# On the Scope Interaction of Japanese Indefinites An Epsilon Calculus Approach *

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**Abstract.** This study explores the scope properties of some indefinites in Japanese in terms of epsilon calculus. Different from ordinary noun phrases, quantificational noun phrases like indefinites are assigned higher-order categories and/or types in syntax, and taken to denote functions from sets to truth values in semantics, which results in great difficulty in deriving proper interpretations of sentences with quantified expressions, given the tight syntax-semantics relation built into theories of grammar. We simply deal with all quantified expressions as terms of type e, and treat indefinites as choice functions, i.e., functions that apply to sets and arbitrarily select one of their members. Some indefinites can take arbitrarily wide scopes, depending on contextual information, whereas others have limitations on the freedom of scope taking. We adopt Dynamic Syntax to implement this idea, making it possible for the scope of indefinites to be left unspecified and fixed in a later stage of parsing.

**Keywords:** indefinite expression, epsilon calculus, choice function, Skolemization, Dynamic Syntax

## 1 Introduction

In languages like English, the distinction between definite and indefinite NPs are explicitly indicated by syntactic devices such as determiners, demonstratives and articles, while such distinctions are blurred in languages like Japanese, with the exception of NPs containing demonstratives, and both of them simply occur as bare nominals (without determiners). English indefinites have been treated as existentially quantified expressions, but they are quite different from universally quantified ones like $any$ N or $all$ Ns in that the former often do not obey the island conditions and can take arbitrarily wide scopes and/or function as referential terms. As for the construal of indefinites, several different approaches have been proposed. The first one sticks to the parallel treatment of universal and existential quantifiers, both of which are treated as generalized quantifiers, and some new mechanism of assignments deals with peculiar properties of indefinites. The second approach posits two different categories for indefinites (referential nominal and existential quantifier), as proposed by Fodor and Sag (1982). The third one deals with indefinites as discourse referents, suggested by so-called Discourse Representation Theories (Kamp and Reyle, 1993), arguing that indefinites do not express existential force, but introduce new discourse referents to the contexts. The last one, which we will adopt in this paper, is to regard indefinites as choice functions. Among them, we will explore the use of epsilon terms as a syntactic counterpart of choice function, as proposed by Meyer Viol *et al.* (1999), Kempson *et al.* (2001), Cann *et al.* (2005),

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von Heusinger (2000), Peregrin and von Heusinger (2004), among others. We will argue that the use of $\epsilon$-operator allows a flexible treatment of indefinites to account for their divergent behaviors concerning scope choice, and give a unified account of surprisingly different interpretations of indefinites with respect to scope taking.

(1) a. Every boy loves a girl. ($\forall > \exists$, $\exists > \forall$)

b. Every boy loves a certain girl. ($*\forall > \exists$, $\exists > \forall$)

c. Every building has a guard standing in front of it. ($\forall > \exists$, $*\exists > \forall$)

The three underscored objects in (1) show different scopal properties, as the scope preferences in parenthesis show. Though linear interpretation is overwhelmingly preferred in (1a), the indefinite object $a\ girl$ can take scope over the subject if some appropriate situation is given. "$A\ certain$ + N" forms as in (1b) usually do not get narrow scope interpretations, but still it is possible to receive intermediate interpretations depending on context. We will show this scope interaction on the basis of Dynamic Syntax (Kempson *et al.*, 2001; Cann *et al.*, 2005). Relational nouns like guard in (1c) almost always require dependent scope relations irrespective of the positions they appear in sentences. We will try to give a unified explanation of these three kinds of noun phrases in terms of choice function and a scope-choice device in this paper.

## 2 Scope Independence and Skolemization

First, we give an outline of our choice function approach to the scope of indefinites, and introduce some assumptions necessary to account for their peculiarities regarding scope taking. It is assumed that sentence (1a) has two interpretations, represented in (2a) and (2b):

(2) a. $\forall x[Bx \rightarrow \exists y[Gy\ \&\ Lxy]$

b. $\exists y[Gy \wedge \forall y[Bx \rightarrow Lxy]]$

Fodor and Sag (1982) attempted to explain arbitrarily wide scope phenomena of indefinites and island insensitivity, classifying them into the two groups, quantificational indefinites, as illustrated in (2a) and referential indefinites, as in (2b). This dichotomy of indefinites was refuted by many researchers who cite a sentence like (3) as a counter example.

