

A Denotational Analysis of Anaphora in Attitude Contexts

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Jae-Il Yeom. 2004. A Denotational Analysis of Anaphora in Attitude Contexts. *Language and Information 8.2*, 47-72. In general, it is assumed that a pronoun refers to the same individual as the referent of its antecedent. However, when a pronoun and its antecedent are in different information or belief states, the two may not refer to the same individual. Then a question arises what a pronoun refers to. In this paper, two cases are considered. When a pronoun occurs in an attitude context, one case is where its antecedent occurs in a belief context, and the other is where the antecedent occurs in the main context. I propose that a pronoun refers to an individual concept which links two different subjects in two different contexts, and that the selection of a proper individual concept is restricted by the discourse. So a pronoun can be used felicitously only when there is a unique individual concept supported by the individual concept introduced by the discourse and which can link two subjects in two different contexts. (Hongik University)

Key words: anaphora, pronoun, individual concept, attitude context, subject

1. Introduction

What does a pronoun refer to? When it is used anaphorically, formally it can have a proper name, an indefinite or definite description, or even a pronoun as the antecedent. Semantically, however, it is not easy to answer that question, especially when the antecedent is not in the same context as the one where the pronoun occurs. In this paper I will only deal with cases where the antecedent is an indefinite description, but the application of this analysis is not limited to these cases. An indefinite description is traditionally interpreted as an existential quantifier, but in dynamic semantics, it is assumed to introduce a new discourse

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referent. When a pronoun is used to refer back to the indefinite, it is assumed to refer to a *specific* object.¹ The question is what kind of object it refers to. This question is related to the question of what conditions must be met for a pronoun to refer to its antecedent felicitously.

Conditions on use of pronouns must be proposed to be able to cover all uses of pronouns regardless of whether an attitude context is involved. Before doing this, however, we need to know what differences there are between anaphora in the main context and anaphora involving (an) attitude context(s). Consider the following examples.

- (1) A student is going to present a paper. *He* is not aware of the problems with the paper.
- (2) A student is going to present a paper. John thinks that *he* is not aware of the problems with the paper.

An indefinite description introduces a discourse referent which is considered a variable in this paper, and if a pronoun refers to the indefinite description, it is taken to have the same discourse referent, or the discourse referent of the pronoun is equated with that of its antecedent. What we need to know is what it means to have the same discourse referent. Common sense says that it would mean referring to the same individual. This seems to be correct in (1). Can we say the same thing about (2) too? It seems so in this example because John can be assumed to know that the student in question is going to present a paper. But in general the information in the main context is not part of someone's belief.

Suppose that Anna is swimming in the pool, but Ralph mistakes her for Beth. A speaker who knows this situation will say the following.

- (3) Anna is swimming in the pool, but Ralph believes she is Beth.

In this sentence, if the pronoun *she* referred to the individual Anna, who is swimming in the pool, Ralph would be understood to believe that Anna is Beth. But the sentence does not have this meaning. What Ralph believes may be said to be false with respect to the actual world, but it should not be false in Ralph's belief state itself because Ralph does not think that he is in an inconsistent belief state: the sentence can be uttered even when Ralph knows who Anna and Beth are. Ralph's belief worlds are possible worlds which are compatible with his belief. If Ralph believed that Anna is Beth, Anna would be Beth in these worlds,

¹ Dekker (1997) claims that the following example supports that in using an indefinite description the speaker has some individual in mind. This is illustrated in the following.

- (i.) John: A man called me up yesterday.
 Mary: Did he have a gravel voice?
 John: That depends: if he called in the morning he did, but if he called in the afternoon, he did not.

Here John's response is odd. This shows that when John mentions a man who called him yesterday, he is supposed to have an individual in mind.

contrary to what he believes. This shows that the pronoun does not refer to the same individual as the referent of its antecedent.

This poses some problems. What does it mean for a pronoun to refer to an antecedent, if not the same individual as the referent of the antecedent? What do we have to refer to by a pronoun in order to use it felicitously? These are the questions to be answered in this paper. In the next section I will consider cases where a pronoun is used in an attitude context and the antecedent occurs in the main context or in another attitude context. In discussing these cases I answer the questions mentioned above on the use of a pronoun in general. Then I will look over two previous analyses on the phenomena and point out some problems with them, and compare them with mine.

2. Pronouns in attitude contexts

In the introduction, it is pointed out that a pronoun does not refer to the same individual as the referent of the antecedent when the two occur in different contexts. When a pronoun occurs in an attitude context, the antecedent may be in the main context or in another attitude context. The latter case was first discussed by Geach (1967) under the name of **intentional identity**. I will discuss anaphora between the main context and an attitude context first.

2.1 Anaphora between the main context and attitude contexts

In the main context, if a pronoun refers back to an antecedent, we can say that the pronoun refers to the same individual as the one the antecedent refers to. A pronoun in a belief context, however, does not refer to the same individual as the one denoted by its antecedent in a different context. Before dealing with the reference of pronouns, I want to point out that there is no identification between an individual in the main context and an individual in an attitude context. This is clear from Quine's (1956) *double vision* cases. Consider the following situation.

There is a certain man in a brown hat whom Ralph has glimpsed several times at the beach. Ralph suspects he is a spy. Also there is a grey-haired man, vaguely known to Ralph as rather a pillar of the community, whom Ralph is not aware of having seen several times at the beach. The two men are actually one and the same person, and the name is Ortcutt. But Ralph does not know it.

In reporting this situation, we can say the following two sentences in two different occasions.

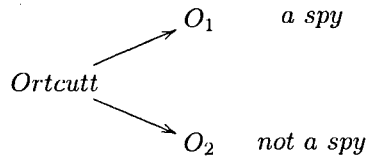
- (4) a. Ralph believes Ortcutt to be a spy.
- b. Ralph believes Ortcutt not to be a spy.

But we cannot say the following sentence.

- (5) Ralph believes Ortcutt to be a spy and not to be a spy.

Ralph does not believe he has a contradictory belief. In (4) the proper name refers to one and the same man named Ortcutt in the actual world, but it does not refer to the same individual in Ralph's belief worlds. This shows that there are two different individuals, O_1 and O_2 , in Ralph's belief worlds and the two individuals are taken to be Ortcutt in the actual world, regardless of whether a pronoun is used or not. Note that the relation of one individual with two individuals in Ralph's belief worlds is given in the context.

(6) Correspondence relation:



What connects Ortcutt and O_1 , on the one hand, and Ortcutt and O_2 , on the other, as the same individual? In this context, the former is something like *the man in a brown hat* and the latter *the grey-haired man*. The following two examples show that the pronoun refers to a different individual depending on the context.

- (7) a. Ralph is talking with *Ortcutt*. He believes *him* to be a spy.
 b. Ralph is talking with *Ortcutt*. He believes *him* not to be a spy.

In both examples, the antecedents of the pronouns are *Ortcutt*, but what they refer to are different: in (7a), the pronoun refers to the man in a brown hat, while in (7b) the pronoun refers to the grey-haired man.

We have seen that if a pronoun in a context has its antecedent in a different context, they can refer to different individuals, and that when an individual in a context is linked to two different individuals in another context, a pronoun in the latter context picks out one of the two individuals depending on the context. Now consider a case where a pronoun and its antecedent occur in the same context.

- (8) Ralph is talking with *Ortcutt*. He believes *him* to be a spy, and he (also) believes *him* not to be a spy.

