Semantics for Specific Indefinites

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Yeom, Jae-Il. 1997. **Semantics for Specificity**. *Language and Information.* There has been no unanimous analysis of specific indefinites. It is still disputed even whether specificity is a matter of semantics or pragmatics. In this paper, I introduce some properties of specific indefinites, and explain them based on the meaning of specificity. Specificity intuitively means that the speaker or someone else in the context has some individual in mind, which is generally accepted among linguists. The main issue is how to represent the meaning of 'have-in-mind'. I review some philosophical discussions of cognitive contact and show that when the use of an expression involves 'have-in-mind', the expression is a rigid designator in the belief of the agent who has an individual in mind. In the use of a specific indefinite, this applies only to the information state of the agent of 'have-in-mind'. To represent this asymmetry, I propose a new theory of dynamic semantics, in which a common ground consists of multiple information states, as many as the number of the participants in a conversation. Moreover, each information state is structured as a set of epistemic alternatives, which is a set of possible information states of a participant in the context. Based on this semantics, the properties of specific indefinites are explained. (**Yonsei University**)

1. Introduction

There has been no agreement in formal analyses of specific indefinites, but the analyses tried to capture the intuition that when a speaker uses a specific indefinite, the speaker or someone else in the context has some individual in mind. I will express

the intuition by the relation of a person "having **cognitive contact** (= **cogtac**) with" an individual. What does this mean? Consider the following sentence:

(1) A student of mine died last night.

When a speaker uses the indefinite in the specific reading, he or she has some student, say, John, in mind, and thus has a singular proposition that John died last night. Yet when he utters the sentence, the audience cannot identify John, and thus they understand the sentence as meaning that there is a student of mine that died last night, instead of meaning that John died last night. Then one question is whether it is part of the proposition that the speaker has some student in mind. It is a question difficult to answer when there is no overt marker of specificity in the sentence. Even in cases where specificity is marked with an expression like *a certain*, it is still arguable that specificity is semantic. In this paper, I am going to show that specific indefinites are different from nonspecific indefinites in some respects, but it is not an issue whether they are semantically different.[1] I deal with specific indefinites within a framework of information theory, and the distinction between semantics and pragmatics is not necessary. The main purpose of this paper is to represent the information that someone has an individual in mind in an information theory.

One of the difficulties in studying specific indefinites is that they are not distinguished from nonspecific ones in their forms,

[1]Ludlow and Neale (1991) tried to refute the idea that specific and nonspecific indefinites are semantically different, but I do not think they succeeded. Thus they advocate pragmatic analysis of specific indefinites by resorting to a weak argument: the Kripkean methodological considerations. See Kripke (1977).

and that it is difficult to see whether or not some properties of indefinites are attributed to specificity. To avoid this, I will only deal with indefinites with the expression *a certain*. When specificity is expressed explicitly, it must be part of the content conveyed by the utterance that the speaker or someone else has an individual in mind. The standard dynamic semantics, in which there is one information state in the common ground, is not adequate for representing specificity. Consequently, I propose a new dynamic semantics in which a common ground consists of multiple information states, each of which is mapped to a participant in the conversation. Moreover, each information state is required to consist of a set of smaller information states, which I will call **epistemic alternatives**. The new semantics seems complex, but it is necessary to represent specificity. Specificity gives rise to asymmetric information states between speakers and audiences, and complexity allows for sufficient expressive power for the representation of specificity.

In analyzing specific indefinites, we need to distinguish two subcases for expository purpose.[2]

One is the case where the speaker has cogtac with an individual, which is illustrated in (1). The other is the one in which someone other than the speaker does. A traditional view of specificity has focused on the first case, but it has nothing to say

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[2]A specific indefinite can be used when a person has cogtac with a relation, which was discussed in Hintikka (1986). This is illustrated in the following:

(i) Every true Englishman adores a certain woman - his mother.

This sentence can be uttered in the situation in which the speaker does not know who the women are and who the true Englishmen are. The speaker has in mind a relation between the two sets of individuals, that is, 'mother-of'. I will ignore this case.

about some uses of specific indefinites. Let's consider one example of such a case.

(2) There is a (certain) dragon which Alberta believes ate her petunias.

In making this statement, the speaker does not believe that there is a dragon, nor does he have cogtac with any dragon. Only Alberta has cogtac with a dragon, which Alberta believes ate her petunias. This can be dealt with only when we allow for specific indefinites when someone other than the speaker has cogtac with an individual. I will discuss cases where a speaker has cogtac first, and the application of the analysis will be extended to the other cases.

Before I discuss the formal analysis of specificity, I will briefly sketch the overall analysis. I claim that cogtac is the core meaning of specificity. It has been discussed by the name of 'acquaintance relation'. I will briefly review some philosophical discussions of the relation. It will become clear that 'A having cogtac with C in using a specific indefinite α' implies that C is a rigid reference of α in A's information state. If this is the right analysis of specificity, it will cause problems in representing specificity in traditional dynamic semantics. In order to avoid these problems, I propose multiple information states in common grounds, and propose to partition the information states of the agents who have cogtac with individuals into epistalts so that the specific indefinites in question can be rigid designators in each of the epistalts. This will lead us to a new dynamic semantics which is partially representational and partially denotational.

2. Properties of Specific Indefinites

I claimed that using a specific indefinite implies that the speaker has cogtac with an individual. This must be observed empirically. When a speaker uses a specific indefinite, he has knowledge of 'knowing *who*' in the sense of Boër and Lycan (1986). Consider the following examples:

(3) A: A certain student of mine was called before the dean.
B: Who was it?
A: Bill/??I don't know.
(4) A: A student of mine was called before the dean.
B: Who was it?
A: Bill/I don't know.

These two examples are a minimal pair with regard to specificity. In the first example, where speaker A used a specific indefinite, it is odd for A not to know who the student was. This is contrasted with the second example, where the speaker used a nonspecific indefinite. In using a nonspecific indefinite, the speaker is not required to know who the student was.

There is other indirect evidence for taking specificity as having cogtac with an individual. The following two sentences are different in acceptability.

(5) (a) ??A certain gentleman does not exist.
(b) A certain particle that many physicists took for granted turned out not to exist after all.

This can be easily accounted for when considering who has

cogtac with objects. In (5a), the speaker has cogtac with a gentleman, and thus at least assumes that there is a gentleman he has in mind. Thus the sentence becomes awkward when the speaker is contradicting himself by denying the existence of the gentleman. In (5b), on the other hand, those who assume the existence of the particle are other than the speaker, and it is not contradictory for the speaker to deny its existence. Who has cogtac with an object affects the acceptability of a sentence, which can be indirect evidence for analyzing specificity as conveying the information that someone has cogtac with an individual.

Second, specific indefinites do not have scalar implicatures, which are generally observed in sentences with nonspecific indefinites.

(6) A dog is barking.
(7) A certain dog is barking.

In uttering the sentence in (6), there is a scalar implicature that only one dog is barking, as far as the speaker knows. There is no such implicature in uttering (7). Even if the speaker knows that more than one dog is barking, he does not care about dogs other than the one he has in mind. This difference must follow from our analysis of specific indefinites.

Third, specific indefinites are different than nonspecific indefinites with respect to anaphora. A nonspecific indefinite in a desire context is not accessible from the main context or a belief context:

(8) John wants to have a Porsche. ?? He believes his mother will buy it for him.

The indefinite *a Porsche*, which occurs in John's desire context, is not accessible to the pronoun *it*, which occurs in John's belief context. Compare this with the following example:

(9) John wants to catch a certain monster. He believes it will show up soon. Of course, it is a figment of his imagination.

The specific indefinite *a certain monster* stays within John's desire context, but it is referred to from his belief context, and even from the main context.

Now we need to see an example in which a specific indefinite occurs in a belief context. In general, if a nonspecific indefinite occurs in a belief context, it is not accessible to a main context pronoun. But it is not clearly observed in an actual example since an indefinite in a belief context is automatically construed as a specific one when a pronoun is used to refer to it from the main context, as seen in (10a). To avoid this unwanted effect, we may use an expression like *at least one*, as in (10b), in which case the indefinite is not referred to from the main context.