(3) Every professor rewarded every student that read some book on his reading list. (Abusch, 1993)

Sentence (3) allows the intermediate scope reading, meaning that, for every professor $x$, there is a certain book $y$ such that for every student $z$, $x$ rewarded $z$ who read $y$ on $x$'s reading list, in which $some\ book$ takes scope over the preceding universally quantified expression $every\ student$ in the matrix clause but still co-varies along with the choice of professor.

Recently, a new approach has been proposed to deal with the (unboundedly) wide scope phenomena of indefinites by Kratzer (1998), Reinhart (1997), Winter (1997), Chierchia (2001), among others. The object $girl$ in (1a) can be taken to be a choice function, which picks out a witness to the existential quantifier which satisfies the formula. Following Meyer Viol *et al.* (1999), Kempson *et al.* (2001), Cann *et al.* (2005), von Heusinger (2000), Peregrin and von Heusinger (2004), we adopt the $\epsilon$-notation as its syntactic counterpart, originally proposed by David Hilbert in the early 20th century. Different from the existential quantifier which denotes a function from sets (or relations) to truth values, the epsilon operator is a term constructor. Since the epsilon operator is interpreted by a choice function, it assigns one of its elements to a non-empty set $s$. Observe (4) as an example.

(4) Uma -ga kusa -o tabe-te -iru.
horse SB grass OB eat -PROG -PRES
"A horse is eating (or horses are eating) grass."

(4) is true if and only if there is at least one entity belonging to the set of horses, and it is eating grass. $Uma$ in (4) can be expressed as an $\epsilon$-term as $\epsilon x(Horse(x)$ & $Eat(grass)(x))$. The predicate logic with the epsilon calculus allows the conversion as seen in (5).

(5) $P(\epsilon y(P(y)) \leftrightarrow \exists y[P(y)]$

So we can get the existential formula $\exists x[Horse(x)$ & $Eat\text{-}grass(x)]$ via conversion (5) from Eating-grass($\epsilon x(Horse(x)$ & $Eating(grass)(x)$)).

In addition to this version of the choice function theory, we appeal to the concept of Skolemization here. Suppose that we have the prenex normal form (6a) and (6b) from interpretation (2a) and (2b), respectively.

(6) a. $\forall x \exists y[(Bx \wedge Gy \wedge Lxy) \vee (\neg Bx \wedge Gy \wedge Lxy) \ldots \vee (\neg Bx \wedge \neg Gy \wedge \neg Lxy)]$

b. $\exists x \forall y[(Bx \wedge Gy \wedge Lxy) \vee (\neg Bx \wedge Gy \wedge Lxy) \ldots \vee (\neg Bx \wedge \neg Gy \wedge \neg Lxy)]$

We can eliminate the existential quantifier from the formulae in (6) via replacing the variables bound by the existential quantifier with a new function symbol $f$ in (6a) or with a Skolem constant in (6b). The Skolemized formulae obtained from (6a) and (6b) are (7a) and (7b), respectively:

(7) a. $\forall x[Bx \wedge G(fx) \wedge L(x,fx)) \vee (\neg Bx \wedge G(fx) \wedge Lx(x,fx)) \ldots (\neg Bx \wedge \neg G(fx) \wedge \neg Lx(x,fx))]$

b. $\forall x[Bx \wedge G(a) \wedge L(x,a)) \vee (\neg Bx \wedge G(a) \wedge Lx(x,a)) \vee (\neg Bx \wedge \neg G(a) \wedge \neg Lx(x,a))]$

Then, in the Skolemized formula in (7a), the variables bound by the existential quantifier in (6a) get dependent on those bound by the universal quantifier (i.e., Skolemized functions), while the variables bound by the existential quantifier in (6b) are interpreted as a (Skolem) constant, denoting some unique individual satisfying the whole formula.

Now, we are ready to give a unified account for Japanese indefinites, with the notion of "Skolemized choice function" in the sense of Chierchia (2001).

## 3 Indefinite with Underspecifie Scope

The Japanese data we will examine here are illustrated as in (8):

(8) a. Dono seito mo inu o sewa -shiteir -u.
every pupil SB a dog OB care-for -PROG -PRES
"Every pupil takes care of a dog"

b. Hotondo-no Kyōju ga dono gakusei-mo aru ronbun-o yomuyouni-itta.
most professor SB every student a certain paper OB tell-to-read -PAST
"Most professors told every student to read a certain paper."

c. Dono juumin mo omaturi ni kodomo o turete-kita.
every resident SB festival NI child OB take PAST
"Every resident took his or her child to the festival."