In this example, the antecedent of the first pronoun is *Ortcutt*, and the pronoun refers to the man in a brown hat. If the second pronoun takes the first pronoun as the antecedent, it refers to the man in a brown hat, not the gray-haired man. This makes the sentence contradictory. But there is another antecedent for the second pronoun. The proper name *Ortcutt* can be the antecedent again and now it refers to the gray-haired man. This shows that a pronoun and its antecedent refer to the same individual if they occur in the same individual, while they refer to two different individuals if they occur in different contexts. In (8), the second pronoun is supposed to refer to the proper name in the main context because the other reading leads to contradiction.² So take a sentence which does not lead to contradiction.

² This example shows that anaphora cannot be captured by variables and their bindings. Two pronouns can refer to different individuals even when they take the same antecedent.

- (3') Anna is swimming in the pool, but Ralph believes she is Beth. Ralph believes that she is insane.

In this example the first pronoun does not refer to the same individual as its antecedent *Anna*, but some other individual linked to Anna in the actual world by the property of being a person who is swimming in the pool, but the second pronoun refers to the same individual as the referent of the first pronoun in Ralph's belief state. These two different uses of a pronoun must be covered by the same notion of anaphora, and the notion must be able to capture corresponding relations between individuals across different contexts (and so different possible worlds). The correspondence relations between individuals across possible worlds are called **individual concepts**. The individual concept for the same discourse referent picks out Anna in the actual world and Beth in Ralph's belief worlds. And the two individuals Anna and Beth are taken to be epistemically the same individual because they are the realizations of the same individual concept.

An individual concept is generally defined as a partial function from a set of possible worlds to a set of individuals, but I will represent it as a set of pairs of a possible world and an individual. A pronoun (or, a variable in formal language) and its antecedent range over individual concepts. If an individual concept is determined, it refers to different individuals according to which context the pronoun is located in. The following is an example of an individual concept.

(9)

w_1	w_2	w_3	w_4	w_5	w_6
a	b	a	c	c	e
main context			Ralph's belief state		

Given an individual concept, the context determines a set of possible worlds, each of which determines a unique individual: the instantiation of the individual concept in w_1 is a , the one in w_2 is b , etc. When a pronoun and its antecedent occur in the same context, the individual concept may determine more than one individual in that context. But since we consider each possible world and one possible world determines a unique individual for an individual concept, we can say that the two refer to the same individual in each world of the same context. On the other hand, if a pronoun and its antecedent occur in different contexts, we have to consider different worlds each of which belongs to a different context, and the two different possible worlds determine different individuals for the same individual concept. In the example above, suppose $\{w_1, w_2\}$ is the main context, and $\{w_4, w_5, w_6\}$ is Ralph's belief context and that a pronoun occurs in the belief context and its antecedent in the main context. Then the antecedent may refer to a or b , and the pronoun refers to c or e . So the two always refer to different individuals, regardless of which possible world is considered.

There is a notion of *subject*, which was first proposed by Dekker (1993). It is similar to, but not quite the same as, the notion of *individual concept*. Both notions the agent of an information state epistemically takes to be individuals in his information state, but the crucial difference is that a subject is only defined with respect to one information state or belief state: it is not linked to another subject in another information state. Suppose that an information state is a set of

possibilities, each of which is a pair of a possible world and an assignment. Then a subject associated with a variable x with respect to an information state s can be defined as follows.

$$(10) [x]_s = \text{the function } f \in [S \rightarrow D] \text{ such that } \forall \langle w, g \rangle \in s : f(\langle w, g \rangle) = g(x).$$

In the representation, for a possible world w there can be more than one assignment which pairs with w . This means that a subject may not be an individual concept, in which a possible world is paired with a unique individual. Even if a subject can be redefined as a function from a set of possible world (not from a set of possibilities) to a set of individuals, it is only defined with respect to an information state. In contrast, an individual concept is a notion that is defined regardless of any information/belief state, and can connect two subjects which belong to two different information/belief states and which are epistemically taken to be the same individual.

There should be some restriction on the choice of an individual concept as the reference of a pronoun and its antecedent. How is a relevant individual concept determined? The determination of a relevant individual concept is often dismissed as given in the context unsystematically, but examination of some examples shows that the question is very important in using a pronoun felicitously. I will show that the relevant individual concept is determined systematically by the discourse and the speaker's own information state.

Consider another example of *double vision puzzles*, assuming the following situation.

Smith and Jones are dead. A single person murdered both of them. Detective Arsky investigates both cases, and comes to believe that someone murdered Smith and that someone murdered Jones, but he doesn't have anyone in particular in mind as a suspect. Arsky does not believe that Smith's murderer and Jones's murderer are the same person. (Edelberg 1995, 318)

In this situation, the first sentence below is true and the second false. This problem Edelberg calls the *variable about-ness problem of attitude de re*.

(11) Someone murdered Smith, and Arsky thinks *he* didn't murder Jones.

(12) ??Someone murdered Smith, and Arsky thinks *he* murdered Jones.

Van Rooy (2000) refuses to use the notion of individual concept, thinking that if variables range over any individual concepts, there is a single concept *the murderer of Jones* that would also make the second sentence true. Its instantiation in the actual world murdered Smith and its instantiation in Arsky's belief worlds also murdered Jones in each of them.

If an indefinite ranges over individual concepts, we need to exclude the individual concept *the murderer of Jones* in interpreting the sentences above. The discourse is what does this. The following examples show this. In the situation above, the same person murdered Smith and Jones, but the following three discourses have different truth values.

- (13) a. Someone murdered Jones, and Arsky also thinks *he* murdered Jones.
 b. ??Someone murdered Jones. He also murdered Smith. Arsky thinks *he* murdered Jones.
 c. ??Someone murdered Smith and Jones. Arsky thinks *he* murdered Jones.

If an arbitrary individual concept can be used to verify the sentences, the three sentences should be true because of the individual concept *the murderer of Jones*. But the acceptability of the sentences is determined by the discourse preceding Arsky's belief statement. Unlike (12), (13a) is true. The only difference between them is the first conjunct. So we can presume that the first statement, in which the antecedent of the pronoun introduces a discourse referent in the main context, determines the relevant individual concept. In (12), the first statement introduces the murderer of Smith in the discourse. So the relevant individual concept becomes *the murderer of Smith*, which makes the belief statement that follows false. In (13a), on the other hand, the first statement selects *the murderer of Jones*, which makes the belief statement true. In (13b), the first statement introduces *the murderer of Jones*, and the second statement attributes the property of murdering Smith to the same individual because the pronoun occurs in the same context as its antecedent, which makes the individual concept *the murderer of Jones and Smith*. We can suppose that in Arsky's belief state, there is no individual which corresponds to that individual concept, so any belief statement of Arsky's with a pronoun referring to *the murderer of Smith and Jones* is not felicitous. The same thing happens in (13c) too.

Felicity of the use of a pronoun is affected by the discourse, as well as the actual relationship between the murderer of Smith and Jones in the actual world and the two subjects in Arsky's belief state given in the context. The former is reflected in the common ground based on the information exchanged in the discourse, whereas the latter is determined by the speaker's own information state (plus the information exchanged in the discourse).³ Consider (13a). When the speaker utters the whole sentence, his information does not actually increase, because he utters what he already knows. But he also has to maintain the common ground which records what is exchanged in the discourse (or, what is shared by the interlocutors in the context). After uttering the first conjunct, the speaker registers the discourse referent for the indefinite *someone* in the common ground, though he already has a subject in his own information state which corresponds to the discourse referent. He knows that the discourse referent in the common ground, not the subject in his own information state, allows him to refer to it in a later discourse. I have also shown that the information attributed to the discourse referent in the common ground, not the subject in his own information state, constrains the selection of the relevant individual concept among the ones given in his own information state.

