Multiply Quantified Internally Headed Relative Clause in Japanese: A Skolem Term Based Approach

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Abstract

This paper presents an analysis of Internally Headed Relative Clause (IHRC) construction in Japanese within the framework of Combinatory Categorial Grammar (Steedman 2000). Shimoyama (1999) argues that when an IHRC appears within the scope of a universal quantifier, the interpretation of the IHRC exemplifies E-type anaphora and that the LF representation of the IHRC should have a variable bound by the quantifier in the matrix clause. To accommodate this argument Shimoyama posits a free variable of functional type to which the bound variable is applied, and whose denotation is determined by the context-dependent assignment function. However since there is no limit to the number of quantifiers in the matrix clause (and accordingly that of bound variables in the IHRC), the semantic type of the free variable would be highly ambiguous if the IHRC occurs within the scope of multiple quantifiers. The current analysis assumes that the interpretation of IHRCs exhibits an instance of generalized Skolem term (Steedman 1999, 2004), a term whose denotation varies with the value of bound variables introduced by scope-taking operators, but which is interpreted as a constant in the absence of such operators. This paper provides a straightforward account for the semantics of the construction without invoking the complexities of the type ambiguity of free variables.

1. Introduction

This paper presents an analysis of Internally Headed Relative Clause (IHRC) construction in Japanese paying particular attention to the effect of quantification on its interpretation. (1) illustrates the basic form of the construction:[1]

(1) Taroo-ga [Hanako-ga ringo-o muita] no-o tabeta.
Taro-NOM Hanako-NOM apple-ACC peeled NML-ACC ate
'Taro ate the apple that Hanako peeled.'

The bracketed string *Hanako-ga ringo-o muita* 'Hanako peeled an apple' is a clause followed by nominalizer *no*. The whole NP obtained is marked with accusative particle *-o*, and is construed as the object of the matrix verb *tabeta* 'ate'. Since the verb requires as its semantic restriction that the object be an edible thing, it anaphorically picks up the referent of *ringo* 'apple' from the embedded clause. A brief note on terminology is in order. If we say the *antecedent* of an IHRC, we mean the referent of the IHRC which functions as the argument of the matrix predicate. And the *head* of the IHRC refers to the linguistic element in the IHRC which describes the antecedent. So for example, in (1) the antecedent is the apple that Hanako peeled, and the head is the noun *ringo* 'apple'.

[1] Abbreviations used: ACC = accusative, ALL = allative, CL = classifier, COMP = complementizer, COP = copula, GEN = genitive, LOC = locative, NML = nominalizer, NOM = nominative, TOP = topic.

This paper is organized as follows. In section 2, we discuss the interpretational characteristics of IHRC, drawing on the study of Kikuta (2000). We then review the observation made by Shimoyama (1999) and her E-type analysis of IHRC. We address the problem that the E-type analysis would raise focusing on multiply quantified IHRCs. Section 3 introduces the notion of generalized Skolem term, which provides a straightforward account for multiply quantified IHRC. Finally, section 4 concludes.

2. Previous Analysis and Its Problem

2.1. The Interpretational Characteristics of IHRC

Anaphoric nature of IHRC is best illustrated by the fact that the antecedent of an IHRC is occasionally not expressed as a linguistic element. (2a–c) are such examples of 'headless' IHRC from Nomura (2000).[2]

(2) a. [Nikai-de suisoo-ga ahureta] no-ga sita-ni morete kita.
second:floor-LOC fish:tank-NOM overflowed NML-NOM downstairs-ALL leak came

'The fish tank upstairs overflowed and (the water) leaked to downstairs.'

b. [Kesa kao-o sotta] no-ga yuugata-niwa mata nobite kita.
this:morning face-ACC shaved NML-NOM evening-TOP again growing came

'I shaved my face in the morning, and (the beard) started to grow again in the evening.'

c. [Tuti-o hotta] no-o ue-kara nozokikonda.
soil-ACC dug NML-NOM up-from looked:into

'I dug the soil, and lookd into (the hole).'