(8a) is ambiguous between subject and object wide scope readings (though the preferred interpretation is that $every\ pupil$ has scope over $a\ dog$, it is possible to imagine a situation something like pupils keeping and taking care of one dog at school etc.). In (8b), $a\ certain$ must take a wide scope with respect to $every\ student$, but its value can still co-vary with the choice of $professor$. The choice of the referent of $child$ in (8c) must be dependent on the particular choice of a referent of $resident$ and the inverse scope interpretation is impossible.

One of advantages of using $\epsilon$-terms is that quantified terms can be dealt with as individual denoting expressions, not as generalized quantifiers, and that we can eliminate existential quantifiers from formulae. Suppose that we want to derive the two different interpretations for sentence (1a) or (8a) from a single formula with the $\epsilon$-term. Kempson *et al.*/Cann *et al.*/von Heusinger propose to remove a predicate corresponding to a nuclear scope from a $\epsilon$-term, and let it denote a choice function picking out a witness from the denotation of the restrictor (referred to by the common noun), and the scope determination can be delayed to allow for scope inversion. So, if our initial $\epsilon$-term translation for (8a) is something like $\epsilon y(Pupil(y))$, formula (9) is obtained:

(9) $\forall x[Pupil(x) \rightarrow Take\text{-}care(x, \epsilon y(Dog(y)))]$

Notice that the $\epsilon$-term in (9) is underspecified with respect to scope choice because scope is finally determined pragmatically. Following Kempson *et al.* (2001) and Cann *et al.* (2005), we assume that final scope determination requires two elements: formulae with epsilon terms like (9) and scope statements in the form of $Scope(S{<}x{<}y)$, where S is interpreted as some temporal index. In other words, the scope interaction is defined from the pair $\langle$scope statement, formula with an $\epsilon$-term (or $\epsilon$-terms)$\rangle$. An $\epsilon$-formula with a specified scope relation, which can be translated into a regular formula via SCOPE EVALUATION rule in (10) (modified from the one in Kempson *et al.* (2001)):

(10) $$\frac{Scope(S{<}x{<}\ldots) : \psi[\epsilon x(\phi))]}{\exists x[\psi x \;\&\; \phi x]}$$

Suppose that the scope statement for (6a) with the narrow scope existential quantifier is $Scope(S{<}x{<}y)$, while the one for (6b) with the wide scope existential quantifier is $Scope(S{<}y{<}x)$. The Scope Evaluation rule converts the common formula ($\forall x[Pupil(x) \rightarrow Take\text{-}care(x,\epsilon y(Dog(y)))]$) of sentence (8a) to (11a) and (11b) according to their scope statements, which in turn should be translated to Skolem Normal Forms in (12a) and (12b) respectively.

(11) a. $\forall x[Pupil(x) \rightarrow \exists y[Dog(y) \wedge Take\text{-}care(x, y)]]$

b. $\exists y[Dog(y) \wedge \forall x[Pupil(x) \rightarrow Take\text{-}care(x, y)]]$

(12) a. $\forall x((P(x)\wedge D(fx)\wedge T\text{-}C(x, fx))\vee(\neg P(x)\wedge D(fx)\wedge T\text{-}C(x, fx))\vee(\neg P(x)\wedge D(fx)\wedge \neg T\text{-}C(x, fx))\vee(\neg P(x)\wedge\neg D(fx)\wedge T\text{-}C(x, fx))\vee(\neg P(x)\wedge\neg D(fx)\wedge\neg T\text{-}C(x, fx)))$

b. $\forall x((P(x)\wedge D(a)\wedge T\text{-}C(x,a))\vee(\neg P(x)\wedge D(a)\wedge T\text{-}C(x,a))\vee(\neg P(x)\wedge D(a)\wedge\neg T\text{-}C(x,a)))$

As we showed above, our approach to indefinites as $\epsilon$-terms allows us to derive unique formulae with a $\epsilon$-term/terms (with relative scope underspecified) from a sentence with multiple quantified expressions, and then, to translate it into multiple logical formulae only after the Scope Evaluation rule processes the $\epsilon$-formulae and the scope statement.

## 4 Scope Interpretation of *Certain* Ns form and Relational Nouns

### 4.1 Incremental Parsing based on Dynamic Syntax

At first glance, it appears that NPs of *a certain* + N form simply take the widest scope, yielding referential interpretations, but, as seen from (3) and (8b), the referents of *a certain* + N form can vary according to the choice of the value of higher quantifiers. They should also be taken to be choice functions with the existential presupposition of their referents. Let us assume that the scope properties should be partially defined in the lexical entry of *certain*, while partially determined contextually (i.e., with respect to the choice of wide or intermediate scope readings).