³ The speaker's information state is given from the beginning of a discourse, and the common ground changes as the discourse goes. But the common ground is also part of the speaker's own information state. So we have to admit that the latter also changes.

This is why a common ground and the speaker's own information state must be considered in discussing anaphora.

In (13a), the first conjunct is uttered based on the murderer of Jones and Smith in his own information state. On the other hand, he knows that the subject is related to the two murderers in Arsky's belief state. So in his own information state, the speaker deals with three individual concepts: *the murderer of Jones and Smith*, *the murderer of Jones* and *the murderer of Smith*. *The murderer of Jones and Smith* is the intersection of the other two individual concepts. The conjunct attributes the property of murdering Jones to the discourse referent, which selects *the murderer of Jones* among the three, despite the individual concept *the murderer of Jones and Smith* in his own information state. This shows that the subject (and so the relevant individual concept) in the common ground changes with information change, and that the relevant individual concept must be supported by the attribution given in the common ground. The notion of 'support' can be understood to be the inclusion relation of information: A supports B iff the information conveyed by A includes all the information by B. *The murderer of Jones and Smith* is not selected in (13a) because it is not supported by the property of murdering Jones. In (13b) or (13c), the three individual concepts are all supported by the utterance at the point just before Arsky's belief statement. But the relevant individual concept is *the murderer of Jones and Smith*. This indicates that the strongest one is selected among those supported by the discourse. So we can propose the following Felicity condition on anaphora.

(14) Felicity Condition on Anaphora (temporary):

Given a subset of the set of individual concepts ($I \subseteq IC$) in the context a pronoun p_x in a context bs takes its antecedent NP_x in a context bs' if and only if (i) there is a maximal individual concept $ic \in I$ such that ic is supported by the subject for x in the bs of the *common ground* and (ii) there is an ic' such that ic' denotes the same individual as ic in bs and ic' connects two subjects from the pronoun and the antecedent in the *speaker's information state*.

($IC = \{D^U | U \subseteq W\}$, where D is a set of individuals and W a set of possible worlds.)

(15) A subject (or individual concept) α supports a (subject or) individual concept β iff

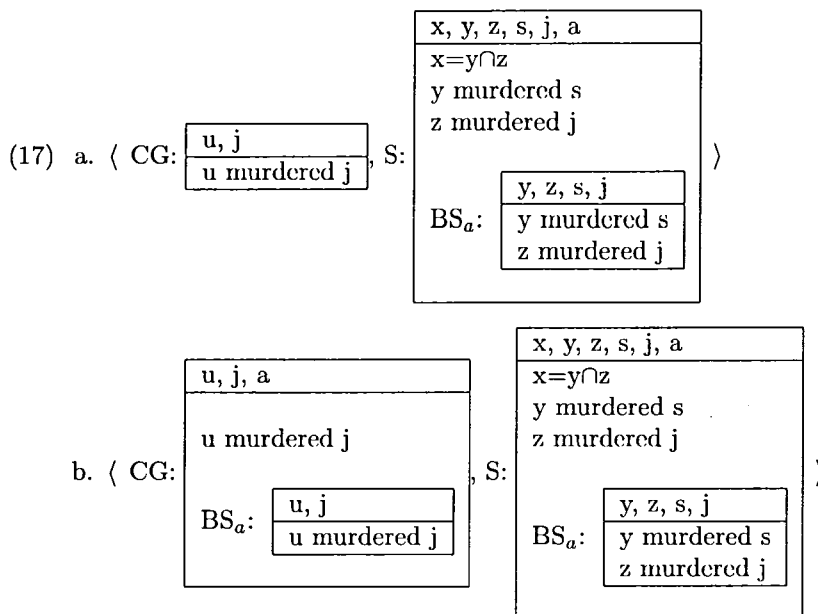
$$\{\langle w, d \rangle \in \alpha | w \in \text{dom}(\alpha)\} \subseteq \{\langle w, d \rangle \in \beta | w \in \text{dom}(\beta)\}$$

(16) An individual concept $ic \in I$ is maximal in I iff ic supports every $ic' \in I$.

Here the notion of 'support' is expressed as a subset relation between two sets of pairs of a possible world and an individual. In eliminative dynamic semantics, a smaller set carries more information. An individual concept is maximal among a set of individual concepts if and only if it is the one that conveys the most information in the set. The condition above says that an anaphoric relation between a pronoun and its antecedent is legitimate if in a set of individual concepts given in the speaker's own information state, there is a maximal individual concept among

those that are supported by the property attributed to the antecedent in the *common ground* and links the two subjects from the pronoun and the antecedent in the *speaker's information state*.

The Felicity Condition on Anaphora can account for the observations we have made so far. This paper assumes a denotational semantics, but only for expository purposes I will use Discourse Representation Structures which are slightly different from standard ones in that variables are used to denote individual concepts and variables are introduced in every context where the variables are accessible.⁴ Let's consider (13a). After the first conjunct is uttered, we can get (17a).

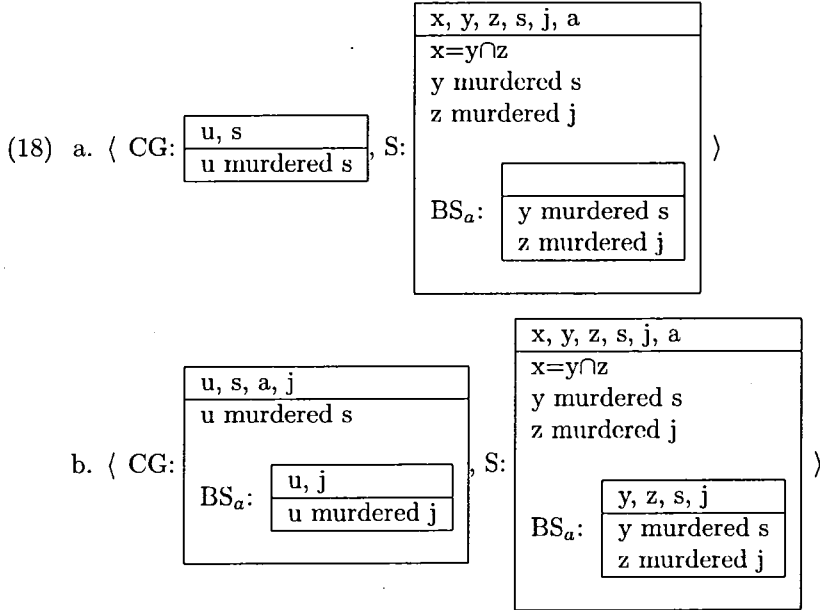


Here CG is the common ground and S is the speaker's own information state: BS_a is Arsky's belief state. And x is the murderer of Smith and Jones, y the murderer of Smith, and z the murderer of Jones. x is a composite individual concept from y and z . This is expressed as $y \cap z$. Since an individual concept is assumed to be a set of pairs of a possible world and an individual, a composite individual concept of two individual concepts will be the intersection of the two concepts. We assume that the speaker's own information state is given, together with the three individual concepts, before the discourse begins. When the speaker utters the first conjunct in (13a), u is introduced in the main context of the CG by the property of murdering Smith. This might correspond to x or z in his own information state, but only z is supported by the property of murdering Jones and trivially maximal. So u corresponds to z at the moment. If a pronoun takes u as its antecedent now, it

⁴ The reason is that accessibility defined with respect to DRSs does not account for all anaphora observations. Normally a discourse referent in the main context is accessible for a pronoun in a belief context, but it is not the case in (13b) and (13c). So all accessibility relations of variables must be specified for each context.

