possible, where a complete DRS is a DRS which does not contain a λ-operator.

The strategy (16) forces the λ-operators in conditions to be replaced with the discourse referents in the same box as early as possible. The idea behind (16) is that a parser tries to reduce λ-operators as soon as a verb shows up in Japanese. In other words, by (16) the NPs that immediately precede a verb are interpreted as arguments of that verb as long as the NPs' case information is compatible with the verb's argument structure. Given this strategy, the derivation in (15) is not allowed, since the two λ-operators remain not to be replaced in spite of the fact that they should have been replaced with u and v at the prior stage.

Now let us see how the rest of the sentence (9) is processed and the DRS is constructed.

(17)   a. $[e, u, v: \text{police-officer}(u), \text{criminal}(v), \lambda y\lambda x[\text{catching}(e) \wedge \text{agent}(x, e) \wedge \text{theme}(y, e)]\,]$
        b. (17a) $\underline{\otimes}\,[r: \text{man}(r)] \Rightarrow$
            $[e, u, v, r: \text{police-officer}(u), \text{criminal}(v), \text{catching}(e), \text{agent}(r, e), \text{theme}(v, e), \text{man}(r)]$
        c. (17b) $\underline{\otimes}\,[s: \text{thanks}(s)] =$
            $[e, u, v, r, s: \text{police-officer}(u), \text{criminal}(v), \text{catching}(e), \text{agent}(r, e), \text{theme}(v, e), \text{man}(r),$
            $\qquad\quad \text{thanks}(s)]$
        d. (17c) $\underline{\otimes}\,\lambda z\lambda y\lambda x[\text{saying}(e') \wedge \text{agent}(x, e') \wedge \text{theme}(y, e') \wedge \text{goal}(z, e')] \Rightarrow$
            $[e, e', u, v, r, s: \text{police-officer}(u), \text{criminal}(v), \text{catching}(e), \text{agent}(r, e), \text{theme}(v, e),$
            $\qquad\quad \text{man}(r), \text{thanks}(s), \text{saying}(e'), \text{agent}(u, e'), \text{theme}(s, e'), \text{goal}(r, e')]$

After the GP effect took place at the point of merging of *otoko-ni* 'man-DAT', the parser traces back to (10d), repeated as (17a), where the λ-reduction does not apply yet. Then the discourse referent associated with *otoko-ni* 'man-DAT' is introduced; it bears the agent role of *tsukamaeta* 'caught' as (17b). The boxes associated with *ree-o* 'thanks-ACC' and *itta* 'said' intra-sententially merge to DRSs in (17b) and (17c), respectively, resulting in (17d), the literal translation of which is "a police officer said thanks to the man who caught a criminal."

4.2 The Quantification Effect Case

Next, let us consider the incremental derivation of the sentence (2), repeated as (18).

(18) *Subeteno keekan*-ga   [$_{VP}$ hanni-o   tsukamaeta] otoko-ni ree-o   itta.
      all   police.officer-NOM criminal-ACC caught   man-DAT thank-ACC said
   'All police officers extended their thanks to a/the man who caught a criminal.'

The universal quantifier (Q) *subeteno* 'all' is translated into the complex DRS as shown in (19).

(19)
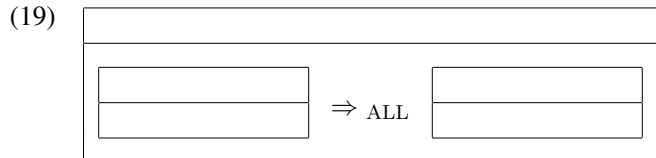
At the next step, the box [u: police-officer(u)] introduced by *keekan-ga* 'police.officer-sc nom' intra-sententially merges to (19), which has three possible merging boxes; the main box, the left sub-box, and the right sub-box. Here we assume that the internal structure of quantified NP gives the information of the merging operation, as shown in (20).