We adopt a version of Dynamic Syntax (Kempson *et al.*, 2001; Cann *et al.*, 2005) as the framework in order to implement the scope interaction of *a certain*. Dynamic Syntax is a framework which allows the parser to process each word in an incremental fashion, yielding semantic representation. The tree structure is built up or *grows* as the parsing proceeds from left to right, step by step. Meta-variables, for example $U$ or $V$, are introduced by the lexical specifications and used to *merge* variables or tree structures. Tree growth is driven by the application of lexical specifications and transition rules. The initial state of parsing is defined as (13) with the type information

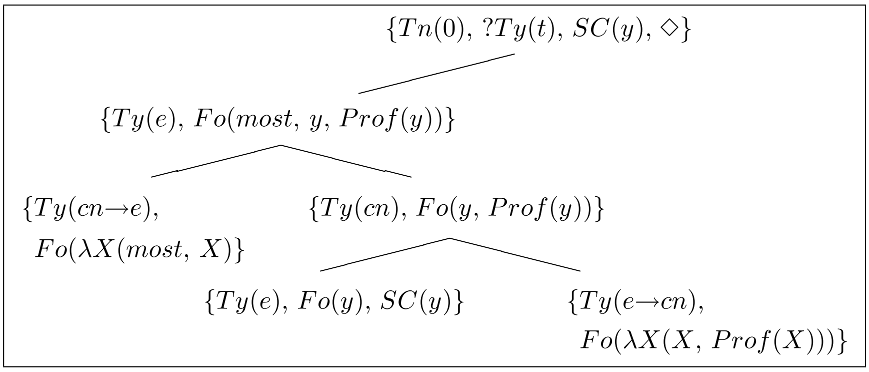


**Figure 1:** Tree Structure after Scanning *hotondo-no kyōju ga*

$Ty(t)$, tree address $Tn(n)$ and the pointer $\diamond$ indicating a node where transition rules and lexical specifications are applied.

(13) $\{?Ty(t), ?Tn(n), \diamond\}$

The prefixed '?' is called a *requirement*. Requirements indicate that the prefixed information needs to be satisfied some time before the end of parsing has finished, so $?Ty(t)$ of the initial state in (13) means that the strings that a parser will scan are supposed to be a sentence of type $t$.

Let us describe how the scope interaction in (8b), which is repeated here as (14) for convenience, is implemented on the basis of Dynamic Syntax, starting from the initial state (13).

(14) Hotondo-no Kyōju ga dono gakusei-mo aru ronbun-o yomuyouni-itta.
most professor SB every student a certain paper OB tell-to-read -PAST
"Most professors told every student to read a certain paper."

In head-final languages like Japanese, parsing is driven mainly by scanning each word, i.e., the tree structure is expanded by the application of information of lexical items, whereas new nodes are introduced by transition rules in head-initial languages such as English. After scanning the initial NP *hotondo-no kyōju ga* 'Most professors', the tree structure is transferred from (13) to Figure 1. As seen in Figure 1 the NP *hotondo-no kyōju ga* has its internal structure and the NP's top node, unlike generalized quantifiers, is decorated by the type $e$. The NP also has the annotation of the scope statement $SC(y)$ and the scope statement is moved up to the root node of type $t$ by the application of one of the transition rules, the COMPLETION rule. In this paper we define the lexical item of *aru* 'a cerntain' as (15)

(15) IF $\{?Ty(e)\}$
THEN make($\langle\downarrow_1\rangle$); go($\langle\downarrow_1\rangle$); put($Ty(cn\rightarrow e)$, $Fo(\lambda X.\ (\epsilon, X))$); go($\langle\uparrow_1\rangle$);
make($\langle\downarrow_0\rangle$); go($\langle\downarrow_0\rangle$); put($Ty(cn)$);
make($\langle\downarrow_0\rangle$); go($\langle\downarrow_0\rangle$); put($Ty(e)$); freshput($Fo(x)$, $SC(x < U)$); go($\langle\uparrow_0\rangle$)
ELSE ABORT

As seen in (15) the lexical item takes the form of a rule IF . . . THEN . . . ELSE . . .. The operation 'make($\langle\downarrow_1\rangle$)' introduces a functor daughter node to the pointed node whereas 'make($\langle\downarrow_0\rangle$)' makes an argument daughter node. The operation 'go($\langle\downarrow_1\rangle$)' moves the pointer to the functor argument node. What (15) means is that if the node with the pointer is of type $e$, it expands the tree structure and introduces type information and the scope statement. In (15) the scope statement is $SC(x < U)$, which means that the variable $x$ takes scope over the meta-variable $U$ unifying another variable or other scope statement.