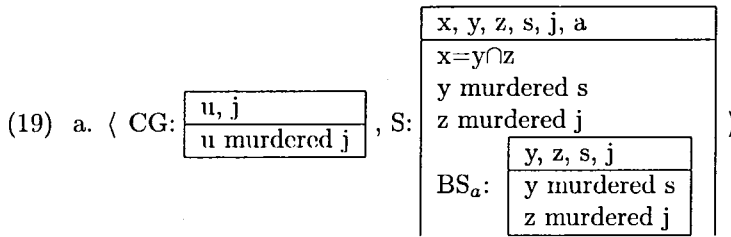
refers to *the murderer of Jones*. When the second conjunct is uttered, we get (17b). The speaker uses the pronoun *he* in Arsky's belief statement to refer to *u*. This pronoun is felicitously used if the second conjunct is true with the pronoun referring to *z* in the BS_a of S. This is exactly what the discourse representation structure (17b) above shows, so the use of the pronoun is felicitous and the sentence is true.

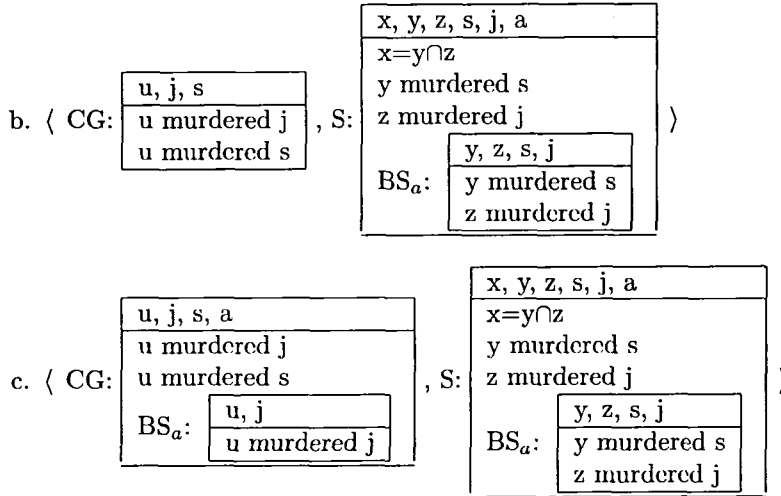
Consider (12). When the first conjunct is uttered, we get (18a).



In (12), the first conjunct introduces *u* by the property of murdering Smith in the main context of the CG. Only *y* is supported by the property in S's information state. If a pronoun takes *u* as the antecedent now, it refers to *y*. The speaker utters the second conjunct using a pronoun in Arsky's belief statement to refer to *u*, which results in (18b). But the second conjunct is not true in S with the pronoun referring to *u* because *y* did not murder Jones in BS_a of S. This is why the whole statement is false. In this example, the selection of *y* is determined in the main context of the CG, and the pronoun is supposed to refer to this.

Finally, consider (13b). When the first sentence is uttered we get (19a).





In (19a) *u* corresponds to *z* because *z* is the only one that is supported by the property of murdering Jones. If a pronoun takes *u* as its antecedent now, it refers to *z*. The second sentence includes such a pronoun, so it must be verified with the pronoun referring to *z*. The three individual concepts are different, but in the speaker's information state, *x*, *y* and *z* denotes the same individual. The situation can be roughly illustrated as follows.

(20)

	w_1	w_2	w_3	w_4	w_5	w_6
the murderer of Smith	a	b	a	c	c	e
the murderer of Jones	c	e	a	c	b	a
the murderer of Smith and Jones			a	c		
speaker's information state	—————					
Arsky's belief state	—————					

In the speaker's information state the three individual concepts denote the same individual for each possible world, whereas in Arsky's belief state *the murderer of Smith* and *the murderer of Jones* denote different individuals in each possible world. Since *y* and *x* murdered Smith, *z* also murdered Smith, which verifies the second sentence. Now the property attributed to *u* has changed. In (19b) *u* has the property of murdered Jones and Smith, which supports *x*, *y* and *z*. Among these *x* is the maximal. Now if a pronoun takes *u* as the antecedent, it refers to *x*. Arsky's belief statement includes such a pronoun, and in (19c) there is no subject corresponding to *x* in Arsky's belief state. This makes the sentence awkward.

The antecedent of a pronoun may have more information than what the relevant individual concept carries. Consider (3) again. The antecedent of the pronoun has the properties of being Anna and swimming in the pool. But Ralph does not know that the person swimming in the pool is Anna: that is, in the given context the property of being Anna cannot be a distinctive property by which Ralph tells Anna from other individuals, regardless of whether Ralph knows who Anna is. Instead the property of swimming in the pool is the distinctive property by which

Anna is linked to Beth in Ralph's belief state. This shows that some property contributes to the determination of a relevant individual concept and others do not. The difference depends on whether the property contributes to the identification of an individual in the speaker's information state. We do not have to look into what properties contribute to the determination of a relevant set of individual concepts. We simply assume that a set of individual concepts is given in the speaker's own information state, and the information in the common ground selects one among them.

I have claimed that a pronoun refers to an individual concept introduced by its antecedent, and that it connects individuals or subjects in more than one information state. We saw that an individual concept is determined by some distinctive property which picks out a unique individual in each world. There should be some motivation for this connection between the use of a pronoun and the property by which the antecedent is introduced. Some rough idea is suggested in Boër and Lycan (1986). They proposed the following as the representation of 'knowing who *d* is':

$$(21) \exists \alpha [Impname(\alpha, d, P) \wedge \exists \beta [\mathbf{R}](\beta, d) \wedge K_S(\beta \text{ is } \alpha)]$$

Knowing *who* is the crucial property of having some individual in mind, which is required for anaphora across different epistemic states. Here α is the name of *d* and carries the property of the individual *d* for a purpose *P* in the context, and β is another name for the individual *d* to the speaker. β rigidly designates the individual *d* and the speaker knows that β is α . Here α is some property shared by the speech community which is believed to pick out the individual *d* for the purpose *P* determined by the context. This can be taken to be the property which connects two different subjects in two different information states or belief states, because it is shared among the conversational participants. On the other hand, β carries some property which the speaker attributes to α . Boër and Lycan's (1986) proposal may not be complete, but it implies at least that there should be some shared property which allows us to connect two different subjects in different contexts. This corresponds to the notion of individual concept.

In the example about two murder cases, the individual Arsky has in mind has the property of being a man who killed Smith. For the same individual there should be some property which is shared by other members of the community than Arsky. In this example at hand, it is the same as what Arsky believes about the same individual: the property of being the man who killed Smith. It is true that in the actual world the object at hand has another property that he killed Jones, but it should not be mentioned because the speaker knows that the already mentioned property corresponds to what Arsky knows about the individual Arsky has in mind, and, more importantly, if the additional property were mentioned, the richer name (or property) for the individual does not correspond to anyone in Arsky's belief state. For this reason, the pronoun in Arsky's belief state can refer to the man who killed Smith only when the first property is mentioned. One thing to add here is that even though the object is represented as something like 'the man who killed Smith' in Arsky's belief/knowledge state, it is introduced by an indefinite in a discourse because it is not part of the common ground.

I tried to show that a pronoun refers to the individual concept determined by the properti(es) attributed to the individual the speaker has in mind. But there is something missing here. When a pronoun refers to an individual concept, intuitively it is supposed to be the same individual as its antecedent, but this intuition is not captured in the denotation of an individual concept: for an individual concept two possible worlds may determine two different individuals. Still epistemically we take them to be the same individual. That's why a pronoun is used to refer to its antecedent. This intuition can be captured in the more complex notion of *character*. Let's consider the following example.