(10) a. John believes that he saw a unicorn. It is a figment of his imagination.
b. John believes that he saw at least one unicorn. *It is a figment of his imagination.

When the indefinite in (10a) is forced to be construed as nonspecific, the use of the pronoun is not quite natural. A specific indefinite behaves differently:

(11) John believes that he saw a certain unicorn. It is a figment of his imagination.

John has a certain unicorn in mind, and the pronoun refers to it quite naturally. This does not mean that the indefinite has wide scope over the belief operator since the speaker does not believe that the unicorn actually exists. A question arises how the specific indefinite is accessible to the pronoun in the main context even when it stays within the scope of the belief context. This is a question to which my analysis must give an answer.

Among the three properties, I assume the first to be the basic one, and will account for the other two properties based on it. That is, the only difference of specific indefinites from nonspecific ones is the information that the speaker has cogtac with an individual. I assume that a specific indefinite has the following translation in dynamic predicate logic:

(12) (i) a certain $\alpha_{<i,j>}$

(ii) $\exists_j\alpha'(j) \wedge$ hccw(i,j), where 'hccw' stands for 'have cogtac with'.[3]

This indicates that a specific indefinite has two indices in the syntax. We do not assume that there is a special existential quantifier for specific indefinites, but that the existential quantifier is interpreted just like the one introduced by a nonspecific indefinite.

[3]My representation of predicate logic formulae is different from the convention of the authentic predicate logic in that discourse referents are used in place of variables.

3. Motivations for Structuring Information States

I am going to show in this section that the standard dynamic semantics, in which a common ground is represented as a single information state, cannot deal with specific indefinites. In dynamic semantics, a sentence is construed as a common ground change potential, which is a partial function from the set of common grounds to the set of common grounds. Thus a common ground s is updated with a sentence ϕ into a new common ground s'. This is represented as follows:

(13) $s + \phi = s'$

Then the function '+' can be defined differently, depending on the type of the common ground s. In this section I will explicate why a common ground with one information state cannot represent specificity, and propose common grounds with multiple information states. Then new common grounds are of new type, and we need new semantics.

3.1. Cogtac and Rigidity of Reference

In this subsection I review philosophical studies on the semantics of the relation 'have cogtac (or be in acquaintance relation) with'. Considering these studies leads us to get the semantic implication that a specific indefinite is a rigid designator in the information state of the agent who has cogtac. This can be observed in the following examples:[4]

[4]I used the quantifier NP *only one unicorn* in order to avoid ambiguity in its scope or specificity. Indefinites are ambiguous in their scopes with respect to the

(14) a. John believes that he saw only one unicorn, but he thinks that it couldn't touch him.

b. ??John believes that he saw only one unicorn, but it does not exist.

c. John believes that he saw a certain unicorn, but it does not exist.

In the first example, the unicorn in John's belief can be referred to by a pronoun which occurs within his belief. In the second example, on the other hand, the unicorn in John's belief is not accessible to the pronoun in the main context. This is accounted for in possible world semantics by the multiplicity of unicorns in John's belief. In other words, for one possible world, which is presumed to be the actual world, there are many possible worlds which are compatible with John's belief. This set of possible worlds is understood as the representation of John's belief context. Each possible world in his belief context has a unique unicorn in order for the first conjunct in (14b) to be true, but from the perspective of the presumed actual world, there are many unicorns in John's belief context. Thus when a pronoun is used to refer to a unicorn, it is not decided which unicorn it refers to. Considering the awkwardness of the second example, the third example is surprising since the same one-to-many relation between the actual world and the possible worlds compatible with John's belief holds in this case, too. It might be thought that the indefinite in (14c) has scope over the belief operator, but this cannot be obtained since the speaker denies

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belief operator, or between specific and nonspecific readings. On the other hand, quantifiers with *only* do not have scope over the belief operator when they are used within the operator.

that the unicorn exists in the actual world. Thus the indefinite must stay within the scope of the belief operator. The only possible explanation is that there is one and the same unicorn across John's belief worlds.[5]

I am going to find support for this idea from two philosophical studies on cogtac, that is, Kaplan (1969) and Boër and Lycan (1986). Their claims are different in a few respects, but I will be concerned only with what they have in common. Kaplan (1969) discussed the topic to account for the *de re* readings of NPs which occur within the scope of the belief operator:

(15) Ralph believes that the man on the beach is a spy.

In the *de re* reading of the definite *the man on the beach*, Ralph is supposed to know who the man on the beach is. This means that in Ralph's present mental state, he can pick out one and the same individual across his belief worlds. Kaplan claims that in order to do so, Ralph must have what he calls a vivid name. In his belief, the vivid name is associated with a unique individual which it actually denotes. Kaplan claims that the vivid name must be *of* the individual that Ralph has in mind. Thus the relation of Ralph, a vivid name α, and an object x is represented as follows:

(16) α represents x to **Ralph** (symbolized: "R(α, x, **Ralph**)")
iff (i) α denotes x,

[5]It would be wrong to say 'one and the same individual' if we assume a counterpart theory. What I mean by the expression is that when an individual is cross-identified across possible worlds by stipulation, that individual is regarded as one individual. It is conceivable that people has some way of cross-identification, which is not an issue of this paper.

(ii) α is a name *of* *x* for **Ralph**, and
(iii) α is (sufficiently) vivid.

The first condition requires that the vivid name denote an actual object *x*, which is meant to exclude hallucination. The second condition implies that the vivid name must be associated with the individual *x* by some causal chain of events originating from the event of baptizing *x* with the vivid name α. The third condition means that Ralph must have *x* in mind. In other words, the definite description is associated with an actual individual *x* across Ralph's belief worlds, and Ralph has some images and properties attributed to the individual.

Boër and Lycan (1986) criticize Kaplan's claim in a couple of respects. They point out that the vividness of descriptions of an individual *x* is rather vague and too much emphasized in Kaplan (1969). They claim that the descriptions must be relativized to purposes or projects, independently of the agent of belief. Thus the agent must know of the individual what other members in the speech community know of the same individual. According to Kaplan, some vivid name is directly associated with an individual in the world. On the other hand, Boër and Lycan claim that the speaker has some expression of his language of thought, which is an individual in his mind. This individual in his mind is believed to have some properties (part of) which are shared by the speech community, on the one hand, and is associated with an object in the actual world. This implies that the individual in his mind must be a rigid designator within the agent's belief state. This idea is preliminarily represented as follows:

(17) $\exists\alpha$ [Impname(α, N, P) & $\exists\beta$[®(β, N) & K_s[β is α']]].

"Impname(α, N, P)" is read, "α is an important name of the individual N for a purpose P." You have to know that α applies to N in order to be able to say that you know who N is. "®(β,N)" means that β, which corresponds to an individual in the speaker's belief context, referentially designates N. One thing to note is that β ranges over expressions of the speaker *S*'s language of thought, which means that β depends on *S*. Thus β is a rigid designator of N "for *S*". And *S* must know that β is α.[6] This implies that when a speaker uses an expression with some individual in mind, it must be associated with that individual in his belief or information state.

So far I have shown that when a person has cogtac with an individual, an expression which is used to pick out the individual is a rigid designator in his belief or information state. Before closing this section, I must point out that the meaning of 'knowing *who*' cannot be directly applied to the semantics of specificity. In ordinary cases where an agent has cogtac with an individual, the individual must actually exist so that hallucination is excluded. However, this condition cannot be forced in the use of specific indefinites.

(18) Alberta believes that she saw a certain unicorn.

In this example, the use of the specific indefinite does not require that a unicorn exist in the actual world. Alberta is hallucinating. This shows that the use of a specific indefinite does allow hallucination.

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[6]Boër and Lycan revised the representation of the meaning of knowing *who* again, but what I want to show for my purpose from their discussion of the meaning of knowing *who* is represented enough in the representation above. I will not go into details of what they claimed.