In addition to the lexical specification in (15), we need COMPLETION rules to excute $\beta$-reduction and cull logical formula from its daughter nodes. We propose the following COM-

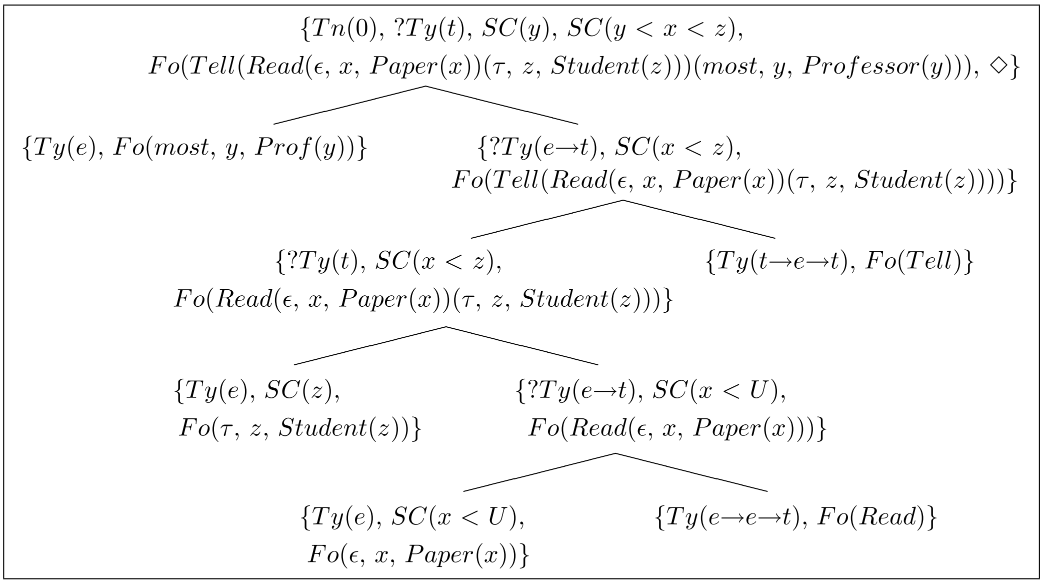


**Figure 2:** Intermediate Reading of $aru\ ronbun$ (14)

PLETION rule 1 in (16) for the node without meta-variables and COMPLETION rule 2 for that of with Meta-variables in the scope statement in (17).

(16) $$\frac{\{\ \ldots \{?Ty(Y),\ \langle\downarrow_0\rangle Fo(Q),\ \langle\downarrow_0\rangle Ty(X),\ \langle\downarrow_1\rangle Fo(P),\ \langle\downarrow_1\rangle Ty(X\rightarrow Y),\ \langle\downarrow_0\rangle SC(z),\ \langle\downarrow_1\rangle SC(x),\ \ldots,\ \Diamond\}\ \ldots\ \}}{\{\ \ldots \{Ty(Y),\ \langle\downarrow_0\rangle Fo(Q),\ \langle\downarrow_0\rangle Ty(X),\ \langle\downarrow_1\rangle Fo(P),\ \langle\downarrow_1\rangle Ty(X\rightarrow Y),\ \langle\downarrow_0\rangle SC(z),\ \langle\downarrow_1\rangle SC(x),\ Fo(P(Q)),\ SC(z < x),\ \Diamond\}\ \ldots\ \}}$$

(17) $$\frac{\{\ \ldots \{?Ty(Y),\ \langle\downarrow_0\rangle Fo(Q),\ \langle\downarrow_0\rangle Ty(X),\ \langle\downarrow_1\rangle Fo(P),\ \langle\downarrow_1\rangle Ty(X\rightarrow Y),\ \langle\downarrow_0\rangle SC(z),\ \langle\downarrow_1\rangle ?SC(x < U),\ \Diamond\}\ \ldots\ \}}{\{\ \ldots \{Ty(Y),\ \langle\downarrow_0\rangle Fo(Q),\ \langle\downarrow_0\rangle Ty(X),\ \langle\downarrow_1\rangle Fo(P),\ \langle\downarrow_1\rangle Ty(X\rightarrow Y),\ \langle\downarrow_0\rangle SC(z),\ \langle\downarrow_1\rangle SC(x < U),\ Fo(P(Q)),\ SC(x < z) \vee (SC(z),\ ?SC(x < U)),\ \Diamond\}\ \ldots\ \}}$$