Determining the antecedent of a headless IHRC obviously requires inference of some sort. Kikuta (2000) addresses the question exactly how much information is needed for this inference within the framework of Generative Lexicon (GL). To recapitulate Kikuta's argument, if the inference always requires unconstrained pragmatics, the theory would overgenerate IHRC with illicit antecedents. There should be a more restricted way for determining the antecedent. And indeed she shows that the antecedent can be identified using only the *linguistically* specified information by adopting GL, which posits the lexicon containing relatively rich semantic information. Kikuta's conclusion is that the possible antecedent of the headless IHRC must meet the following conditions: (i) necessary involvement in the event described by the main predicate in the IHRC; (ii) recoverability of the denotation from linguistically pre-specified information; and (iii) presence in the resultant state of the event described by the main predicate in the IHRC. For example in (2a), the antecedent is the water. Note that this is the element necessarily involved in the overflowing event, lexically specified by the predicate *ahureta* 'overflowed', and exists in the resultant state. Other examples also satisfy these conditions. In contrast, violating these conditions leads to unacceptability. Following Kikuta's result (but simplifying the matter somewhat), in our analysis we will use a predicate *result'* where *result' px* means that an element *x* is involved in the resultant state of the event described by proposition *p*.

However, above three conditions cannot be straightforwardly applied to IHRCs in general. Consider (3), the example taken from a news article (*asahi.com*, Jun. 22, 2004):

[2] In the translation, antecedents are given in brackets.

(3) [Denwa-o kawatta betuno otoko-ga nakizyakutteita] no-o syuhu-wa
phone-ACC got the:other man-NOM sobbing NML-ACC housewife-TOP

kaisyain-no otto da to omoikonda.
office:worker-GEN husband COP COMP believed

'The housewife took the other man sobbing on the phone as her office worker husband.'

The main predicate of the IHRC is *nakizyakutteita* 'sobbing', which denotes an activity, apparently lacks a lexical specification of the resultant (or consequent) state. So there is no way to satisfy the condition (iii). And yet the antecedent *betuno otoko* 'the other man' is an entity necessarily involved in the described event, in accordance with the above condition (i). In such cases, we will use a predicate *abt'* for 'aboutness' relation defined informally such that *abt' px* means that an element *x* is necessarily involved in the event described by a proposition *p*. Now we have two different relations (i.e. *result'* and *abt'*) to describe the semantic constraint on the possible antecedent of IHRCs. Note that *result'* is a subtype of *abt'* since the former entails the latter. We will define the nominalizer category as initially having the interpretation containing the predicate *abt'*, which is on occasion replaced with *result'*. In the following, we give an informal sketch of how this replacement is done. But in our analysis in section 3, we will take this replacement for granted, treating *result'* as if it is given lexically.

Given the fact that an IHRC is syntactically a complete sentence, we assume an IHRC constitutes a separate information unit from the matrix clause. And we adopt SDRT's claim (Asher and Lascarides 2003) that every information unit or proposition is connected via some rhetorical relation in order for the entire discourse to be coherent. Then the IHRC and the matrix clause must be connected via some rhetorical relation. By way of illustration, let us consider (2a) again. Here, we have two clauses, namely the IHRC and the matrix clause, and two corresponding propositions: *the fish tank upstairs overflowed* (π_1), and SOMETHING leaked to downstairs (π_2). In the latter proposition, SOMETHING corresponds to the nominative argument IHRC. Being anaphoric, this must be resolved in some way. In addition, the two propositions need to be connected via some rhetorical relation. Suppose that the latter requirement is somehow fulfilled by inferring *Result* (π_1, π_2) as the relevant rhetorical relation. Then the semantics of *Result* entails that the event of π_1 caused that of π_2. Now, SOMETHING in π_2 can plausibly be equated with the water, making the discourse (consisting of two clauses) coherent. We assume that the relation symbol *abt'* originated from the lexical information is replaced with the more specific relation symbol *result'* in the process of such inference.

Note, incidentally, that this kind of approach may provide a way to account for the relevancy condition on IHRC discussed by Kuroda (1975–6):

(4) The Relevancy Condition: For a p.-i. relative clause [IHRC] to be acceptable, it is necessary that it be interpreted pragmatically in such a way as to be directly relevant to the pragmatic content of its matrix clause.