3.2. Rigidity and Indeterminacy

In this subsection I will discuss two cases where cogtac is involved, namely the use of specific indefinites and identity statements. I will explicate why these two cases cause difficulty in updating contexts in common grounds with only one information state. When a speaker uses a specific indefinite with some individual in mind, the indefinite must be a rigid designator in the speaker's information state: the information that the speaker knows who the referent is makes the specific indefinite a rigid designator in the speaker's information state. Rigidity requires a unique value for the expression in the speaker's information state. However, the common ground is not supposed to identify the unique value yet: a specific indefinite does not tell who the referent is. Lack of such knowledge is only represented as multiple possible values for the expression in dynamic semantics. Thus the common ground must satisfy two seemingly incompatible requirements, **uniqueness for rigidity** and **multiplicity for lack of knowledge**.

Similar incompatible requirements are observed in dealing with identity statements. When a speaker uses a proper name appropriately, the speaker and the audience are supposed to know who the referent is. This means that the proper name is a rigid designator in the speaker's and the audience's information states. A problem with identity statements arises due to the fact that they contain two proper names:

(19) Cicero is Tully.

The two proper names must be metaphysically rigid in the

common ground, but then it is necessary that they refer to the same individual or that they refer to different individuals in the common ground. This implies that identity or non-identity is already established in the common ground. Thus the statement is necessarily true or necessarily false in the current information state. It is, however, well-known that identity statements are informative. This means that the statement must be true in some possible worlds, and false in others, in the common ground. Only such a statement will update the common ground non-trivially. This requires that the two names be assigned various values in the common ground so that they can refer to different individuals in some possible worlds. Due to the metaphysical rigidity of proper names, they must have unique values in the common ground, on the one hand. But due to epistemic uncertainty of the values, it must have multiple values on the other. The two seemingly incompatible requirements must be satisfied in order for a common ground to be updated with an identity statement.

To resolve this apparent incompatibility of the two requirements, I propose to structure common grounds into sub-information-states, which I call **epistemic alternatives** (= **epistalts**). An epistalt is a possible information state of an agent. If an expression has a fixed value in each epistalt in an information state, this information state indicates that it is a rigid designator in the agent's information state. That information state, however, does not tell yet which individual the expression refers to since the expression may be associated with a different individual in each epistalt. In other words, metaphysical rigidity can be expressed within each of the epistalts, and epistemic uncertainty can be represented by the multiplicity of the epistalts.[7]

[7]The notion of epistemic alternatives is not quite new. Beaver (1992) proposed

3.3. Asymmetric Information States and the Possibility Operator

I have claimed that an information state must be structured into epistalts under the assumption that a specific indefinite is a rigid designator in one agent's information state. This is not sufficient to represent specificity in the common ground. The use of a specific indefinite induces asymmetric information states. A specific indefinite conveys the information that the speaker knows who the referent is. However, the audience do not know *who*. This does not mean that the information is not shared by them. It is also part of mutual knowledge. Therefore such asymmetry must be represented in the common ground. I propose that the common ground has multiple information states, each for each participant in the conversation. When a participant uses a specific indefinite, his cogtac with an individual only structures his own information state, with others unaffected. This is supported empirically.

Suppose that A(lberta) teaches three students, st1, st2, and st3. C(hris) knows this. Alberta and Chris both know that st3 has no watch. While Alberta and Chris are talking, Davis approaches to Alberta, and starts the following dialogue:

(20) D: I found a watch on the floor in your office.
A: A student of mine was there. He might have lost it.

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the idea of epistemic alternatives in discussing the interaction of presuppositions and implicatures. I would say that the introduction of epistalts in his discussion is rather technical, as I discussed it in Yeom (1996). On the other hand, epistalts in this paper are necessary for representing information states which can be updated with specific indefinites or identity statements.

After this dialogue, Davis leaves, and Alberta and Chris resume their talk. At this point, we can derive the common ground between Alberta and Chris. Since Alberta used an indefinite which can be interpreted as nonspecific, it is possible that Alberta does not have a particular student in mind. In this situation, the student who was in Alberta's office may have been st1, st2, or st3. Of course it is also possible that the student who was in her office did not lose the watch. Thus the possibility remains that st3 was in her office and someone else lost the watch.

Let's modify the example slightly as follows:

(21) D: I found a watch on the floor in your office.
A: A certain student of mine was there. He might have lost it.

In this discourse, Alberta used the adjective *certain* indicating that she has a particular student in mind. When Chris hears Alberta utter the two sentences, he will think that the student who was in her office was not st3. If it had been st3, Alberta would not have said that he might have lost it because she knows that st3 had no watch.[8] This will be easily accounted for if we assume that Alberta's information state consists of three epistalts, in each of which st1, st2 and st3 was in her office respectively. Each epistalt is checked with regard to the

[8]Under the assumption that A knew that st3 was in A's office, it is possible that A's second sentence is interpreted as objectively describing the current information state. However, in that interpretation, A is regarded as violating the maxims of quantity and quality. In her information state, it is not possible that st3 has lost the watch. In this sense, she is violating the maxim of quality. When A only considers the present common ground, her second sentence is right, but she could have contributed more information on the basis of her own information state. Therefore she is violating the maxim of quantity.

possibility that the student lost the watch. Among the three, the epistalt in which st3 was in Alberta's office is excluded since st3 could not lose any watch. Considering these examples, we can see that the right result can follow only when Alberta's information state consists of a set of epistalts. I have already claimed for this in the previous subsection.

However, a set of epistalts is not sufficient for the semantics of specificity. Note that only Alberta has cogtac with a student and that only her information state is structured into epistalts. The audience does not have such an information state. Compare the following with the previous two examples:

(22) D: I found a watch on the floor in your office.
A: A certain student of mine was there.
C: He might have lost it.

In this example, Alberta used a specific indefinite with *certain*, as in (21). On the other hand, the sentence with the possibility operator was uttered by Chris. Even though Alberta knows who was in her office, Chris's statement does not exclude the possibility that st3 was in Alberta's office. The only difference from (21) is that the user of the possibility operator is not Alberta, but Chris. Given that the possibility operator is regarded as a test of an information state, the last sentences in (21) and (22) test different information states. This implies that Alberta's and Chris's information states were different at the point when the last sentence was uttered. We can guess that the difference came from the use of the specific indefinite. The comparison of (21) and (22) suggests that there are two different information states in the common ground. Moreover, it is implied that the

possibility operator is a dyadic operator and that one of its two arguments indicates which information state is tested by the possibility operator.

I have claimed for common grounds with multiple information states. Now each information state can be updated with the others unaffected. This allows us to represent the asymmetry of the speaker's information state and the others'. An information state can be structured into smaller epistalts leaving the others' information states unchanged. This is what we need in updating a common ground with a specific indefinite. This change requires a new information theory and new update rules.

4. An Information Theory Based on Epistalts

In the standard dynamic semantics, the meaning of a sentence is generally regarded as a function from common grounds to common grounds, and a common ground consists of one information state, regardless of how many participants there are in a conversation. I claimed that a common ground needs information states as many as the number of the participants in a conversation. Also the new theory needs to employ indices in order to indicate which information state belongs to which participant in a conversation. In this sense, the new theory is partially representational.[9]

Now let's look at the new information theory. I am assuming possible world semantics. We always have partial information

[9]The property of being partially representational is not limited to this extent. Updating an information state with someone's belief context also needs representational treatment, which will be clear in a later section.

about the actual world or the individuals in the world. We represent such a state as a set of possible worlds compatible with the partial information state. In each world, individuals are fully specified. I call them **objects**. The individuals in our information states are only partially specified, and so can be represented by sets of pairs of a possible world and an object. I call them **partial objects**, or preferably, **subjects**. To each subject is assigned a discourse referent. Based on these assumptions, we can define information states:

(23) (i) A model M is a quadruple M = <W, G, D, F>, where W is a set of possible worlds, D a domain of objects, G a set of assignment functions (or simply **sequences**) from the set of discourse referents to D, and F an interpretation function, which assigns extensions to individual constants and predicates for each world. D_w is the domain of individuals for each world. It is derived by the union of all extensions for individuals and predicates in the world w.