$\langle\downarrow_0\rangle Ty(X)$ means that the argument daughter node is of type $X$ and $\langle\downarrow_1\rangle Ty(X\rightarrow Y)$ means that the functor daughter is of type $X\rightarrow Y$. As seen in (16) and (17) application of COMPLETION excutes $\beta$-reduction, adding type and semantic representations to the mother node. We stipulate that in (16) the scope statement is fixed in a way sensitive to linearity: our framework allows a higher NP to have wider scope relative to lower NPs as the initial setting. By contrast the indefinite in (14) can enjoy the widest scope and intermediate scope where its value depends on the left-peripheral NP. This scope interaction can be realized simply by assuming a meta-variable seen in (17): according to (17) the variable $x$ referring to $aru\ ronbun$ 'a certain paper' in (14) can take scope over the variable referring to $dono\ gakusei$ 'every students' at the type $t$ node of the embedded clause by unification or its scope statement can be underspecified and passed up to the root node, which yields the intermediate scope reading and the widest scope reading of $aru\ ronbun$ 'a certain paper'. The lexical specification of $aru$ 'a certain' in (15) and the COMPLETION rules in (16) and (17) give rise to the following two readings (18a) and (18b) and their corresponding tree structures are Figure 2 and Figure 3 respectively.

(18) a. $SC(y{<}S{<}x{<}z)$:
$Tell(Read(\epsilon,\ x,\ Paper(x))(\tau,\ z,\ Student(z)))(most,\ y,\ Professor(y))$

b. $SC(x{<}S{<}y{<}z)$:
$Tell(Read(\epsilon,\ x,\ Paper(x))(\tau,\ z,\ Student(z)))(most,\ y,\ Professor(y))$

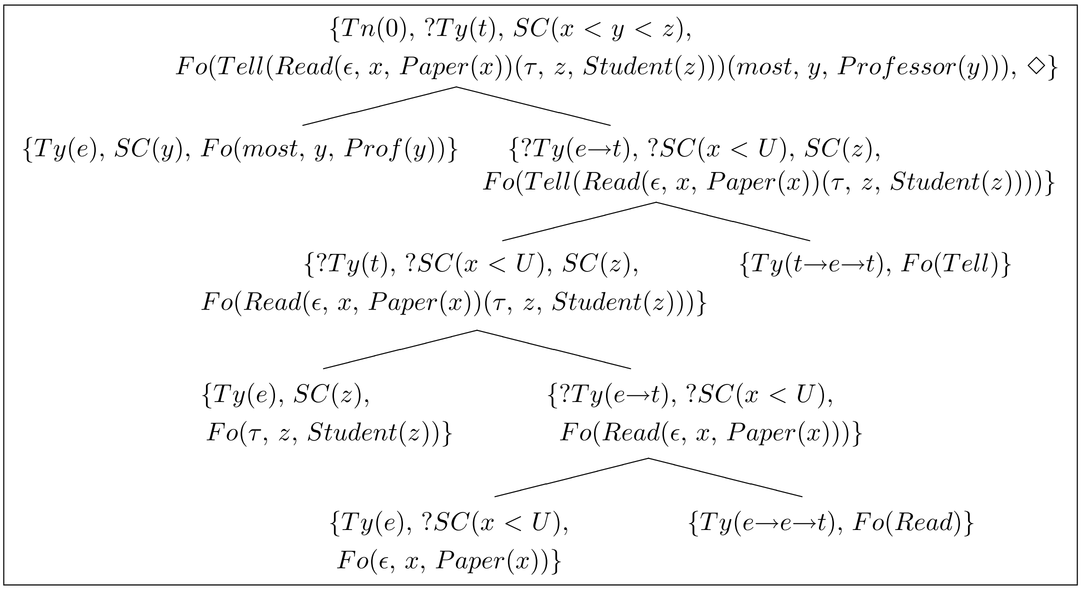


**Figure 3:** The Widest Scope Reading of $aru\ ronbun$ (14)

(18a) should be translated to (19a) and (18b) should be translated to (19b) respectively by applying the SCOPE EVALUATION rule.

(19) a. $Most\_y[Professor(y) \rightarrow \exists x[Paper(x) \wedge \forall z[Student(z) \rightarrow Read(x)(z)]]]$

b. $\exists x[Paper(x) \wedge Most\_y[Professor(y) \rightarrow \forall z[Student(z) \rightarrow Read(x)(z)]]]$

The scope statements specifies that the referents of $a\ certain$ + N must not be referentially dependent on the values of variables bound by the (most) local universal (or other existential) quantifiers, but it does not prohibit its value from co-varying along with the choice of the referents bound by the highest quantifiers. Note here that, though the scope statement is pragmatically fixed at the last stage of a derivation of a clause, as we stated in Section 3, some part is lexically determined, and inherited from the word or complex expression to the larger constituent. The quantifier evaluation rule in (10) will yield the interpretations in which the value of a paper depends on the choice of professors, or refers to some unique paper, understood according to context, depending on where the closure operation of the choice function applies. Then we have the prenex normal forms (20a) and (20b) from interpretation (19a) and (19b) respectively.