As the effect of the relevancy condition, events described by an IHRC and the matrix clause are typically related in either of the following ways: (a) temporal overlap, (b) relevance of purpose, (c) relevance of motivation, or (d) spatial proximity. Note that Kuroda stated the relevancy condition as a mere descriptive generalization, whereas in our approach sketched above, this can be viewed as a consequence of the principle of discourse coherence in general, since if IHRC cannot be connected by some rhetorical relation, there would be no way to attach the information of IHRC to the matrix clause in a coherent manner. And the effects of the relevancy condition mentioned above can be regarded as entailments of the inferred rhetorical relation.

2.2. Shimoyama's (1999) E-type analysis

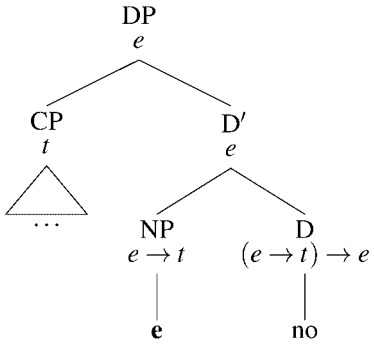
Now let us turn to another aspect of the construction. Shimoyama (1999) claims that when IHRC appears within the scope of a universal quantifier, the interpretation of IHRC exemplifies E-type anaphora:

(5) Dono gakusei$_i$-mo [soitu$_i$-ga kongakki peepaa-o san-bon kaita] no-o kesa
Every student he-NOM this:semester paper-ACC three-CL wrote NML-ACC this:morning
teisyutusita.
turned:in

'Every student turned in the three term papers he or she wrote this semester this morning.'

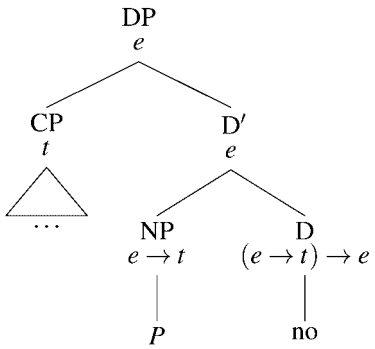
In (5), the subject of the embedded clause is bound by the universal quantifier in the matrix clause. Note that "[t]he matrix object [...] does not refer to any particular set of term papers (Shimoyama 1999:156)," and the interpretation of the matrix object is paraphrased by the definite description *the term papers he or she wrote this semester*. Thus, the interpretation of the relative clause is an instance of E-type anaphora. Given this observation, Shimoyama (1999) proposes the LF structure of IHRC as schematized in (6):

(6)



According to this analysis, CP in the Spec of DP corresponds to the relative clause, which is interpreted independently because of type mismatch. The DP is headed by the nominalizer *no*. The complement NP indicated by **e** is an empty pronoun. In essence, the interpretation of this empty pronoun determines the argument of matrix predicate. For example, in the LF representation (7a) of the IHRC in (1), the empty pronoun is interpreted as free variable P of type $e \rightarrow t$. Now, it is assumed that free variables in general are assigned a value by the assignment function g relative to the context. In this case, P is assigned the value in (7b): the set of apples which Hanako peeled.

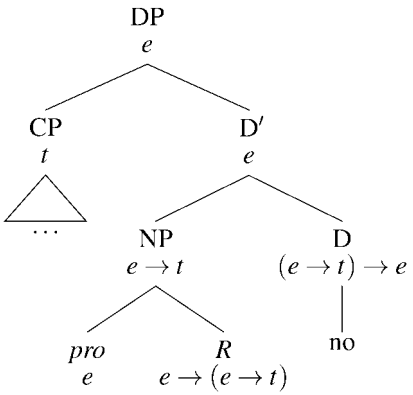
(7) a.



b. $[\![P]\!]_g = \lambda x.apple'x \wedge peel'x\,hanako'$

Shimoyama assumes that the nominalizer *no* is interpreted as the function from a set to the maximality of the set, adopting Link's (1983) analysis of definite descriptions.[3] As a result, the denotation of IHRC is equivalent to English definite description 'the apples that Hanako peeled.' In the case of (5), the LF representation of the IHRC is something like (8a), in which the empty pronoun is further divided into *pro* and a free variable *R*.