- (22) ??Alberta believes that only one dragon ate her petunias, but she only imagined it.

In each world of Alberta's belief context, there is a unique dragon which ate Alberta's petunias. This would make something denotationally similar to the definite individual concept over all possible worlds in Alberta's belief state. But this is not referred back to by a pronoun in the main context. The dragon in each of Alberta's belief worlds is not taken to be the same. This is contrasted with a case where a pronoun in the main context can refer to an individual in a belief context.

- (23) Alberta believes that a dragon ate her petunias, but she only imagined it.

In this example, the dragon in Alberta's belief context can be referred to from the main context. This does not mean that the indefinite has wide scope over the belief operator. The sentence does not entail that the dragon exists in the actual world.

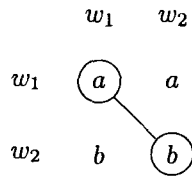
The sentence with an indefinite description can be paraphrased as follows:

- (24) There is a dragon that Alberta believes ate her petunias.

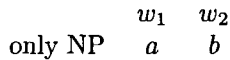
Here the sentence does not entail the existence of a dragon in the main context. This does not pose any problem when we assume a variable ranges over individual concepts.⁵ A difference between (22) and (23) is that in the second example, the indefinite description introduces a specific indefinite which is taken to be the same individual whereas in the first example, the quantifier with *only* is not taken to be the same individual. This difference is not captured in the notion of individual concept. It may be necessary to introduce something like *two-dimensional* theory of reference proposed by Kaplan (1989) and Stalnaker (1979). This can be illustrated in the following.

⁵ For this case Fodor (1970) proposes another existential quantifier which does not entail ontological existence. We can suppose that the existential quantifier does not quantify over individuals in the actual world, but over individual concepts, as suggested by Saarinen (1978) for intentional identity between two belief subjects. Aloni (1997) also proposes, in dynamic semantics, that variables and quantifiers range over individual concepts.

(25) a (specific) dragon



(26) only a dragon



The indefinite description is metaphysically a rigid designator for each context w_1 and w_2 , but it may refer to two different individuals a and b epistemically. For a proper communication, the hearer derives the *diagonalization* of the two-dimensional reference, which is regarded as what the speaker intends to mean in the current context. The diagonalization gives us $\{\langle w_1, a \rangle, \langle w_2, b \rangle\}$. On the other hand, the expression *only one dragon* plus the rest of the sentence simply gives us an individual for each of Alberta's belief worlds. But this is not taken to be the same individual at all. In w_1 , the unique dragon which ate Alberta's petunias is a by accident, and in w_2 it is b . It was not meant to be the same individual. This explains why an individual concept is not a rigid concept even though it is intended to refer to the same individual.

2.2 Anaphora between attitude contexts

In this subsection, we will consider anaphora between two attitude contexts. This phenomenon was first discussed by Geach (1967), and there have been some attempts to explain it in static and dynamic semantics under the name of intentional identity. Let's consider Geach's own example.

(27) Hob thinks one witch blighted Bob's mare, and Nob thinks she killed Cob's sow.

On the intended reading of this sentence, it can be true even when there is no woman or any existing individual about which Hob or Nob has the relevant beliefs. This is illustrated in the following Geachian story:

Last night, Bob's mare became quite ill. Hob, who tends Bob's barn, inferred that a witch blighted her. This morning Hob said to his friend, Nob, "A witch blighted Bob's mare." Nob believes what Hob has told him. He thinks for a moment, and says, "Cob's sow died early this morning. I'll bet the same witch killed the sow, too." But in fact both animals fell ill due to perfectly natural causes. (Edelberg 1986, 1f)

In the framework of traditional Montague semantics, the pronoun in the second clause must be bound by the quantifier introduced by the indefinite description *a witch*. But when there is no individual in the actual world which corresponds to

the witch in Hob's and Nob's belief state, it is not easy to get a representation in which the pronoun is bound by the quantifier. The following translations are attempts to represent the tentative meanings of the sentence in the traditional semantics:

- (28) a. $Bel(h, \exists x[W(x) \wedge BBM(x)]) \wedge Bel(n, KCS(x))$
 b. $Bel(h, \exists x[W(x) \wedge BBM(x) \wedge Bel(n, KCS(x))])$
 c. $\exists x[W(x) \wedge Bel(h, BBM(x)) \wedge Bel(n, KCS(x))]$
 d. $\exists x[Bel(h, W(x) \wedge BBM(x)) \wedge Bel(n, KCS(x))]$

In (28a) the variable x is not bound by the existential quantifier, so it is not a well-formed formula. Representation (28b) is not what is intended by the sentence because Nob's belief cannot be part of Hob's belief: Hob does not know what Nob believes. Representation (28c) is not what the sentence means because the witch does not exist in the actual world. Finally representation (28d) is not the correct representation because it entails the existence of an individual which corresponds to the witch about which Hob and Nob have the beliefs.

Saarinen (1978) tried to account for intentional identity attributions by assuming that the variables range over *individual concepts* and that the concepts do not have to be instantiated in the actual world. This would be the notion we need for correspondence between subjects across attitude contexts. One problem pointed out by Edelberg (1986), however, was that it cannot explain asymmetry in anaphora in the following case, which is very similar to (11-12):

Arsky and Barsky investigate the apparent murder of Smith, and they conclude that Smith was murdered by a single person, though they have no one in mind as a suspect. A few days later, they investigate the apparent murder of a second person, Jones, and again they conclude that Jones was murdered by a single person. At this point, however, a disagreement between the two detectives arises. Arsky thinks that the two murderers are completely unrelated, and that the person who murdered Smith, but not the one who murdered Jones, is still in Chicago. Barsky, however, thinks that one and the same person murdered both Smith and Jones. However, neither Smith nor Jones was really murdered. (Edelberg 1995, 317)

In this situation, the first sentence in the following is true, but the second one is not. Edelberg calls this problem the *asymmetry problem about intentional identity*.

- (29) Arsky believes that someone murdered Smith, and Barsky believes *he* murdered Jones.
 (30) Barsky believes that someone murdered Jones, and Arsky believes *he* murdered Smith.

These two sentences can be translated into the following:

$$(31) \exists x Bel(a, Px) \wedge Bel(b, Qx)$$

$$(32) \exists x Bel(b, Qx) \wedge Bel(a, Px)$$

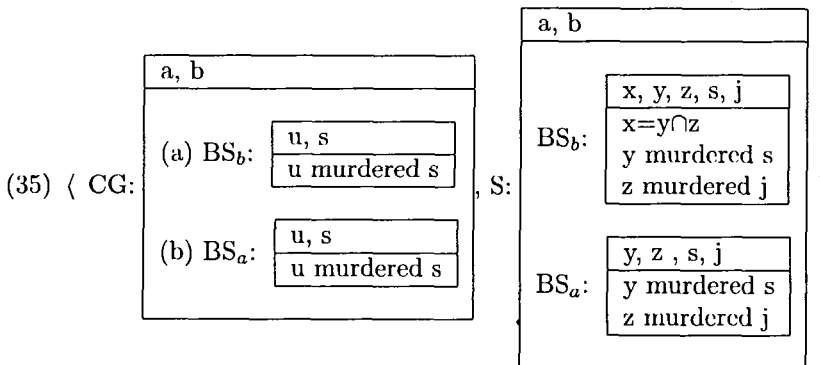
Under the analysis of intentional identity by individual concepts, the two representations could have the same truth value with respect to the individual concept *the murderer of Smith*.⁶

As I said, however, the problem can be solved when we assume that the discourse determines the relevant individual concept for the statement.⁷ Consider the following examples.