(ii) the set of epistalts with *n* subjects : $Pow(W \times G_n)$
(I use variables *s*, *s'*, ..., etc., for epistalts.)

(iii) the set of information states with *n* subjects:
$Pow(Pow(W \times G_n))$[10]

(iv) all information states: $U\ ^{m}_{n=1}Pow(Pow(W \times G_n))$, where *m* is the domain of D.
(I use variables *S*, *S'*, ... , etc., for information states.)

[10]An information state is represented as a set of world-sequence pairs, and an an object is assigned to a discourse referent. Then a subject can be defined from an information state.

I assume that sequences are partial functions from the domain of subjects to D. An information state is a set of epistalts, each of which is represented as a set of world-sequence pairs. As I claimed, a common ground is a set of information states, each of which is mapped to a participant in a conversation. This is also indicated with discourse referents: each participant in the conversation and corresponding information state are marked with the same discourse referent. Now a common ground can be defined as follows:

(24) $<S_i, ..., S_j>$, where S_i, ..., S_j are information states, is a common ground.

Common grounds have different types depending on the number of participants in conversations, so it is implausible to define different interpretation functions for different types of common grounds. Thus I will define updating rules with regard to information states, instead of common grounds. This allows us to maintain a consistent interpretation function $||\ \ ||$. Instead, we need a special rule for updating common grounds.

(25) $\downarrow S = s$ if $S = \{s\}$, otherwise undefined.

(26) $S||R(1, 2, ..., n)|| = \{\{wg \in t | <g(1),g(2), ..., g(n)> \in F_w(R)\} | t \in S\}$

$S||\neg\phi|| = \{t \setminus \downarrow(\{t\}||\phi||) | t \in S\}$, where "X\Y" stands for the intersection of X with the complement of Y.

$S||\exists_i\phi|| = \{\bigcup_{d \subset D}(\downarrow(\{\{wf \in t | \exists g <_i f \wedge f(i)=d \wedge d \in D_w\}||\phi||))| t \in S\}$

$S||\phi \wedge \psi|| = S||\phi||\ ||\psi||$

$S||\forall i\phi|| = S|| \neg \exists i \neg\phi||$

$S||\phi \rightarrow \psi|| = S||(\neg\phi \wedge \neg\psi)||$

(27) $\langle S_1, ..., S_n\rangle + \phi = \langle S_1||\phi||, ..., S_n||\phi||\rangle$

Updating is carried out pointwise, as shown in (26): each epistalt is updated by being changed into an information state with a singleton epistalt. When we need to revert it to an epistalt, we use a function which applies to a singleton set and yields the member as its value. The function is represented as a down arrow in (25). The rule for the existential operator is formulated as a distributive update. This is motivated by its scope interaction with the possibility operator. This is adopted from Groenendijk, Stokhof, and Veltman (1994).[11] This rule can be used to interpret nonspecific indefinites. In (27) I used "+" as a notation for updating a common ground with a sentence. Note that when a common ground is updated with a sentence, every information state in it is updated with the interpretation of the sentence.

The interpretation rule for *hccw* also must apply to every information state in a common ground, but affect only the information state of the agent who has cogtac with an individual. Suppose that the agent and the individual are assigned discourse referents j and k respectively. Then the interpretation rule for *hccw* can be formulated as follows:

(28) $S_i||hccw(j,k)|| = (i)\ \{\{wf \in s|\ f(k) = d\}\ |\ s \in S_i \wedge d \in D\}$ if $i = j$

(ii) S_i otherwise.

[11] I will discuss this in a later section in relation to scope interactions of specific indefinites and the possibility operator.

If i is identical to j, the information state S_i is the one for the agent j.[12] Therefore each epistalt in it is partitioned into cells of epistalts so that each of them has a rigid value for the discourse referent k. The rule changes a common ground $<S_i,S_j>$ as follows:

(29) $<S_i,S_j> + hccw(j,k) = <S_i||hccw(j,k)||,S_j||hccw(j,k)||>$
$= <S_i, \{\{wf\in s \mid f(k) = d\} \mid s\in S_j \wedge d\in D\}>$

Since S_j is the information state of the agent who has cogtac with the individual k, the epistalts in it are partitioned into smaller epistalts, each having a fixed value for the discourse referent k. Since the information state S_i is the one for the person who does not have cogtac, it does not change at all. In this way *hccw* affects only one information state and thus results in asymmetric information states.

Finally I give the interpretation rule for the possibility operator. The possibility operator is generally regarded as a test. In the new information theory, it is a test for epistalts. It checks whether an epistalt in an information state allows for a certain possibility. If it does, it remains in the information state. Otherwise, it is eliminated from the information state. This is formulated as follows:

(30) $S||\Diamond\phi|| = \{s\in S| \downarrow(\{s\}||\phi||) \neq \emptyset\}$ (Temporary)

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[12] I have said that information states in common grounds are indexed with discourse referents. They are used only in the interpretation of some predicates or operators. Other predicates or operators do not use them at all. The predicate 'cogtac', the belief operator, and the possibility operator below belong to the former case.

However, this is not sufficient to account for the discourses in (21-22). In (21), we have observed that when Alberta used the possibility operator, it actually reduced the information state: namely, the epistalt where st3 was in her office is eliminated. This is contrasted with the case where Chris used the possibility operator. His information state remains as it is. This difference leads us to conclude that the interpretation of the possibility operator must be relativized to the agent who is responsible for the use of the possibility operator. This suggests that the possibility operator be a dyadic operator. This is formulated as follows:

(31) $S_i||\Diamond_j\phi|| =$ a) $\{s \in S_i | \downarrow(\{s\}||\phi||) \neq \emptyset\}$ if $i = j$
b) S_i otherwise.

When a common ground like $<S_1, ..., S_i, ..., S_n>$ is updated with the formula $\Diamond_i\mathbf{f}$, only S_i is affected.

5. Properties of Specific Indefinites: Their Explanation

5.1. Interaction between Specificity and the Possibility Operator

I mentioned three properties of specific indefinites, and proposed the semantics for specificity. In this section I will explain them in the new semantics. First I will explicate the scope interaction between specificity and the possibility operator, which we observed in (21-22). I have repeated the discourses here for convenience, and they are translated into dynamic predicate logic.

(32) D: I found a watch on the floor in your office.
A: A certain student of mine was there.
X: He may have lost the watch.

(33) D: ∃3[watch(3)] ∧ found-on-floor-in-office(2,3)
A: ∃4[student-of-1(4)] ∧ hccw(1,4) ∧ was-in-1's-office(4).
X: $\Diamond_1$have-lost(4,3)

As I said, Alberta and Chris know that st1, st2, and st3 are Alberta's students and that st3 has no watch. To see how a common ground updates, I assume the model as follows: W = {w1,w2,w3,w4}, and D = {a(lberta), c(hris), d(avis), wa(tch)1, wa2, st1, st2, st3}, where st1, st2, and st3 are Alberta's students, and wa1 and wa2 are watches. The possible worlds are further specified as follows:

(34) in w1: st3 has no watch. st1 was in Alberta's office. st1 has lost wa1. Davis found wa1.
in w2: st3 has no watch. st2 was in Alberta's office. st2 has lost wa2. Davis found wa2.
in w3: st3 has no watch. st3 was in Alberta's office. Someone other than st3 has lost wa1. Davis found wa1.
in w4: st3 has no watch. No one was in Alberta's office. Davis found no watch.

At the beginning, the domain of sequences is assumed to be {1, 2}, in which the two numbers are assigned to Alberta and Chris respectively.

(35) G_2 = {g_2}, where g_2 = {<1,a>,<2,c>}: that is, the sequence g_2 assigns a to 1, and c to 2.

Then the common ground at the beginning stage can be represented as a set of pairs of a possible world and the sequence g2:

(36) CG1 = $<S_1,S_2>$, where $S_1 = S_2 = \{\{w1g_2, w2g_2, w3g_2, w4g_2\}\}$.[13]

This common ground is updated with Davis's statement.