(8) a.



b. $[\![R]\!]_g = \lambda x.\lambda y.paper'y \wedge wrote'yx$

c. $[\![R]\!]_g([\![pro]\!]_g) = \lambda y.paper'y \wedge wrote'yx$ (x is bound by $\forall x$)

pro is a variable of type *e* bound by the universal quantifier in the matrix clause. On the other hand, *R* is free variable of type $e \rightarrow (e \rightarrow t)$, to which an assignment function *g* assigns the value in (8b) as a salient two-place predicate in the context. The latter takes *pro* as its argument to yield the interpretation shown in (8c). In words, this is the set of *y* such that *y* is a set of papers that *x* wrote, where *x* is bound by the universal quantifier. Then the result serves as the argument for *no* as before. In the end, (5) is interpreted as 'for every student *x*, *x* wrote three papers this semester, and *x* turned in the papers *x* wrote this semester this morning.'

This analysis poses two problems. First, as is noted by Shimoyama herself, the assignment function is not properly constrained. It just picks up a property or relation which is 'salient' in the context. We discussed this problem in section 2.1. We will assume that the appropriate constraints can be captured by the predicate *result'* or *abt'*, although we have given only a quite informal sketch of how to decide between these two options. The second and more severe problem is the ambiguity in the semantic type of the free variable. As we have just seen, the assignment function *g* assigns a value to a free variable relative to the context. And in order to assign a value, at least the semantic type of the variable needs to be known. But the semantic type of that free variable can be determined only *after* the context is available. Then how can the context be available before context-dependent interpretation comes in? This is not entirely clear. And what is worse, the semantic type of the free variable can be arbitrarily complex according to the number of universal quantifiers in the matrix clause. This is illustrated in (9–10):

(9) Dono sensei-mo subeteno zyugyoo-de [menomae-de gakusei-ga neteiru] no-o
every prof all class-LOC before:eyes-LOC student-NOM sleeping NML-ACC
tatakiokosita.
woke:up:roughly

'Every prof, in all the classes, woke up a student who are sleeping before his eyes.'

[3] Note in passing that our analysis in section 3 assumes that plurals are translated as set individuals.

(10) Dono bando-no dono gitarisuto-mo subeteno suteezi-de dono kyoku-demo
Every band-GEN every guitarist all stages-LOC every number-LOC

[gitaa-no tyuuningu-ga kurutteiru] no-o sonobade tatakikowasita.
guitar-GEN tuning-NOM wrong NML-ACC on:the:spot broke

'Every guitarist of every band smashed the guitar which was out of tune in every number on all stages.'

In principle, there is no limit to the number of quantifiers in the matrix clause; therefore, a mechanism that does not invoke the complexity of this sort should be preferred. In the next section, we propose the analysis that can derive the interpretation of such multiply quantified IHRC in the same way as the quantifier-free cases (1) and singly quantified cases (2) by introducing the concept of generalized Skolem term proposed in Steedman (1999, 2004).

3. Skolem Term Analysis

3.1. Generalized Skolem Term

Steedman (1999, 2004) introduced the concept of generalized Skolem term to give an analysis of the alternation of quantifier scope. We briefly sketch the basic idea and then show how to apply it to the analysis of multiply quantified IHRCs.