(20)   The Tripartite Structure Rule
    (i) The box associated with the NP in the sequence 'Q NP-case marker' are merged to the left sub-box introduced by the box associated with Q.
    (ii) The boxes associated with the other intra-sentential NPs are merged to the other boxes (i.e. to the main box or to the right sub-box).

According to the rule (20), in the sequence '[$_Q$ *subeteno*] [$_{NP}$ *keekan*]-*ga*,' the box introduced by *keekan* 'police.officer' is merged to the left sub-box, yielding (21).

(21)
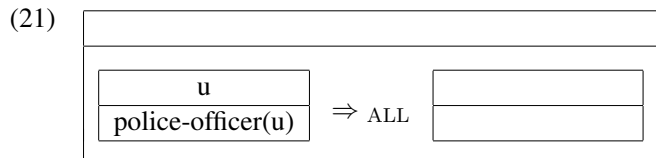
(21) correctly represents the fact that the NP following Q serves as the restrictive clause of that Q. At this point, one might claim that the DRS for the universal quantifier should be something like [: [u : P(u)] $\Rightarrow$ $_{ALL}$ [: Q(u)]], where the both sub-boxes contain the variable u in their conditions. Given the usual translation of a universal quantifier $\lambda Q\lambda P\forall x[P(x) \to Q(x)]$, in which the antecedent and the consequent clauses share the same variable x, it seems reasonable to assume that the two subordinate boxes in (19) 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 cooccurrence 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 (22).

(22)   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 (21) the variable introduced in the left sub-box by the tripartite structure rule (20) is u, and the ban on vacuous quantification (22) requires that u should appear in the right sub-box. This requirement is satisfied if a λ-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 DRS of the sentence (18).

(23) a. [: [u: police-officer(u)] $\Rightarrow$ $_{ALL}$
          [e, v: criminal(v), $\lambda y \lambda x$[catching(e) $\wedge$ agent(x, e) $\wedge$ theme(y, e)]]]

    b. [: [u: police-officer(u)] $\Rightarrow$ $_{ALL}$
          [e, v: criminal(v), λx[catching(e) $\wedge$ agent(x, e) $\wedge$ theme(v, e)]]]

In (23a) *hannin-o* 'criminal-ACC' and *tsukamaeta* 'caught' merge to the right box, following the rule (20), then in (23b) λy is replaced with v, following the locality preference of λ-reduction (11).

At this point, it is important to consider how a sentence like (24) is interpreted.

(24) Subeteno keekan-ga   hannin-o   tsukamaeta.
      all   police.officer-NOM criminal-ACC caught

      'All police officers caught a criminal.'

In Japanese linguistic literature (e.g. Hoji (1985) among others), it is claimed that in a structure 'Q NP-NOM Q NP-ACC V,' the Q NP-NOM takes wide scope over the Q NP-ACC. In (24), 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 (18) are ambiguous between the wide scope reading of the Q NP subject and that of the dative bare NP. The question is then what interpretation the participants in Kurafuji *et al.*'s (2007) experiment 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 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 (24) is interpreted as "There is a criminal such that all police officers caught her/him together," since this kind of interpretation seems the easiest to obtain.[6]

The interpretation such as "all police officer caught a criminal 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 (25).[7]

(25) [$_{\text{main box}}$: ... [$_{\text{sub-box}}$ e : ...] ...] $\rightarrow$ $_{project\ e}$ [$_{\text{main box}}$ e : ... [$_{\text{sub-box}}$: ...] ...]

Let us go back to DRS (23b). In (26a), the discourse referent in the sub-box e is projected to the main box following the operation in (25). The DRS (26a) has a variable x bound by the λ-operator, and how to treat this variable is important in derivation. If the sentence ends at this point, this variable is replaced with u in the left box as in (26b).

