Reasoning with Generics Based on Truth-Conditional Semantics*

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Generics have been analyzed in two main trends. In this paper, they are analyzed in the truth-conditional semantics. One major problem with previous truth-conditional analyses is that they did not make correct predictions on reasonable inferences, especially on inferences related to so-called graded normality. And so far negations of generics, which I call weak generics, have not been seriously handled. In this paper, I propose a truth-conditional analysis which considers weak generics as well as strong generics and allows us to account for nonmonotonicity in reasoning with generics, and in doing this, I introduce the notion of minimal world/frame and constrain a frame with regard to each generic sentence including weak generics. It will be shown that weak generics may make a frame inconsistent, but they have significant effect only when they are exceptions to other generic sentences.

Key words: generic, default logic, nonmonotonic, truth-conditional, normal conditional

1. Introduction

So-called genericity includes two distinct phenomena. Krifka (1987) called them i(ndefinite)-generic and d(efinite)-generic. D-generics are statements which convey properties which could be attributed only to a kind. Sentences in (1) are examples:

(1) a. <u>This tiger</u> is in danger of extinction.
b. <u>The potato/Potatoes</u> was/were introduced into Ireland by the end of the 17th century.

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The underlined NPs do not refer to a specific individual tiger or potato. They are kind-referring NPs. I-generics are statements which attribute a property to an individual as well as a kind.[1]

(2) $\left(\begin{array}{l}\text{The apple}\\ \text{An apple}\\ \text{Apples}\end{array}\right)$ contain(s) vitamin C.

The property of containing vitamin C can be attributed to an individual apple as well as the apple as a kind.[2] I-generics are also called characterizing sentences. In this paper we are only concerned with characterizing sentences, and I will simply call them generic sentences (or generics).

There have been proposals for analyzing generic sentences. One is the large amount of work that has been done under the rubric nonmonotonic logic. (Reiter 1980, Moore 1984, McCarthy 1980, etc.) Nonmonotonicity is a pattern of reasoning that a theory of generic sentences should capture. By the term, we mean that one draws a conclusion at one incomplete information state, and retracts it when given new evidence against it. Nonmonotonic logic tries to provide a formal mechanism for this process of reasoning. In this tradition generic sentences are rules which guide us to make valid inferences from a given set of facts: they are not truth-conditional statements like episodic statements. Veltman (1996) can be said to follow this tradition in that he claims that generic sentences are not truth-conditional.

A second tradition is the one in which it is assumed that generic sentences are truth-conditional and they are analyzed as a type of conditionals. Still in this tradition, generic sentences play a role in

1) Heyer (1985) makes a slightly different distinction. Krifka distinguishes generics according to the NPs which are characterized by the rests of the sentences. On the other hand, Heyer classifies generics according to whether the predicate requires a kind-referring subject or not. If a predicate requires a kind-referring subject, it is called a simple generic. Otherwise, it is called a personal generic. A sentence like *The apple contains Vitamin C* is a D-generic because the subject *the apple* is a kind-referring NP, but it is a personal generic because the predicate *contains Vitamin* C can be predicated of an individual.

2) The indefinite article *a(n)* cannot be used to refer to a kind. So sentence (i) is ungrammatical.

(i) A potato was introduced into Ireland by the end of the 17th century.

making inferences: they are also rules and regulations which form real part of the world, as Carlson (1995) pointed out. This means that generic sentences are non-accidental but contingent generalizations: that is why the following sentences are not taken to be true.

(3) Dogs are black and white.
Students live near the campus.

Being black and white is not regarded as a property that a dog is expected to have and neither is living near the campus as a property of a normal student. There should be causal forces behind the array of the observed instances. In the conditional-analysis of generic sentences the causal relation is captured by the relation between possible worlds. Despite the relationship between possible worlds, generics are contingent statements, just like conditionals.

There is a third analysis for generic sentences which is taken to be more practical. Recently Cohen (1999a, b) argues that generics express probability judgments. He analyzes generics just like sentences with the frequency adverb *usually* with minor provisos. He is against the conditional-analysis of generics by claiming that generics is intensional only with respect to time indices. His analysis, as presented in the paper, does not say anything about how we make inferences based on generic sentences.

In this paper I follow the conditional-analysis of generic sentences because it is the only way of capturing the dual roles of generic sentences: both as a statement which describes the world and as a rule to follow in making an inference. But I do not know of any analysis which accounts for both of the aspects systematically. And also there is no analysis which considers the negation of a generic sentence extensively. I am going to propose an analysis in which the truth-conditions of generic sentences and inferences from generic sentences are systematically related. In doing it, I will consider the negations of generic sentences extensively, and discuss how they affect our inference from a given set of propositions. In chapter 2, I will discuss motivations for analyzing generics in a modal conditional approach. In chapter 3, I will give the truth condition of a generic sentence, and the conditions on the whole set of generic sentences which are true in a possible world. Here the consideration of the negations of generics is quite important. In chapter 4,

I discuss how an inference is made from a given set of propositions. In doing this, I do not rely on a separate informational processing of generic sentences, but on the frames themselves which verify the generic sentences known at the moment. Here I use the notion of "minimality." In chapter 5, I will show how known patterns of inference can be explained in my analysis. In chapter 6, I summarize the whole paper.