A generalized Skolem term is a term whose denotation varies with the value of bound variables introduced by scope-taking operators such as universal quantifiers, but which is interpreted as a constant in the absence of such operators. When introduced as a Logical Form element, a Skolem term appears unspecified as to its arguments. This is indicated as *skolem' p* where *p* designates a nominal property. And at some later step in the derivation, an operation called Skolem specification is applied to this unspecified Skolem term to yield a generalized Skolem term, designated as sk_p^E, where E is the environment, namely an ordered set consisting of the bound variables of the universal quantifiers that take scope at that point of the derivation. sk_p being a function, with E as its argument, its reference depends on the value of bound variables. And if E is the empty set, the sk_p^E denotes a constant. The notion of environment is incorporated in the grammatical rule of Combinatorial Categorial Grammar (CCG) in the following way. (11) illustrates the function application rule.[4]

(11) a. $X/Y : f' \quad Y : a' \quad \Rightarrow \quad X : f'a' \quad (>)$

b. $Y : a' \quad X\backslash Y : f' \quad \Rightarrow \quad X : f'a' \quad (<)$

The environment is the operator bound variable identifier and is associated with the propositional body of the interpretation. Thus, the transitive verb *loves* has the following category with its environment being the empty set:[5]

(12) loves := $(S\backslash NP_{3S})/NP : \lambda x.\lambda y.[loves'xy]^{\{\}}$

Application of a rule induces environment passing in the following way: if a function with environment F is applied to an argument with environment A , the environment of the argument in the resulting LF is the union of the two ($F \cup A$). We often omit the environment from the notation where it is of little interest.

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[4] In this paper, we use only the application rule, which (apart from the notational convention) is common to all variants of Categorial Grammars. For other rules of CCG, we refer the reader to Steedman (2000).

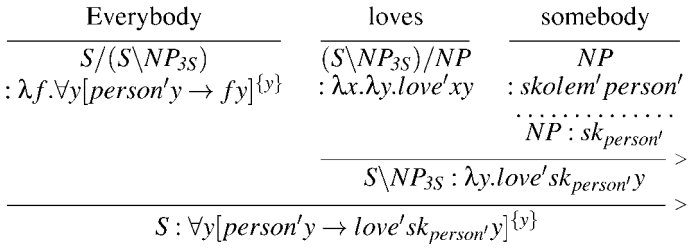
[5] The left associativity convention is used throughout, so that *love' xy* is equivalent to (*love' x*)*y*.

So much for the definition. Now we turn to the way it works.

(13) a. Everybody loves somebody.
b. Somebody loves everybody.

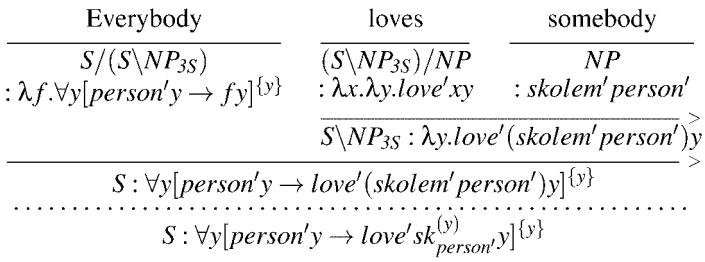
Expressions traditionally analyzed as existential quantifier such as *somebody* is reanalyzed as an unspecified Skolem Term *skolem' person'*. In (13a), for example, if specification applies at a point of derivation in which the Skolem term has not yet been in the scope of the universal quantifier, the resulting generalized Skolem term is $sk_{person'}$. That is, the wide scope reading of *somebody* is obtained. This derivation is shown in (14). Skolem specification is indicated by the dotted underline.

(14)