(37) $<S_1,S_2>||\exists 3[\text{watch}(3)] \wedge \text{found-on-floor-in-office}(2,3)||$
$= \{<S_1||\exists 3[\text{watch}(3)] \wedge \text{found-on-floor-in-office}(2,3)||,$
$S_2||\exists 3[\text{watch}(3)] \wedge \text{found-on-floor-in-office}(2,3)||>\}$
$= \{<S_1||\exists 3[\text{watch}(3)]|| \; ||\text{found-on-floor-in-office}(2,3)||,$
$S_2||\exists 3[\text{watch}(3)]|| \; ||\text{found-on-floor-in-office}(2,3)||>\}$

Updating the common ground with the existential quantifier '$\exists 3$' increases the domain of the sequences to {1,2,3}, and the number of sequences expands to the size of D, with each in D assigned to 3.

(38) $G_3 = \{g_31, g_32, g_33, g_34, g_35, g_36, g_37\}$, where
$\{g_31 = \{<1,a>, <2,c>, <3,wa1>\},$
$g_32 = \{<1,a>, <2,c>, <3,wa2>\},$
$g_33 = \{<1,a>, <2,c>, <3,st1>\},$
$g_34 = \{<1,a>, <2,c>, <3,st2>\},$
$g_35 = \{<1,a>, <2,c>, <3,st3>\},$
$g_36 = \{<1,a>, <2,c>, <3,a>\},$
$g_37 = \{<1,a>, <2,c>, <3,c>\}$, and
$g_38 = \{<1,a>, <2,c>, <3,d>\}.$

[13]The two discourse referents are fixed as Alberta and Chris respectively, which means that the expressions associated with them are rigid designators in CG1.

Among these sequences, only the first two survive after the common ground is updated with the formula 'watch(3)'. After the common ground is updated with Davis's second formula 'found-on-floor-in-office(2,3)', we get the following common ground.

(39) CG2 = <S1', S2'> = {{w1$g_3$1, w2$g_3$2, w3$g_3$1},{w1$g_3$1, w2$g_3$2, w3$g_3$1}}

The world w4 is excluded since Davis found no watch in that world.

Now let's update the common ground with Alberta's statement. Again the existential quantifier expands the domain of sequences. Given that 4 is a student of Alberta's, the expanded sequences are as follows:

(40) G_4 = {g1, g2, g3, g4, g5, g6}, where
g1 = {<1,a>,<2,c>,<3,wa1>,<4,st1>}
g2 = {<1,a>,<2,c>,<3,wa2>,<4,st1>}
g3 = {<1,a>,<2,c>,<3,wa1>,<4,st2>}
g4 = {<1,a>,<2,c>,<3,wa2>,<4,st2>}
g5 = {<1,a>,<2,c>,<3,wa1>,<4,st3>}
g6 = {<1,a>,<2,c>,<3,wa2>,<4,st3>}.

When CG2 is updated with Alberta's first formula 'student-of-1(4)', we get CG3:

(41) CG3 = <S1'', S2''>, where S1'' = S2'' = {{w1g1, w1g3, w1g5, w2g2, w2g4, w2g6, w3g1, w3g3, w3g5}}.

This is updated with 'hccw(1,4)'. Note that the formula changes only 1's information state.

(42) CG4 = <S1", S2">+hccw(1,4) = <S1"||hccw(1,4)||,
S2"||hccw(1,4)||> = <S1"||hccw(1,4)||, S2">

S1" is partitioned into smaller cells of epistalts while *S2"* remains as it is.

(43) S1"||hccw(1,4)|| = {{wg∈s| g(4) = d} | s ∈ S1" ∧ d∈D} =
{{w1g1,w2g2,w3g1}, {w1g3,w2g4,w3g3}, {w1g5,w2g6,w3g5}}

The next formula 'was-in-1's-office(4)' requires the student 4 to have been Alberta's office. In *w*1, only the sequence which assigns st1 to 4 survives. Similarly, st2 and st3 must be assigned to 4 in *w*2 and *w*4 respectively. Thus we get the following:

(44) CG5 = <S1*, S2*> = <{{w1g1},{w2g4},{w3g5}},
{{w1g1, w2g4, w3g5}}>

We observe that *hccw* has the effect of making the two information states asymmetric. The asymmetry only lies in the structure. We can see that for each participant, the union of all epistalts is the same.

(45) ∪S1* = ∪S2*

Structuring the speaker's information state makes each epistalt of his smaller than those of the other participants in the conversation. The smaller an epistalt is, the more information it

represents. Thus the difference in structures represents that the speaker has more information than the audience about the individual associated with the specific indefinite.

The common ground CG5 is updated with the next formula '$\Diamond_i$have-lost(4,3)', in which the discourse referent *i* may be bound by Alberta or Chris depending on who utters the sentence. First, suppose that it is uttered by Alberta:

(46) $<S1*, S2*> + \Diamond_i$have-lost(4,3)
$= <S1*||\Diamond_i$have-lost(4,3), $S2*||\Diamond_i$have-lost(4,3)$||>$
$= <S1*||\Diamond_i$have-lost(4,3)$||, S2*>$
$= <\{\{w1g1\},\{w2g4\}\}, \{\{w1g1, w2g4, w3g5\}\}>$[14]

The final result obtains like the following:

(47) $S1*||\Diamond_i$have-lost(4,3)$|| = \{s \in S1* | \downarrow (\{s\}||$have-lost(4,3)$||) \neq \emptyset\}$

(48) $\downarrow (\{\{w1g1\}\}||$have-lost(4,3)$||) = \{w1g1\}$
$\downarrow (\{\{w2g4\}\}||$have-lost(4,3)$||) = \{w2g4\}$
$\downarrow (\{\{w3g5\}\}||$have-lost(4,3)$||) = \emptyset$

*S1** has three epistalts, and each of them is tested with the formula '$\Diamond_i$have-lost(4,3)'. The epistalt in which st3 was assigned to 4 is excluded since it is impossible that the student lost the watch 3.

Suppose that the same statement is uttered by Chris. Then the

[14]This is not a desirable result since the common ground is the information state shared by all the participants in a conversation. If Chris knows S1* is significantly reduced, he knows that his own information state S2* must be reduced to {{w1g1, w2g4}} in some way. I claim that this is a separate process by which the common ground is to be maintained consistent and parsimonious. This will be discussed later.

update goes as follows:

(49) <S1*, S2*> + $\Diamond_2$have-lost(4,3)
= <S1*||$\Diamond_2$have-lost(4,3)||, S2*||$\Diamond_2$have-lost(4,3)||>
= <S1*,S2*||$\Diamond_2$have-lost(4,3)||>
= <{{w1g1},{w2g4},{w3g5}}, {{w1g1, w2g4, w3g5}}>

(50) S2*||$\Diamond_2$have-lost(4,3)|| = {s∈S2*| ↓ ({s}||have-lost(4,3)||) ≠ Ø}

(51) ↓ ({{w1g1,w2g4,w3g5}}||have-lost(4,3)||) = {w1g1, w2g4} ≠ Ø

In this case the possibility operator applies to Chris's information state, as in (49). Since he does not know who the student was, his epistalt allows for the possibility that st1, st2, or st3 was in Alberta's office. In this epistalt, the student who had been in Alberta's office might have lost the watch, because the student may have been st1 or st2. The student who was in Alberta's office might not have lost the watch if it was st3. However, this does not make the epistalt the empty set, as shown in (51).

I have shown that a specific indefinite structures the information state of the agent who has cogtac. This suggests an interesting implication: specific indefinites are different from nonspecific ones in their scope phenomena when they are uttered by the agent who has cogtac. For comparison, I need to discuss Groenendijk, Stokhof, and Veltman (1994). They proposed to interpret the existential operator in a distributive way, as given in (26). They claim for the distributive interpretation of the existential quantifier with examples like the following:

(52) A student was in Alberta's office. He might have lost the watch.

(53) A student who might have lost the watch was in Alberta's office.