(33) Barsky believes that someone murdered Smith, and Arsky also believes *he* murdered Smith.

(34) ??Barsky believes that someone murdered Smith and Jones, and Arsky also believes *he* murdered Smith.

(33) is true while (34) is not acceptable. Compared with (30), these examples show that the use of a pronoun is affected by the discourse or the common ground formed by the discourse. The speaker's own information state provides a set of individual concepts which can be relevant in the discourse. And the discourse itself selects one of them by the information exchanged in it. These can be shown below. First, consider (33).



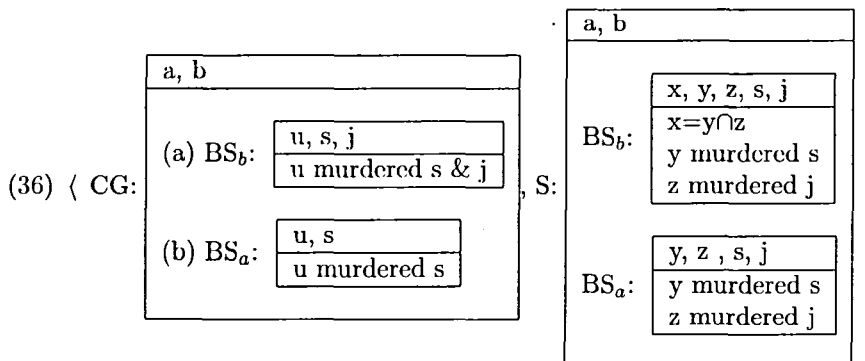
In these examples, a set of possibly relevant subjects is given in S: *x is the murderer of Jones and Smith, y the murderer of Smith and z the murderer of Jones*. In S,

⁶ Van Rooy (2000) calls this problem *symmetry problem*.

⁷ Edelberg (1992, 1995) uses the notion of subject instead of individual concept. A difference between subjects and individual concepts is that the former is defined with respect to a belief state while the latter is defined with respect to all possible worlds. In the analysis in terms of subjects, anaphora is a matter of counterpart relation between subjects, as proposed in van Rooy (2000). Using the notion of subject, Edelberg claims that even for Barsky the subjects associated with *the murderer of Smith* and *the murderer of Jones* should be distinct. This might not be the case in Barsky's belief state, because we could say that in Barsky's belief state only one subject exists and if a pronoun is used, it is expected to refer to that subject.

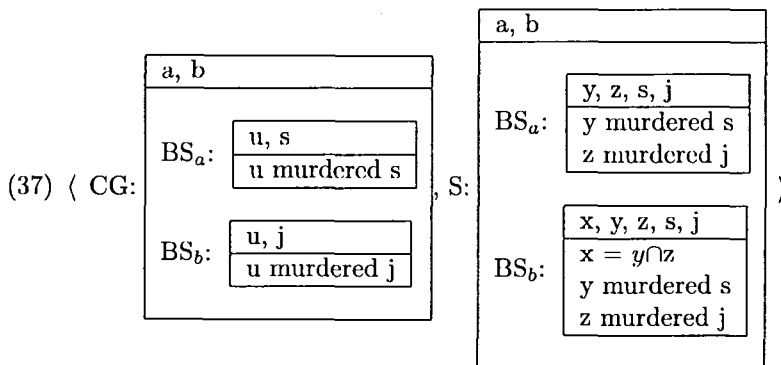
x in BS_b does not correspond to any subject in BS_a .⁸ In (33), the utterance of Barsky's belief statement introduces u in BS_b of the CG. The property attributed to u is murdering Smith, which supports only y . When the speaker uses a pronoun in Arsky's belief context taking u as the antecedent, Arsky's belief statement must be true with the pronoun referring to y in S . This is supported because y in BS_a of S murdered Smith.

Now consider (34), whose representation is given below. The account is similar to that of (13b).



Here the speaker introduces u in BS_b of the CG by the first conjunct, which results in (a) in (36). The property attributed to u in BS_b of the CG is murdering Smith and Jones, which supports the individual concepts x , y and z . The individual concept x is the maximal. Arsky's belief statement is uttered in which a pronoun refers to u , so it must be verified with respect to x . But there is no individual concept that corresponds to x in BS_a of S . So the use of the pronoun is not felicitous.

Next, consider (29), in which denotations of individual concepts are involved, as in (13b).



The speaker introduces u in BS_a of the CG by the property of murdering Smith, which supports only y . When the speaker uses a pronoun in Barsky's belief state

⁸ This correspondence relation is different from the one van Rooy (2000) posits. I will show below my position is right.

taking u as the antecedent, it refers to y and Barsky's belief statement means that y murdered Jones in Barsky's belief worlds. In BS_b of S , however, y did not murder Jones, but z did. In Barsky's belief state, on the other hand, y and z makes x . This means that y , z and x are the same individual in BS_b of S , as in (20). This is shown below.

(38)

	w_1	w_2	w_3	w_4	w_5	w_6
the murderer of Smith	a	b	a	c	c	e
the murderer of Jones	c	e	a	c	b	a
the murderer of Smith and Jones			a	c		
Arsky's belief state	_____					
Barsky's belief state	_____			_____		

The three individual concepts are different, but they denote the same individuals in Barsky's belief worlds. Even if the common ground selects *the murderer of Smith* as the relevant individual concept, it denotes the same individual as the other two individual concepts in each possible world in Barsky's belief state of the speaker's information state. So in BS_b , if y murdered Smith, it means that z murdered Smith. The same individual makes Barsky's belief statement true.

So far I have analyzed various examples on the basis of (14), but one problem is that when an individual concept is used as the referent of a pronoun, the agent of a belief state is supposed to know the information carried by the individual concept. But sometimes this is not the case. Consider the following situation.

Monday: Smith and Jones have been shot, at opposite ends of Chicago/ Arsky and Barsky are investigating both cases, but neither knows that Smith is the mayor or that Jones is the commissioner. Smith and Jones, though hospitalized, are (and are known by both detectives to be) still alive. Arsky and Barsky have discussed the two cases at length, and though they think someone shot Smith and that someone shot Jones, both believe the two cases are entirely unconnected. At this time, neither has anyone in mind as a suspect.

Tuesday: Both Smith and Jones have died of their gunshot wounds. Arsky knows Smith died, and thus now believes that the person who shot Smith murdered him, but doesn't know Jones is dead. Likewise, Barsky knows Jones died, and thus now believes that the person who shot Jones murdered him, but doesn't know Smith is dead. After reflecting on certain similarities between the two cases, Barsky infers that the man who shot Smith is the same person as the man who shot Jones. He communicates this to Arsky, saying, "The man man who shot Smith is the man who shot Jones." Arsky disagrees, but Barsky persists in his opinion. (Edelberg 1986, 16f)

In this situation, (29) is still true and (30) false. But (29) and (30) cannot be evaluated with respect to *the murderer of Smith* and *the murderer of Jones* respectively. Arsky does not know that Jones was murdered, so in Arsky's belief state,

(40) Felicity Condition on Anaphora (final):

Given a set of individual concept $I \subseteq IC$ in the context a pronoun p_x in a context bs takes its antecedent NP_x in a context bs' if and only if

- (i) there is a maximal individual concept $ic \in I$ such that ic is supported by the subject for x in the bs of the *common ground* and (ii) there is a *unique* individual concept ic' such that ic' denotes the same individuals as ic and ic' connects two subjects from the pronoun and its antecedent in the *speaker's information state*.