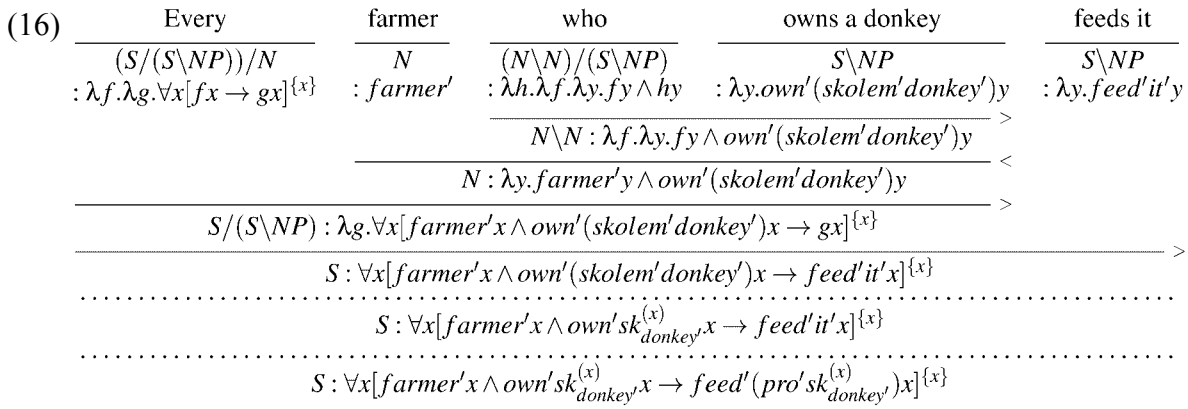
In contrast, if specification applies after it enters within the scope of the universal quantifier, the resulting generalized Skolem term is $sk^{(y)}_{person'}$ where $sk_{person'}$ is a function which takes the variable *y* bound by the universal quantifier as its argument, hence the narrow scope reading of *somebody*. (15) illustrates the derivation of this reading.

(15)



The scope alternation in (13b) is accounted for in a quite similar way. And a so-called donkey anaphora is treated as referring to the Skolem term introduced by an indefinite. Consider (16):

(16)



The donkey anaphora *it* is initially interpreted as *it'*, and then identified with the Skolem term introduced by *some donkey*, whose referent is dependent on *every farmer*.

3.2. Distributivizing Verb Category in Japanese

Before we go into the Skolem term approach to IHRC, let us consider how the scope alternation is achieved in Japanese. In (17), we observe that Skolem term *dareka* 'somebody' allows only the narrow scope reading. That is, the Japanese counterpart of (13b) fails to show scope alternation (cf. Nakamura 1993):

(17) Dareka-ga daremo-o aisiteiru.
Somebody-NOM everybody-ACC love
'Somebody loves everybody' $(\exists\forall/*\forall\exists)$

However, if the object NP is scrambled to the sentence initial position, and precedes the putative universal quantifier *daremo* 'everybody', both narrow and wide scope readings are available.

(18) Daremo-o dareka-ga aisiteiru.
Everybody-ACC somebody-NOM love
'Somebody loves everybody' $(\forall\exists/\exists\forall)$

This situation is quite unlike English example. To accommodate this fact, we tentatively adopt Steedman's suggestion (2004:49, fn.50) that languages such as Japanese entirely lack generalized quantifier NPs and that the work of the universal quantifier in such languages are done by distributivizing verb categories. We assume that *daremo* 'everybody' denotes a set individual whose member is all the people in the universe of discourse, indicated as *all_people'*. (19) illustrates the derivation of (18), in which *dareka* 'somebody' is interpreted as having narrow scope.

(19)

$$\dfrac{\dfrac{\dfrac{\text{Daremo-o}}{NP_{ACC} : all\_people'} \quad \dfrac{\text{dareka-ga}}{NP_{NOM} : skolem'person'} \quad \dfrac{\text{aisiteiru}}{(S_{DIST}\backslash NP_{ACC})\backslash NP_{NOM} : \lambda y.\lambda x.\forall w[w \in x \rightarrow love'wy]^{\{w\}}}}{S_{DIST}\backslash NP_{ACC} : \lambda x.\forall w[w \in x \rightarrow love'w(skolem'person')]^{\{w\}}}<}{S_{DIST} : \forall w[w \in all\_people' \rightarrow love'w(skolem'person')]^{\{w\}}}<$$

$$S_{DIST} : \forall w[w \in all\_people' \rightarrow love'w\ sk^{(w)}_{person'}]^{\{w\}}$$

Here, we defined the category of the verb so that the member of the set *all_people'* distributes over the Skolem term introduced by the subject NP. If we further assume the distributivizing as well as scrambling is realized by a lexical rule, then the fact that distributive reading is absent in non-scrambled sentence can be thought of an accidental lack of such lexical rule. The derivation (20) illustrates the only possible reading for (17).