(20) a. $Most\_y\exists x\forall z[(Prof(y)\wedge Paper(x)\wedge St(z)\wedge Read(x,z))\vee(Prof(y)\wedge Paper(x)\wedge\neg St(z) \wedge\neg Read(x,z))\vee \ldots \vee(\neg Prof(y)\wedge\neg Paper(x)\wedge St(z)\wedge Read(x,z))]$

b. $\exists x Most\_y\forall z[(Paper(x)\wedge Prof(y)\wedge St(z)\wedge Read(x, z))\vee(Paper(x)\wedge Prof(y)\wedge\neg St(z) \wedge Read(x, z))\vee \ldots \vee(Paper(x)\wedge\neg Prof(y)\wedge\neg St(z)\wedge\neg Read(x, z))]$

Now we are ready to get the Skolemized formulae (21a) and (21b) from (20a) and (20b) respectively. In (21b) $a$ is a Skolem constant.

(21) a. $Most\_y\forall z[(Prof(y)\wedge Paper(fy)\wedge St(z)\wedge Read(fy,z))\vee(Prof(y)\wedge Paper(fy)\wedge\neg St(z) \wedge\neg Read(fy,z))\vee \ldots \vee(\neg Prof(y)\wedge\neg Paper(fy)\wedge St(z)\wedge Read(fy,z))]$

b. $Most\_y\forall z[(Paper(a)\wedge Prof(y)\wedge St(z)\wedge Read(a, z))\vee(Paper(a)\wedge Prof(y)\wedge\neg St(z) \wedge Read(a, z))\vee \ldots \vee(Paper(a)\wedge\neg Prof(y)\wedge\neg St(z)\wedge\neg Read(a, z))]$

As seen in (21) the widest scope interpretation of $aru\ ronbun$ 'a certain paper' and intermediate scope interpretation can be derived.

## 4.2 Relational Nouns

Let us turn to sentence (8c) with the relational noun $kodomo$. In contrast to the interpretation of $a\ certain$ + N form, the scope of relational indefinites has a strong tendency to depend on other quantifiers, irrespective of their positions in a sentence.

(22) a. A guard is standing in front of every building. ($\forall >\exists$, $*\exists > \forall$)

b. Every building has a guard standing in front of it. ($\forall > \exists$, $*\exists > \forall$) (Winter 2001)

Due to the conflict in scope choice, relational nouns do not comfortably co-occur with $a\ certain$, as in $*?A\ certain\ guard\ is\ standing\ in\ front\ of\ every\ building.$ / $?*Every\ building\ has\ a\ certain\ guard\ in\ front\ of\ it.$ We have to reflect this property scope dependency in the lexical definition of $\epsilon$-terms for relational nouns. A proper form of an $\epsilon$-term for child should be something like (23), which requires the $\epsilon$-term to be an inherent Skolem function.

(23) $Scope(\ S < y < \ldots < x) : \epsilon x(Child\text{-}of(x)(y))$

It should be noted in (23) that the free variable $y$ is introduced into the $\epsilon$-term, which needs to get bound somewhere in the course of derivation, and the scope statement requires its scope to be (most) locally defined. The logical form for (8c) is shown in (24a), which must be converted to the Skolem normal form in (24b):

(24) a. $Scope(S{<}y{<}x) : \forall y[Employee(y) \rightarrow Take(\epsilon x(Child\text{-}of(x)(y))(To\text{-}Festival)(y))]$

b. $\forall y[Employee(y) \rightarrow \exists x(Child\text{-}of(x)(y) \wedge Bring(x)(To\text{-}Festival)(y)]]$

c. $\forall x[(Emp(x) \wedge Bring(x,f(x), \wedge \ldots) \vee (\neg Emp(x) \wedge \ldots) \vee \ldots]$

The variable introduced into the $\epsilon$-terms of relational nouns as their lexical property must always be present within the terms, which prohibits the computation from replacing the variables bound by their corresponding existential quantifiers with a Skolem constant (otherwise, referential interpretations should be given to relational nouns). In the case of $a\ certain$ + N form, the wider scope requirement is expressed in the scope statement of the modifier $certain$ (or the complex form of $a\ certain$). However the narrow(est) scope requirement is defined in the lexical entries of the head Ns (relational nouns). Thus the free variable, which should be bound by higher quantified phrases which the relational nouns scopally depend on, must be present throughout the interpretation process. This motivates our claim that relational nouns should be analyzed as inherent Skolem functions.