These two sentences have different scope relations as follows:

(54) $\exists xQ(x) \wedge \Diamond P(x)$
(55) $\exists x[Q(x) \wedge \Diamond P(x)]$

If the second were interpreted in a non-distributive way, it would give rise to the same result as the first one:

(56) $s||\exists x[Q(x) \wedge \Diamond P(x)]|| = s||\exists x||\ ||Q(x) \wedge \Diamond P(x)||$[15]
$= s||\exists x||\ ||Q(x)||\ ||\Diamond P(x)||$
$= s||\exists xQ(x) \wedge \Diamond P(x)||$

However, this is not correct. Let's see how they are different. As we have seen, when sentence (52) is uttered, it is possible that st3 was in Alberta's office, and that someone else lost the watch. Now consider sentence (53). The speaker considers only a student who possibly lost the watch, and claims that he was in Alberta's office. Therefore st3 is excluded. Note that this result is the same as what we get from the case where a speaker used a specific indefinite and the possibility operator in separate sentences. This indicates that specificity and the possibility operator show scope interaction, even when they occur in separate sentences: that is, when a speaker uses a specific indefinite with some entity in mind, its scope is extended unbounded to his later utterances. The formula 'hccw' partitions the speaker's information state according to the values of the discourse referent of the specific indefinite, and the partition is maintained throughout the context.

[15]They do not assume an information theory based on epistalts, so a sentence is interpreted as a partial function from the sets of world-sequence pairs to the sets of world-sequence pairs. The sets of world-sequence pairs correspond to the epistalts in the information theory based on epistalts.

Thus the scope of the specific indefinite is extended throughout the context.

5.2. Asymmetric Structures Eliciting Questions

I have shown that a specific indefinite structures epistalts in an information state into smaller epistalts by partitioning the set of world-sequence pairs. This reminds us of Groenendijk and Stokhof's (1984) analyzing question radicals as partitions of the set of possible worlds, as in (57). The person who asks a question believes that the addressee has more information than what one of the cells in the partition represents and thus can give an answer to the question by selecting one cell. This can be compared with the partition of world-sequences by the use of a specific indefinite, which is shown in (58).

(57) Who laughs?

no one laughs
st1 laughs (1)
st2 laughs (2)
...
stn laughs (n)
st1 and st2 laugh (1-2)
...
everyone laughs (1-2- ... -n)

(58) A certain man laughs.

<1>: st1 laughs (1), (1-2), (1-3), ..., (1-2-...-n)
<2>: st2 laughs (2), (1-2), (2-3), ..., (1-2-...-n)
...
<n>: stn laughs (n), (1-n), (2-n), ..., (1-2-...-n)

The information state of the agent who has cogtac has the structure of a partition of world-sequences with regard to the referents of a specific indefinite. This structuring reflects the information that the agent of cogtac has the referent in mind. The actual information state of the agent of cogtac is expected to be smaller than one of the epistalts in (58) and thus the agent has one in mind. He is expected to know more of the referent than what is actually expressed by the specific indefinite. Therefore the use of a specific indefinite has the effect of inviting the audience to ask questions about the referent.

One difference between the two partitions in (57) and (58) is that a question radical partitions the set of possible worlds while cogtac partitions the set of world-sequence pairs. When the set of possible worlds is partitioned, a world in which st1 laughs and a world in which st1 and st2 laugh belong to different cells of the partition. Therefore the cell for 'st1 laughs' represents that only st1 laughs. Exhaustiveness is embodied in the partitions representing question radicals. This is not the case in the partition by the relation 'hccw'. Two possible worlds belong to the same cell of the partition as long as the discourse referent for the relevant specific indefinite CAN be assigned the same individual as its value. And one possible world may belong to more than one cell in the partition. Note that the possible worlds in the cells (1-2) in (57) belong to the cells <1> and <2>. The reason for this is easy to see.

Suppose that in a possible world w, two students st1 and st2 laugh, and that the two sequences g1 and g2 assign st1 and st2 respectively to the discourse referent i introduced by the specific indefinite in (58). Then wg1 and wg2 belong to <1> and <2> in (58) respectively. Thus in <1> and <2>, at least st1 and st2

laugh since the possible world w belongs to the two cells. In the present context, each cell has only one value for the discourse referent i, and this is just discourse information. There may be other individuals that satisfy the description, but the speaker is not concerned with them in the present context. Therefore there is no reason to exclude the possibility that other individuals also satisfy the description of the expression. This is why specific indefinites do not have uniqueness implicatures, in contrast with non-specific indefinites.

Let's consider the following examples again.

(59) A dog is barking.
(60) A certain dog is barking.

The first sentence is true if at least one dog is barking, but generally it is understood as saying that only one dog is barking. The increase of strength is regarded as the effect of a scalar implicature which comes from the speaker's following the maxim of quantity. This indicates that the indefinite article *a(n)* and other quantity words like *two*, *three*, ... form a scale. On the other hand, *a certain* does not belong to this scale. Quantity is not all that matters in the use of specific indefinites. Specific indefinites convey information of cogtac. Moreover, as shown above, the unique value of the discourse referent for a specific indefinite in each cell is only discourse information, and so it does not require any compatible possible world to have a unique entity that satisfies the statement.

5.3. Accessibility for the Use of Pronouns

I have mentioned the peculiar property related to anaphora

between main contexts, belief contexts, and desire contexts. I will repeat the examples we have seen above:

(61) John believes that he saw a certain unicorn, but it is just a figment of his imagination.

(62) John wants to catch a certain monster. He believes it will show up soon. Of course, it is a figment of his imagination.

Since we did not discuss how belief/desire contexts are derived within the new information theory, it may be too early to discuss this phenomenon. However, we got the basic idea of specificity, and we can extend it to belief/desire contexts without going through all formal complexities in deriving those contexts. The basic idea is that each epistalt in an information state is partitioned into smaller cells with regard to the values of the discourse referent introduced by a specific indefinite. Discourse referents are also introduced in belief/desire contexts, and thus these contexts can be partitioned in the same way. Actual derivations of belief contexts and the interpretation rule of the belief operator will be discussed in the next section.

The observation in (61-62) cannot be accounted for in terms of accessibility paths defined in structural representations like DRSs unless some special device is contrived to distinguish specific and nonspecific indefinites within belief/desire contexts in a non-arbitrary way. For the present theory, we need to use a different way of defining accessibility for anaphora. One such alternative is Kadmon's (1990) Uniqueness Condition.

(63) A pronoun associated with a variable x is used felicitously

only if for every possible world, for all embedding functions f, g employed in the context, $f(x) = g(x)$.[16]

I adapted her formulation of the condition to my theory, but still I need to make a further modification. In my theory, an information state may have more than one epistalt. The felicity of anaphora must be defined with regard to epistalts since it is defined with respect to the values of a discourse referent and these values are tangible in epistalts. Thus the condition can be reformulated as follows:

(64) A pronoun associated with a variable x is used felicitously only if for every world w, for all embedding functions f, g employed in the context arising from w, $f(x) = g(x)$.

In this condition 'the context arising from the possible world' indicates a belief/desire context derived from a possible world in the main context. With the help of this condition, I can show that specific indefinites are accessible to pronouns in later utterances even when they occur in belief/desire contexts.

Suppose that a specific indefinite is used in the complement clause of a verb like *believe*, and that the agent of the belief has cogtac with an individual associated with the specific indefinite. Then his belief context represented as the set of world-sequences is partitioned into smaller cells of epistalts, in each of which the discourse referent introduced by the indefinite will have a unique value, and the main context includes only the possible worlds

[16]This statement is modified to my purpose, but still insufficiently sophisticated to deal with donkey sentences. We are not interested in sentences like donkey sentences, and thus I want to maintain the condition as simple as possible.

which ensure such epistalts.[17] Therefore, from the perspective of a possible world in the main context, the agent's belief context has only one value for the discourse referent. Of course different epistalts give different values, but what is important, the belief context is known to have a unique value metaphysically even though it is uncertain epistemically what the value is.