(20)

$$\dfrac{\dfrac{\text{Dareka-ga}}{NP_{NOM} : skolem'person'}}{NP_{NOM} : sk_{person'}} \quad \dfrac{\dfrac{\text{daremo-o}}{NP_{ACC} : all\_people'} \quad \dfrac{\text{aisiteiru}}{(S\backslash NP_{NOM})\backslash NP_{ACC} : \lambda x.\lambda y.love'xy}}{S\backslash NP_{NOM} : \lambda y.love'all\_people'y}<$$

$$S : love'all\_people'sk_{person'}<$$

3.3. IHRC as Generalized Skolem Term

The current analysis views the interpretation of IHRC as an instance of generalized Skolem term, and provides a straightforward account for the semantics of the construction. In order to capture the

restriction on the interpretation of IHRC, nominalizer category is defined as in (21), where *R* stands for either *abt'* or *result'* (see section 2.1 for the discussion of this treatment):

(21) *no* := $NP\backslash S : \lambda p.skolem'\,(\lambda x.Rpx)$

The derivation of (1) is shown in (22).

(22)

Taroo-ga	Hanako-ga ringo-o muita	no-o	tabeta
$NP_{NOM} : taro'$	$S : peel'apple'hanako'$	$NP_{ACC}\backslash S : \lambda p.skolem'\lambda x.result'px$	$(S\backslash NP_{NOM})\backslash NP_{ACC} : \lambda y.\lambda z.eat'yz$
	$NP_{ACC} : skolem'(\lambda x.result'(peel'apple'hanako')x)$ <		
	$S\backslash NP_{NOM} : \lambda z.eat'skolem'(\lambda x.result'(peel'apple'hanako')x)z$ <		
	$S : eat'skolem'(\lambda x.result'(peel'apple'hanako')x)taro'$ <		
	$S : eat'sk_{\lambda x.result'(peel'apple'hanako')x}taro'$		

The semantics of the embedded clause is fairly obvious. This is then applied to the function defined in (21). The 'result' predicate *result' px* indicates that the event described by *p* yields an individual *x*. And the IHRC is analyzed as a Skolem term with the property of being involved in the result state of Hanako's peeling an apple. It is further subject to Skolem specification (indicated by the dotted line as before). Since there is no universal quantifier, the resulting generalized Skolem term will denote a constant, i.e. the apple that Hanako peeled. It might be obvious that this analysis can easily extend to the analysis of headless IHRCs. Interpretation of an IHRC is always determined via *abt'* or *result'* relation, regardless of whether the antecedent is explicitly expressed or not. Still, we have to admit that the nominal property of the Skolem term $\lambda x.result'$ (*peel' apple' hanako'*) *x* is not a sufficient characterization of the antecedent, as it can also be applied to the apple skin, rather than only to the peeled apple fruit. Basically this λ-expression should function as a constraint on the possible referent of the IHRC, and it is subject to the process of anaphora resolution. And the resolved Skolem term in this case would be $skolem'\ \lambda x.(result'(peel'apple'hanako')x \wedge fruit'x)$. However, we gloss over this problem here, and the question of how this mechanism works is left open for future research.

Now, let us examine the interpretation of the IHRC that occurs within the scope universal quantifier. The derivation of (5) is shown in (23):

(23)

Dono gakusei-mo	soitu-ga peepaa-o san-bon kaita no-o	teisyutusita
NP : $all\_student'$	NP : $skolem'\left(\lambda x.result'\left(write'3papers'(pro'u)\right)x\right)$	$(S_{DIST}\backslash NP)\backslash NP$: $\lambda z.\lambda w.\forall u[u \in w \rightarrow turn\_in'zu]^{\{u\}}$
	$S_{DIST}\backslash NP : \lambda w.\forall u[u \in w \rightarrow turn\_in'(skolem'\left(\lambda x.result'\left(write'3papers'(pro'u)\right)x\right))u]^{\{u\}}$ <	
	$S_{DIST} : \forall u[u \in all\_student' \rightarrow turn\_in'(skolem'\left(\lambda x.result'\left(write'3papers'(pro'u)\right)x\right))u]^{\{u\}}$ <	
	$S_{DIST} : \forall u[u \in all\_student' \rightarrow turn\_in'sk^{(u)}_{\lambda x.result'\left(write'3papers'(pro'u)\right)x}u]^{\{u\}}$	