In most cases where the maximal individual concept supported by the subject from the antecedent connects two subjects for the pronoun and the antecedent, ic and ic' are identical. This was the case in previous situations we considered earlier. In the new situation we are considering, ic is different from ic' . In (39) *the murderer of Smith* corresponds to ic and *the shooter of Smith* to ic' .

In my analysis, the individual concept in the common ground restricts the relevant individual concept based on a somewhat semantic relation. When a speaker identifies some individual in one belief state with another in another belief state, it is plausible to suppose that the speaker knows something common between the two subjects, even if the two different subjects have quite different attributions in other respects. Consider the following examples.

- (41) John: A man fell off the bridge yesterday.
Mary: He didn't fall off, he was pushed.

- (42) John thinks that a man fell off the bridge yesterday, but Mary thinks that he was pushed.

In the dialogue, the two interlocutors talk about a man, but the two men are quite different. In John's statement the property attributed to the man is quite different from what Mary knows about him. But Mary also knows what other people (including John) know about the man, and there is some common attribution to the man between Mary herself and other people: something like 'being a man whose body fell off the bridge'. That attribution contributes to the formation of an individual concept that connects the man in her own information state and other people's belief states. Notice that the two men are in Mary's own information state, not in Mary's and John's information states separately. This shows that anaphora in a dialogue is not quite different from anaphora across attitude contexts. For this reason, we do not need a common ground between two contexts to account for anaphora across the two contexts, even in a dialogue situation.⁹ This situation can be reported as in (42). John's and Mary's belief states are in the speaker's information state, and the speaker knows that there is some shared knowledge between them, even though there is no common ground between them.

⁹ I suppose that this provides the solution to the problem of source of information. Zimmermann (1998) proposes that two subjects are counterpart of each other if they represent the same source. For a given counterpart or correspondence, the speaker may add new information but it should not change the original counterpart/correspondence relation, even when the added information in two belief states is contradictory with each other.

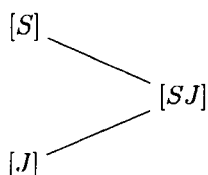
3. Comparisons with Previous Analyses

A couple of attempts have been made recently to account for intentional identity within dynamic semantics. One is van Rooy's (2000) and Dekker's (1997) analyses. I will briefly compare them with mine.

The basic idea of van Rooy's analysis is that there is a counterpart relation between subjects derived in different belief states. He claims that two subjects can be counterparts of each other only if they have the same source, following Zimmermann (1998). And a subject in one belief state can have more than one counterpart in another belief state. It is observed in Arsky-Barsky example. Barsky's *murderer of Jones and Smith* is a counterpart of both Arsky's *murderer of Jones* and *the murderer of Smith*.

(43) Counterpart relations:

Arsky Barsky



[S] = the murderer of Smith; [J] = the murderer of Jones; [SJ] = the murderer of Smith & Jones

Van Rooy tries to explain the asymmetry problem by using a *supervaluation* account of truth, following van Fraassen (1966). That is, a sentence is true (false) if and only if it is true (false) for all admissible ways of picking out counterparts. In (29), the subject of *the murderer of Smith* in Arsky's belief state has only one counterpart in Barsky's belief state, and the sentence is true because the sentence is true for that counterpart. In (30), the subject in Barsky's belief state has two counterparts in Arsky's belief state, and the sentence is true only for one counterpart.

His analysis cannot explain why the following sentence is true.

(44) Barsky believes that someone murdered Jones, and Arsky also believes that he murdered Jones.

This sentence is also true only for one counterpart between the subjects in Arsky's and Barsky's belief states. Van Rooy also mentions a similar example like (45), and says that a sentence must be interpreted with respect to *conversationally relevant* counterparts, without specifying how they are determined.

(45) Barsky thinks that someone murdered Smith, and Arsky thinks that he didn't murder Jones.

But this is not simply a problem of selecting relevant counterpart functions. Suppose that Arsky believes that both *the murderer of Jones* and *the murderer of*

Smith are in Chicago. In this case, the following sentence should be true in his analysis because the sentence is true for all possible counterparts.

- (46) Barsky thinks that someone murdered Smith and Jones, and Arsky thinks that he is still in Chicago.

But our intuition says that the sentence is odd. The problem comes from the fact that in Arsky's belief state there is no counterpart to the relevant subject (i.e., *the murderer of Smith & Jones*) in Barsky's belief state, contrary to what van Rooy claims. And this is exactly what I propose in this paper.

In dealing with subjects in belief states, van Rooy introduces the notion of belief object, and a belief object is introduced by a variable in the main context. He assumes that the information associated with a variable is the function from world-assignment pairs to objects. So for a subject in some belief state, two variables are assigned: one for the main context to refer to the subject and the other for the belief state to refer to an object for each possible world in the belief state. So $Bel(a, \exists xA)$ is interpreted as if it were of the form $\exists xBel(a, A)$. What is the actual meaning of the variable introduced in the main context for a subject? This complexity comes only for technical reasons. This should be avoided if possible. In my analysis, I use the notion of individual concept, which allows us not to embed a variable for a subject in an attitude/belief context but allows us to refer to across attitude contexts. This does not mean that it also allows a variable in a belief context to be accessible for a pronoun in the main context. The reason is that an individual concept for a variable introduced in a belief context is a function whose domain does not coincide with the set of possible worlds which constitute the main context. This prohibits a pronoun in the main context to refer to the variable in the belief context.

Finally, van Rooy deals with two types of objects: normal individuals and belief objects, but the notion of counterpart between subjects (or, belief objects) is not adequate for cases where the antecedent is in the main context and a pronoun occurs in an attitude context. It is implausible, if not impossible, to say that a belief object in an attitude context has a normal individual in the main context as its counterpart, even if the normal individual can be converted into a rigid concept, as he actually does.¹⁰ As discussed above, however, there is no essential difference of anaphora between cases where the antecedent is in the main context and cases where the antecedent is in an attitude context. The use of the notion of subject (or, belief object) forces us to deal with those two different cases separately without much motivation.

Dekker (1997) also proposed an analysis of intentional identity. He assumes that all natural language terms (definite and indefinite NPs alike) relate to specific subjects in the information state of a speaker when a speaker introduces a subject in the discourse, and when another speaker intends to refer to that subject, the reference is not a coreference but a counterpart relation between the subject and

¹⁰ According to Hintikka (1962, 1969), a belief context is derived by the relation of doxastic alternativeness, and for an agent there is one-to-many relation between a possible world and the belief state of that agent from the world. The one-to-many relation also applies to referents of noun phrases.

a subject he has in his own mind. This is a case of intentional identity between two speakers. Dekker calls this Hob-Nob situation, which is distinguished from Hob-Nob sentences. In a Hob-Nob sentence, however, it is the single speaker who is responsible for the counterpart relation. He supposes that in the speaker's information state the common ground of Hob's belief state and Nob's belief state is derived, and the anaphora resolution takes place in this common ground. In Hob-Nob situation, the source of counterpart relation is the speaker's intention to refer to the subject in the other speaker's subject. But in Hob-Nob sentence the counterpart relation is characterized by means of the source relation: that is, the two subjects come from the same source, as Zimmermann (1997) and van Rooy (2000) state. In many respects his analysis is quite similar to van Rooy's.