I have only discussed belief contexts, but this can be easily extended to desire contexts. According to Heim (1992), desire contexts are subsets of belief contexts. Assuming her analysis of desire contexts, if a discourse referent has a unique value in each epistalt of a belief context, it holds in the desire context, too. Moreover, cogtac is basically understood as an epistemic matter, not a matter of desire. Thus even when a specific indefinite is used in a desire context, it partitions the belief context so that the value for the discourse referent has a unique value in the belief context.[18] This represents that the agent believes that he has some individual in mind. If the agent does not assume that the entity exists, the specific indefinite is not accessible to a pronoun in the main context. This is illustrated in (65).

(65) John wants to buy a PARTICULAR car, not any car. ??He believes that it is a little too expensive.

The expression 'particular' is another marker of specificity. When it is focused, the sentence is construed as meaning that John

[17]Belief contexts must be defined in terms of world-sequence pairs so that we can partition them. This will be discussed in detail in the next section.

[18]This seems to be an effect of presupposition triggered by a specific indefinite. When a specific indefinite is used in a desire context, it is presupposed that the agent believes that the entity he has in mind exists. This requires the discourse referent to be introduced in the belief context as well. For details about this, see Yeom (1997).

does not believe that a particular car exists. Given that a desire context is a subset of a belief context, the entity John has in mind only in his desire context exists in some possible worlds in his belief context, but not in others. The pronoun that occurs in the belief context cannot refer to the entity due to the possible worlds in which the entity does not exist.

6. Indirect Cognitive Contact

I have claimed that a specific indefinite has two indices, one of which is bound by the agent who has cogtac. So far I have dealt with cases where it is bound by the speaker. However, I also gave an example which shows that this is not necessarily the case. Look at the example again:

(2) There is a (certain) dragon$_{\langle i,j \rangle}$ that Alberta believes ate her petunias.

Even though the indefinite *a (certain) dragon* is not within the scope of the belief operator syntactically, the dragon is not supposed to exist in the actual world. It is plausible that it exists only in Alberta's belief worlds. Therefore whether or not a specific indefinite structurally occurs in the belief context, it is desirable to derive the belief context. Suppose that the first discourse referent i in (2) is bound by the agent Alberta. This requires us to derive Alberta's belief context. This context is partitioned according to the values of the discourse referent j.

In order to do this, we need to make sure that the belief context is represented in terms of world-sequence pairs. Hintikka (1969) represented a belief context only in terms of possible

worlds. I will first look at his definition of belief contexts, and then revise it for my purposes. Hintikka defined the doxastic alternativeness relation as a relation R between possible worlds with respect to an agent A (= the alternativeness relation pertaining to A's belief):

(66) Let $R(A) \subseteq W \times W$.
Then $\Phi_B(A, w) = \{w^* \in W \mid R(A)(w, w^*)\}$, where $R(A)(w, w^*)$ stands for 'w^* conforms to what A believes in w.'

In this representation, w^* is called a doxastic alternative for A to w. $\Phi_B(A, w)$ is the set of possible worlds which conform to what A believes in w. Heim (1992) adapted this to dynamic semantics without much modification.

Hintikka's doxastic alternativeness relation is not adequate in a couple of respects. For our purpose, the belief must be represented in terms of world-sequence pairs. Moreover his relation is not precise enough to deal with an example like (67):

(67) John believes that a black horse won the race
= There was a black horse that John believes won the race.

Let's assume that this statement is true in w, where there are three black horses, bh1, bh2, and bh3, which verify the statement. When the black horse was bh1, it must exist throughout John's belief worlds. We can say the same thing about the other two cases. Then it is expected that the set of John's belief worlds with the horse being bh1 is different from the set of John's belief worlds with the horse being bh2 or bh3. A question is how can

we derive John's belief worlds only based on the relation between possible worlds. There might be two possible ways to derive John's belief worlds. One is the union of the sets of doxastic alternatives for the three values for the indefinite. However, the problem is that whichever black horse may be selected, some possible worlds in the union do not include the horse. The other way is the intersection of the three sets of doxastic alternatives. In this case whichever black horse may be selected, it is included in the intersection. On the other hand, every possible world in the intersection includes the three black horses, which is not necessary. Thus we have to reject the two ways of deriving John's belief worlds. The real problem comes from the doxastic alternativeness relation, which is based solely on possible worlds. The set of John's belief worlds must be determined by considering the value of the variable introduced by the indefinite *a black horse*. Note that the latter (i.e., the value of the variable) is discourse information.

From the discussion of Hintikka's doxastic alternativeness relation, we can see that the relation must be relativized with respect to the sequences. Now let's redefine the alternativeness relation R' and doxastic alternatives as follows:

(68) $R'(A) \subseteq W \times G \times W$

$\Phi'_B(A, wg) = \{w^* \in W \mid R'(a)(w, g, w^*)\}$

The function Φ'_B gives us a set of possible worlds which are compatible with John's belief with respect to the sequence g. This is not still sufficient for my purpose. We need to represent the belief context in terms of world-sequence pairs, not in terms of possible worlds. Therefore I propose a new relation:

(69) $R'(A) \subseteq W \times G \times W$

$F_B(A, wg) = \{w*g \in W \times G \mid R'(A)(w, g, w*)\}$

The function F_B gives us a set of world-sequence pairs that are compatible with the agent A's belief in the possible world w with respect to the sequence g. The only difference from the previous one is that those possible worlds are combined with sequences so that anaphora between the main context and belief contexts, as well as between belief contexts, can be captured.

In the dynamic semantics here, an information state is represented as a set of world-sequence pairs. For each world-sequence pair, we can derive an agent's belief context. One question is whether the belief context is derived pointwise or globally. When a world-sequence pair gives rise to a set of world sequence pairs compatible with someone's belief, does the derived belief set have to be handled separately as a belief context of his, or be combined with other belief sets derived from other world-sequences to form a belief context as a whole? The following example helps decide which.

(70) There is only one mountain in that country. It is over 1800 m high. Chris believes that if it is that high, it must be covered with snow.

This means that there is a unique mountain in the actual world. Whatever the actual world may be, all possible worlds in F_B(Chris, wg) include that mountain. This means that the NP must be like a rigid designator in F_B(Chris, wg). If this set is regarded as Chris's belief context, he is expected to have cogtac with the mountain. This is not what we want. It may not be the

case that Chris knows which mountain it is, as the following shows:

(71) A: There is only one high mountain in that country. It is over 1800 m high.
C: I don't know which mountain you are talking about, but if it is that high, it must be covered with snow.

(70) above can be regarded as a report of the conversation in (71). In order to represent Chris's correct belief context, we have to derive it globally. This is quite natural when we consider that common grounds consist of structured information states and that a change in one information state does not affect the others. This is illustrated in (72).

(72) There is a certain mountain I'd like to go to. It is over 1800 m high. Chris believes that if it is that high, it must be covered with snow.

Due to the specific indefinite, the speaker's information state is structured according to the values for its discourse referent. If Chris's belief contexts were derived separately from each epistalt of the speaker's information state, the discourse referent will have a fixed value in each of Chris's belief contexts. However, note that Chris does not have cogtac with the mountain. Therefore Chris's belief context must be derived globally regardless of whether the speaker has cogtac with the mountain. Thus in an information state S, Chris's belief context is derived as follows:

(73) $\cup_{wf \in \cup S} F_B(\text{Chris}, wf)$

The information state S may have been structured into epistalts for a reason that is not relevant to the derivation of Chris's belief context, so we need the union of them first. Each world-sequence in the union yields a set of world-sequence pairs by the function F_B. Chris's belief context is represented as the union of these sets.

Finally, a question must be asked whether someone's belief context is maintained in the representation once it is derived, or it is derived temporarily only for updating the main context. In Heim (1992), a belief context is only temporarily derived from each possible world in the main context in order to update the main context. If the derived belief context does not satisfy a new belief statement, the possible world from which the belief context is derived is eliminated from the main context. In this semantics, it is impossible to distinguish whether or not the agent has cogtac with an individual, independently of whether the speaker has cogtac with the individual. This has been shown by the example (67). In this example, the speaker does not have cogtac with a black horse which John has in mind. In this case, whether or not John's belief context is structured does not exert any effect on the main context since the specific indefinite already has wide scope over the belief operator. If John's belief context is derived only for updating the main context and then eliminated afterwards, the information that John has cogtac with the black horse is not reflected in the updated main context at all. Therefore despite the indirect update of the main context through belief contexts, the structured belief contexts must be maintained. This requires the theory to be partially representational: as a

denotational aspect, a change in the belief context is reflected as a change in the main context, and as a representational aspect, the structure of the belief context is still maintained as part of the context.