(26) a. [: [u: police-officer(u)] $\Rightarrow$ $_{ALL}$
          [e, v: criminal(v), λx[catching(e) $\wedge$ agent(x, e) $\wedge$ theme(v, e)]]]
               $\rightarrow$ $_{project\ e}$ [e : [u: police-officer(u)] $\Rightarrow$ $_{ALL}$
                              [v: criminal(v), λx[catching(e) $\wedge$ agent(x, e) $\wedge$ theme(v, e)]]]

    b. [e : [u: police-officer(u)] $\Rightarrow$ $_{ALL}$
          [v: criminal(v), catching(e), agent(u, e), theme(v, e)]]

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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.

This operation does not obey the locality preference of λ-reduction (11). Remember 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 (22) forces the violation of the locality preference of λ-reduction. By replacing of the λ-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 (26b) represents "all police officers caught a criminal (together)."

Now let us consider the case where another NP merges to (26a).

(27) a. (26a) $\underline{\otimes}$ [r: man(r)] $\Rightarrow$
        [e: [u: police-officer(u)] $\Rightarrow$ $_{ALL}$
          [v, r: criminal(v), catching(e), agent(r, e), theme(v, e), man(r)]]

     b. (27a) $\underline{\otimes}$ [s: thanks(s)] =
        [e: [u: police-officer(u)] $\Rightarrow$ $_{ALL}$
          [v, r, s: criminal(v), catching(e), agent(r, e), theme(v, e), man(r), thanks(s)]]

     c. (27b) $\underline{\otimes}$ $\lambda z\lambda y\lambda x$[saying(e') $\wedge$ agent(x, e') $\wedge$ theme(y, e') $\wedge$ goal(z, e')] $\Rightarrow$ $_{project\ e'}$
        [e, e': [u: police-officer(u)] $\Rightarrow$ $_{ALL}$
            [v, r, s: criminal(v), catching(e), agent(r, e), theme(v, e), man(r), thank(s),
               saying(e'), agent(u, e'), theme(s, e'), goal(r, e')]]

As shown in (27a), the box [r : man(r)] associated with *otoko-ni* '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 λ-reduction (11).

Again, the important point here is the treatment of the agent variable of *tsukamaeta* 'caught'. Unlike the case of the sentence (9) discussed in Section 4.1, the u associated with *keekan* 'police officer' 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 *otoko* 'man' is in the same box as the agent variable is, so the locality preference in (11) chooses r as the agent of the verb.

Then *ree-o* 'thanks-ACC' and *itta* 'said' merge to DRSs in (27a) and (27b), respectively. As discussed above, the λx of *itta* 'said' is replaced with u in the left box to satisfy the ban on vacuous quantification. The final DRS (27c) represents the correct truth conditions of sentence (18).

5 Concluding Remarks

This paper investigated Japanese TASs of the form 'NP-NOM NP-ACC V NP-DAT V.' Such sentences with a bare NP subject and with a universally quantified subject show the difference in reading time based on psycholinguistics experiments (Kurafuji *et al.*, 2007). To account for this fact, we developed the new incremental DRS building algorithm under the framework of DRT (Kamp and Reyle, 1993), in which each lexical item is translated into a box-notation and such a box intrasententially merges to 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 *room* 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 a *room* for a new discourse referent, and thus the GP effect does not take place.

We also proposed two parsing strategies; the locality preference of λ-reduction and the early completion strategy. The effects of these 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 apply 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 suggsts that the topic-marked NP introduces a tripartite structure as [u: P(u)] $\Rightarrow$ $_{TOPIC}$ [u: Q(u)], which roughly says "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) among others). Our approach thus hacks up such an idea with the experimental results.

We did not go into detail on other quantified NPs with an existantial quantifier like *aru keekan* 'a police officer' and numeral quantifier like *san-nin-no keekan* 'three police officers.' The status of the sentence begins with the former is not clear since there was no significant diffrence of reading time between such a sentence and the sentence with universal quantifier. Regarding the sentence with the latter, we have not conducted any experiments. We will leave the experiments and analyses of these quantifiers for future work.

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