# 5 Conclusion

We have examined three kinds of indefinites in Japanese, and represented them as $\epsilon$-terms. Since these indefinites show diverse behaviors with respect to scope taking, it appears almost impossible to give a unified account of them. Though the standard scope inversion cases, as illustrated in (1a) and (8a), can be dealt with by any of the theories proposed so far, the same analysis cannot be extended to indefinites of the form $a\ certain$ + N, or those projected from relational nouns. If we try to take all the indefinites dealt with in this study simply as existential quantifiers, the resulting grammar must become highly context dependent to deal with the scope of $a\ certain$ + N forms. It also looks somewhat difficult to extend the simple GQ definition to indefinites with relational nouns.

Following many researchers arguing for the choice function analysis of indefinites, such as Reinhart, Winter, Kratzer, Kempson, Meyor-Viol, and von Heusinger, we have proposed a unified account in which all indefinites are regarded as choice functions, which are formulated as $\epsilon$-terms, which have initially unscoped or partially scoped representations (Meyer Viol *et al.*, 1999). The $\epsilon$-calculus approach enables us to deal with indefinites simply as terms (as individual denoting expressions of type $e$), and we have shown that an approach based on Dynamic Syntax helps us parse sentences reflecting the scope property of $aru$ + N 'a certain' N, following the principle of strong compositionality. The formulae with the $\epsilon$-operator can be converted to standard normal forms with multiple quantifiers.

We have introduced scope statements into our definition of indefinite terms to allow indefinites to take various relative scopes according to context. In this paper, some portion of scope statements should be underspecified to accommodate contextual information in scope determination (especially with respect to standard indefinites showing scope alternation) with the help of meta-variables in Dynamic Syntax. As a lexical property of $certain$, $a\ certain$ + N form cannot take a narrow/local scope, but still it needs to be flexible so as to be scopally dependent on other higher terms). On the other hand, relational nouns must be defined as Skolem terms from the beginning (defined in the $\epsilon$-terms). As a consequence, the corresponding $\epsilon$-terms contain free variables inside the terms, which cannot disappear throughout the interpretation process. This formulation of $\epsilon$-terms assures that they can never get referential interpretation in any context.

## References


Abusch, D. 1993. The Scope of Indefinites. *Natural Language Semantics*, 2, 83-135.

Cann, R., R. Kempson and L. Marten. 2005. *The Dynamics of Language: An Introduction*. Academic Publishers: Elsevier.

Chierchia, G. 2001. A Puzzle about Indefinites. In C. Ceccetto *et al.*,eds., *Semantic Interfaces*, CSLI Publications, 51-89.

Fodor, J. D. and I. Sag. 1982. Referential and Quantificational Indefinites. *Linguistics and Philosophy*, 5, 355-398.

Kamp, H. and U. Reyle. 1993. *From Discourse to the Lexicon: Introduction to Modeltheoretic Semantics of Natural Language, Formal Logic and Discourse Representation Theory*. Kluwer Academic Publishers.

Kempson, R., W. Meyer Viol and D. Gabbay. 2001. *Dynamic Syntax: The Flow of Language Understanding*. Blackwell Publishers.

Kratzer, A. 1998. Scope or Pseudoscope? Are There Wide Scope Indefinites? In S. Rothstein, ed., *Events in Grammar*, Dordrech: Kluwer, 136-196.

Meyer Viol, W., R. Kempson, R. Kibble and D. Gabbay. 1999. Indefinites as Epsilon Terms: A Labelled Dudection Account. In H. Bunt and R. Muskens, eds., *Computing Meaning, Vol. 1*, Kluwer, 203-218.

Peregrin, J. and K. von Heusinger. 2004. Dynamic Semantics with Choice Functions. In H. Kamp and B. Partee, eds., *Context Dependence in the Analysis of Linguistic Meaning*, Elsevier, 255-274.

Reinhart, T. 1997. Quantifier scope: how labor is divided between QR and choice functions. *Linguistics and Philosophy*, 20, 335-397.

von Heusinger, K. 2000. The Reference of Indefinites. In K. von Heusinger and U. Egli, eds., *Reference and Anaphoric Relations*, Dordrech: Kluwer, 247-265.

Winter, Y. 1997. Choice Functions and the Scopal Semantics of Indefinites. *Linguistics and Philosophy*, 20, 399-467.