7. Expanded Common Grounds and New Interpretation Rules

The introduction of belief contexts requires some revisions in the interpretation rules already given in a previous section. First, the common ground must include other individuals' belief contexts embedded in the information states of the participants in the conversation. This is represented as follows:

(74) $\langle S_1\langle S_i, \ldots, S_j\rangle, \ldots, S_n\langle S_i, \ldots, S_j\rangle\rangle$

The information states S_1 through S_n represent the information states of the participants in the conversation, and S_i, ..., S_j the belief contexts of the individuals who are assigned the discourse referents i, ..., j respectively. These belief contexts are embedded in the participants' information states. A new rule of updating common grounds can be given as follows:

(75) $\langle S_1\langle S_i, \ldots, S_j\rangle, \ldots, S_n\langle S_i, \ldots, S_j\rangle\rangle + \phi$
$= \langle S_1||\phi||\langle S_i, \ldots, S_j\rangle, \ldots, S_n||\phi||\langle S_i, \ldots, S_j\rangle\rangle$

When ϕ is not a statement of someone's beliefs, S_1 through S_n are updated with the formula ϕ without affecting the embedded belief contexts. All the rules in (26) belong to this type.

When it is a statement relevant to a belief context, it updates

one of the belief contexts S_i, ..., S_j, and thereby changes S_1, ..., S_n indirectly. However, for the reason I gave in the previous section, the belief context must be maintained in the representation to capture anaphora across the belief operator. The embedded belief contexts are used only in the interpretation of *hccw*, the belief operator, etc., which can be characterized as involving belief contexts. Thus I revise the interpretation rule of *hccw* and give the interpretation rule of the belief operator.

(76) $S_i||hccw(h, m)||<S_j, ..., S_k, ..., S_l> =$

(i) $S_i'<S_j, ..., S_k, ..., S_l>$,
where $S_i' = \{\{wf \in s | f(m) = d\} | s \in S_i \wedge d \in D\}$, if $h = i$

(ii) $S_i<S_j, ..., S_k', ..., S_l>$,
where $S_k' = \{\{wf \in s | f(m) = d\} | s \in S_k \wedge d \in D\}$, if $h = k$

(iii) $S_i<S_j,..., S_k, ..., S_l>$ otherwise.[19]

(77) $S_i||B_h\phi||<S_j, ..., S_k, ..., S_l> =$

(i) $S_i<S_j, ..., S_k||\phi||, ..., S_l>$ if $h = k$

(ii) undefined otherwise.

The relation *hccw* or the belief operator changes the information state (or a belief context) of the agent if it is available in the common ground. If there is no such information state or belief context, it is undefined. This definedness condition has the effect of accommodating a belief context or an information state that is necessary to interpret the statement. In other words, when an

[19]If there is no belief context of the agent who has cogtac in the common ground at all, the interpretation is undefined. This is not easy to specify in the formulation of the rule. I will ignore it here.

agent has cogtac with an individual and his information state or belief context is not yet introduced in the context, it is newly introduced. Likewise, in the interpretation of the belief operator, there must be a belief context which belongs to the agent of the belief. If there is no such belief context, a belief context must be accommodated so that the statement is interpretable.

8. Partially Representational Theory and Imposing Restrictions on Information States

I have claimed that a common ground consists of information states as many as the number of the participants in a conversation, and each information state in turn is made of epistalts. With this notion of a common ground, a statement may change only one of the information states in the common ground with the others unchanged. We have witnessed that a statement with an specific indefinite structures only the information state of the agent who has an individual in mind, with the others' information states untouched. Furthermore, according to the interpretation rule of the belief operator given in (77), changes in someone's belief context do not affect the main context at all. This should not be the case. Someone's belief is also part of the actual world. Thus the introduction of a belief in the context is information increase about the actual world.

One way to handle this is to impose restrictions on the relations between information states and the relations between information states and belief contexts. First, let's consider the former relations. As we have seen in the example (21), Alberta's information state is reduced significantly while Chris's remains unaffected. To remedy the situation, we can impose a restriction as follows:

(78) Let $<S_1<...>, S_2<...>, ..., S_n<...>>$ be the common ground.
Then $\cup S_1 = \cup S_2 = ... = \cup S_n = \cup S_1 \cap \cup S_2 \cap ... \cap \cup S_n$

For every participant in a conversation, the world-sequence pairs of their information states must be the same as the intersection of them. By this restriction, if a world-sequence pair in Alberta's information state is eliminated, then it must be removed from Chris's information state, too.

Second, we can impose a restriction on the relation between the main context and a belief context, or more generally, on the relation between an embedding context and an embedded context:

(79) Let $< ... S_i<S_1, S_2, ..., S_n> ...>$ an information state.
Then for every wf $\in \cup S_i$, for every x from 1 to n,
$\exists s \in S_x[\{F_B(x,wf) \subseteq s]$[20]

Every world-sequence pair in an embedding information/belief state must give rise to a set of world-sequence pairs which is a subset of an epistalt in every embedded information/belief state. Thus when an embedded belief context is updated with a belief or a desire statement and as a result an epistalt is eliminated from the belief context or reduced in size significantly, it is

[20]It may be correct to give the restriction in terms of possible worlds instead of world-sequence pairs:

i) Let $< ... \cup S_i<S_1, S_2, ..., S_n> ...>$ an information state.
For every wf $\cup S_i$, for every x from 1 to n, $\exists s \in S_x[\{w' | \exists g[w'g \in F_B(x, wf)]\} \subseteq \{w'' | \exists h[w''h \in s]\}]$

This is because the domain of the discourse referents between the main context and belief contexts may be different. Therefore subset relations must be defined in terms of possible worlds, not world-sequence pairs.

certain that some world-sequences in the embedding (or main) context do not satisfy the restriction above. In this case they are eliminated from the embedding (or main) context. That is, a belief or a desire statement indirectly changes the main context by changing the belief/desire context.

These two restrictions are necessary because the theory is partially representational. Then what is the relation between information states in my theory and those in purely denotational ones? One good example of representational theory is Discourse Representation Theory, and discourse representation structures can be interpreted in terms of possible world semantics. Similarly, partially representational information states can be interpreted again in some sense.

(80) Let $<S_1<S_x, \ldots, S_z>, S_2<S_x, \ldots, S_z>, \ldots, S_n<S_i, \ldots, S_j>>$ be the common ground.

Then a simple denotational representation of the common ground can be a set of world-sequence pairs, namely,

$s = \{wf|\ (i)\ wf \in \bigcup S_{f(1)} \cap \bigcup S_{f(2)} \cap \ldots \cap \bigcup S_{f(n)} \wedge$

$(ii)\ \forall y \in \{x, \ldots, z\}\, \exists t \in S_y [F_B(f(y), wf) \subseteq t]\}$

We are already familiar with the two conditions (i) and (ii). With the help of the conditions, we can see the relation of our representation of a common ground to the standard representation of a common ground. One crucial difference is that our theory can capture the information that someone has cogtac with an individual while the standard theory does not.

I want to mention one more thing. In my theory, the two restrictions above are introduced as a separate information process. According to Gärdenfors (1988), when one gets new

information, it is necessary to adjust the whole information state in order to maintain a more parsimonious belief state. In my theory, a statement primarily affects the directly relevant information component. The two conditions above can be understood as processes of adjusting the whole information state so that a more parsimonious and simpler information state can be maintained.[21]

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[21]This is not always successful, and more generally we do not notice that we have incompatible beliefs. For this case, a representational theory is favored. I will not go into this matter since at this point I do not know whether my theory can cope with this problem still based on possible world semantics.

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