Here, *soitu* in the IHRC is interpreted as *pro' u*. As the notation may suggest, it is introduced as an ordinary pronoun. This will later get bound by the universal quantifier. We take this process as anaphora resolution of the usual kind. This is because *soitu* could also be interpreted as deictic pronoun, in which case there is a ghostwriter (referred to by *soitu*) who wrote all the papers that every student turned in (a highly implausible situation, though). The last line is the result of Skolem specification. Since the Skolem term is in the scope of the universal quantifier, it takes the bound variable *u* as its argument. Therefore, the resulting generalized Skolem term refers to different sets of term papers, according to the value of *u*. This is the desired result, and this is achieved without

invoking any complexity such as the type ambiguity of the empty pronoun. Multiply quantified cases like (9) can be derived in a similar way:

(24)

Dono sensei-mo	subeteno zyugyoo-de	gakusei-ga neteiru no-o	tatakiokosita
NP : all_prof'	VP/VP : $\lambda f.\lambda y.\forall t[t \in all\_class' \rightarrow during't(fy)]^{\{t\}}$	NP : $skolem'(\lambda x.abt'(sleep'student')x)$	$(S_{DIST}\backslash NP)\backslash NP$: $\lambda z.\lambda w.\forall u[u \in w \rightarrow wake'zu]^{\{u\}}$

$$\frac{}{S_{DIST}\backslash NP : \lambda w.\forall u[u \in w \rightarrow wake'(skolem'\left(\lambda x.abt'\left(sleep'student'\right)x\right))u]^{\{u\}}}\ <$$

$$\frac{}{S_{DIST}\backslash NP : \lambda y.\forall t[t \in all\_class' \rightarrow during't(\forall u[u \in y \rightarrow wake'(skolem'\left(\lambda x.abt'\left(sleep'student'\right)x\right))u]^{\{t,u\}})]^{\{t\}}}\ >$$

$$\frac{}{S_{DIST} : \forall t[t \in all\_class' \rightarrow during't(\forall u[u \in all\_prof' \rightarrow wake'(skolem'\left(\lambda x.abt'\left(sleep'student'\right)x\right))u]^{\{t,u\}})]^{\{t\}}}\ <$$

$$S_{DIST} : \forall t[t \in all\_class' \rightarrow during't(\forall u[u \in all\_prof' \rightarrow wake'(sk^{(t,u)}_{\lambda x.abt'\left(sleep'student'\right)x})u]^{\{t,u\}})]^{\{t\}}$$

Since Skolem term automatically takes the bound variables in its environment, the problem of type ambiguity that the E-type analysis suffered does not arise.

4. Conclusion

We developed an analysis of Internally Headed Relative Clause (IHRC) construction in Japanese within the framework of Combinatory Categorial Grammar (Steedman 2000). In section 2, we discussed the interpretational characteristics of IHRC, drawing on Kikuta's (2000) study of headless IHRCs. We generalized her idea by partly adopting Asher and Lascarides's (2003) theory, and argued that semantics of rhetorical relation would also help the determination of antecedent. And we also suggested that Kuroda's (1975–6) relevancy condition on IHRC can be viewed as a consequence of the principle of discourse coherence in general. We then looked at the argument made by Shimoyama (1999) and her E-type analysis of IHRC. We addressed the problem of type ambiguity that her E-type analysis would raise focusing on multiply quantified IHRCs. In section 3 we introduced the notion of generalized Skolem term, and also disscussed the problem of scope alternation in Japanese, which is quite different from English, and motivated the distributivizing verb category adopting the Steedman's (2004) suggestion. And finally in section 3.3., we integrated the whole discussion into the analysis of IHRCs. Our main point is if we take the interpretation of an IHRC as a generalized Skolem term, we can attain the uniformed analysis for the several kinds of IHRCs, namely, headless IHRC, simple (quantifier-free) IHRC, and (singly or multiply) quantified IHRC.

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