Dekker's analysis does not attempt to give the felicity condition for the use of a pronoun in intentional identity: that is, it does not explain what it means for a pronoun in one belief state is meant to refer to a subject in another belief state. He simply regards counterpart relations as supplied pragmatically. What he ignores is that the discourse itself plays a role in allowing for certain counterpart relations, as we have seen.

Another problem is that for anaphora resolution between belief states, he proposes to derive shared beliefs from the two belief states. But this does not conform to the normal notion of common ground. Information in a common ground is what is shared by the agents relevant, and they know it is shared. But the common ground Dekker derives from the two belief states is not really shared. In the context where intentional identity is considered, one agent may not know what the other agent believes. What Dekker intended to capture by common ground is what is commonly believed by two agents even if they do not know what the other believes. This can be captured by the notion of individual concept in my analysis. The notion of common ground in Dekker's sense is not necessary because all information necessary is in the speaker's own information state. This is the case even with the Hob-Nob situation, as I discussed in (41–42).

4. Conclusion

In this paper, the main point is that in using a pronoun felicitously the discourse itself plays an important role. To specify the condition on the use of a pronoun, I propose that both the common ground from the discourse and the speaker's own information play a role. The felicity condition exploits the semantic relation of support between subjects or individual concepts. This indicates that a set of individual concepts is a partial order. In a speaker's information state, a set of individual concepts is given and the common ground from a discourse selects a relevant individual concept that links the referent of a pronoun and its antecedent.

Appendix

In this appendix, I briefly give the framework of dynamic semantics in which the phenomena we have observed in this paper can be analyzed.

Let $M = \langle W, D, V, G, F \rangle$ be the model. Here W is a set of possible worlds, D a set of individuals, V a set of variables, G a set of assignments, and F an interpretation function for constants in a language. An assignment $g \in G$ is a set of pairs $\langle x, ic \rangle$ such that for every $x \in \text{dom}(g)$ $g(x) = ic$. ic is a *partial* function from a subset of W to D . An individual concept can be undefined with respect to some possible worlds in W .

Information about an individual is carried by a subject in an information state, and I assume that a variable is a formal counterpart of the subject.

A variable assignment is a possibility which determines the value of a variable (or, a pronoun in natural language) in a discourse. A variable assignment is a function from a set of variables to a set of individual concepts.

$G = \{IC^X \mid X \subseteq V\}$, where V is a set of variables.

$IC = \{D^U \mid U \subseteq W\}$, where D is a set of individuals and W a set of possible worlds.

An individual concept is a partial function from a set of possible worlds to a set of individuals because an individual concept may not have a value in some possible worlds.

Each information state is a pair of (i) a set of possible worlds and (ii) a set of variable assignments (a set of functions from a set of variables to a set of individual concepts).

$$s_A \in \{\langle U, E \rangle \mid U \subseteq W, X \subseteq V, E \subseteq IC^X\}$$

By assuming that a variable ranges over individual concepts, we can separate world information and discourse information in the representation of a context. And all variables, in whatever contexts they are introduced, are contained in E .

When a conversational participant A is in a discourse, he is in the following information state:

$\langle \langle U, E \rangle, \langle U', E' \rangle \rangle$, where the first pair is the common ground, and the second A 's own information state.

A 's statement only changes the first pair which anyone else's changes both pairs. Under the assumption that the two information states have the same variables for the same subjects, the relation between the two information states can be represented as follows:

If $\langle \langle U, E \rangle, \langle U', E' \rangle \rangle$ is an information state of someone in a discourse, then $\langle U', E' \rangle$ supports $\langle U, E \rangle$.

$\langle U', E' \rangle$ supports $\langle U, E \rangle$ iff $U' \subseteq U$ and for every $x \in \text{dom}(E)$, $[x]_{\langle U', E' \rangle} \subseteq [x]_{\langle U, E \rangle}$
 ($[x]_s$ will be defined below.)

The common ground is updated by the following rules.

$$\begin{aligned}
\langle U, E \rangle [Rxy] &= \langle \{w \in U \mid \exists g : g \in E, \langle g(x)(w), g(y)(w) \rangle \in F(R)(w)\}, \\
&\{g \in E \mid \exists w : w \in U, g(x)(w) \in F(P)(w)\} \rangle \\
\langle U, E \rangle [-\phi] &= \langle U \setminus W(\langle U, E \rangle [\phi]), E \setminus \{g \in E \mid \exists g^+ : g^+ \in G(\langle U, E \rangle [\phi])\} \rangle \\
\langle U, E \rangle [\exists x \phi] &= \langle U, \{g \cup g' \mid g \in E, g' \in IC^{\{x\}}\} \rangle [\phi] \\
\langle U, E \rangle [\phi \wedge \psi] &= \langle U, E \rangle [\phi] [\psi] \\
(W(\langle U, E \rangle)) &= U; G(\langle U, E \rangle) = E
\end{aligned}$$

For an assignment g , $g^+ = g \cup g'$, where g' is a member of IC^X for some domain $X (\subseteq V)$ of variable assignment.)

For an individual d , d 's pointwise belief state $PBS_{\langle U, E \rangle}(d)(w)$ in a possible world $w \in U$ in the current context $\langle U, E \rangle$ is $\langle dox_d(w), \{ \langle y, ic \rangle \in E \mid \forall w' \in dox_d(w) : \exists d : \langle w', d \rangle \in ic \} \rangle$.

For an individual d , d 's global belief state $GBS_{\langle U, E \rangle}(d) = \bigcup_{w \in U} PBS_{\langle U, E \rangle}(d)(w)$
 $\langle \langle U, E \rangle \cup \langle U', E' \rangle = \langle U \cup U', E \cup E' \rangle$

Now the interpretation of a belief statement is given below:

$$\begin{aligned}
\langle U, E \rangle [Bx\phi] &= \bigcup_{w \in U} \{ \langle \{w\}, E + (F' - F) \rangle \mid \langle T, F \rangle = PBS_{\langle U, E \rangle}(x)(w), \langle T, F \rangle [\phi] = \\
&\langle T, F' \rangle \} \\
E - F &= \{ g \setminus g' \mid g \in E, g' \in F, \forall x \in dom(g') : g(x) = g'(x) \} \\
E + F &= \{ g \cup g' \mid g \in E, g' \in F, dom(g) \cap dom(g') = \emptyset \}
\end{aligned}$$

In this model, an individual concept $[x]_{\langle U, E \rangle}$ corresponding to variable x with respect to $\langle U, E \rangle$ is $\{ ic \in IC \mid \exists g : g \in E \ \& \ ic = g(x) \}$.

From this we can derive a subject with respect to an information state $\langle U, E \rangle$:

A subject $[x]_{\langle U, E \rangle}^s$ corresponding to variable x with respect to $\langle U, E \rangle$ is $\{ \langle w, d \rangle \in ic \mid w \in U \} \mid ic = [x]_{\langle U, E \rangle}$.

The uniqueness condition requires this set to be a singleton set.

Felicity Condition on Anaphora:

Given a set of individual concept $I \subseteq IC$, a pronoun p_x in a context BS_a can refer to its antecedent NP_x in a context BS_b in the information state $\langle \langle U, E \rangle, \langle U', E' \rangle$ iff (i) there is a maximal individual concept ic such that $[x]_{GBS_{\langle U, E \rangle}(b)}^s$ supports ic and (ii) there is a unique ic' such that ic supports ic' and $GBS_{\langle U', \{g[x/ic'] \mid g \in E'\} \rangle}(a) = GBS_{\langle U', E' \rangle}(a)$ and $GBS_{\langle U', \{g[x/ic'] \mid g \in E'\} \rangle}(b) = GBS_{\langle U', E' \rangle}(b)$

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