2. Modal Conditional Approaches

Delgrande (1987) first made an attempt to analyze generic sentences as conditionals. Other conditional approaches include Asher and Morreau (1991, 1995) and Boutilier (1994). In the analysis of conditionals, a selection function is used to capture non-accidental/causal generalizations of generic sentences. Conditionals in natural language are variably strict conditionals, as shown in Lewis (1973). Consider the following conditionals.

(4) If John comes to the party, it will be fun.
If John and Mary come to the party, it won't be fun.
If John, Mary, and Sue come to the party, it will be fun.

As the conditions expand, the previous conclusions are retracted and the opposite conclusions can be drawn. This is what we normally observe in inferences from generic sentences.

(5) a. Birds fly. Tweety is a bird. Then presumably Tweety flies.
b. Birds fly. Tweety is a bird, <u>Tweety is a penguin.</u> <u>Penguins do not fly.</u> Then presumably, Tweety does not fly.

In (5a), from the two premises, we conclude that presumably Tweety flies. When the underlined premises are added in (5b), we come to the opposite conclusion. This property motivates the same analysis of conditionals and generics.

Asher & Morreau (1991, 1995) claim that generic sentences are truth-conditional. If a generic sentence were merely a directive about what to infer, it would not describe the world. If the meaning of a generic sentence were not defined with respect to a possible world, then it would be almost impossible to derive the meaning of a sentence in which a

generic sentence is embedded.

(6) a. John knows that typhoons arise in this part of the Pacific Ocean.
b. People who like climbing live longer.

In (6a), the whole sentence is truth-conditional, and each part of the sentence must have denotation with respect to a possible world. So the embedded generic sentence must be truth-conditional. In (6b), the denotation of *people who like climbing* must be determined compositionally from the meanings of the head noun and the relative clause. If the denotation of the latter were not determined with respect to a possible world, neither would be that of the whole NP. Analyses in which generics are merely rules and regulations do not tell us how the sentences in (6) are interpreted.

Conditionals are generally analyzed on the basis of the ordering relations of possible worlds, as in Lewis (1973) and Stalnaker (1968). Kratzer (1979, 1981) instead uses sets of propositions in analyzing conditionals. Lewis (1981) calls the two analyses ordering semantics and premise semantics, and shows that they are equivalent except that premise semantics includes surplus information concerning the difference of ties and incomparabilities between possible worlds, which makes no contribution to evaluating conditionals or counterfactuals.

I use premise semantics for various reasons. It is equivalent to ordering semantics, as Lewis said, so I have nothing to lose when premise semantics is used. And, as I will show, a frame needs to be constrained somehow in order to explain the ways we make inferences, given a set of facts conveyed by episodic sentences and (default) rules conveyed by generic sentences. To specify the constraints, it is necessary to consider each generic sentence, not the whole set of generic sentences as a lump. In this context, it is convenient to mention each rule conveyed by each generic sentence.

Before I discuss the conditional analysis of generic sentences, I need to ask if it is on the right track to analyze generics based on modality. Cohen (1999a, b) claims that generic sentences are intensional only with respect to time indices. In doing this he discusses the following examples:

(7) a. A computer computes the daily weather forecast.
b. A computer computes the main news item.

(8) a. Bats fly.
b. Animals which John fears fly.

In (7), even if today's weather forecast is the main news item, the two sentences do not mean the same, because the extensions of the two NPs *the daily weather forecast* and *the main news item* are not always the same. In contrast, the two sentences in (8) mean the same if bats are animals which John fears. If John fears bats, then it can be assumed to be so throughout the time indices, because *fear* is an individual-level predicate. This does not require that the extensions of the two NPs be the same in all possible worlds. Based on these observations, Cohen claims that generics are intensional only with respect to time indices. If this were correct, it would be simply wrong to analyze generics as a type of conditionals.

The examples which Cohen discusses has one thing in common: the alternative NPs are mapped into the Restrictor of the semantic representation of a conditional. The meanings of the two sentences in (8) can be represented as follows:[3)]

(9) a. $\mathrm{Gen}(x)[Bat(x)][Fly(x)]$
b. $\mathrm{Gen}(x)[Animals(x)\ \&\ Fear(j, x)][Fly(x)]$

Notice that $Bat(x)$ and $Animals(x)$ & $Fear(j, x)$ go to the Restrictor. But if the alternative NPs go to the Nucleus, the meanings do not seem to be the same. This is illustrated in the following:

(10) a. John computes the daily weather forecast.
b. John computes Mary's favorite newspaper column.

(11) a. Anteaters eat ants.
b. Anteaters eat animals John fears.

Suppose that computing the daily weather forecast is John's job and that the daily weather forecast is Mary's favorite newspaper column in the actual world. Then can we say that computing Mary's favorite newspaper

3) Which part of a sentence goes to the Restrictor or Nucleus depends on focus. See Rooth (1985, 1995) and Krifka (1995) for more details.

column is John's job? Our intuition seems to say no.[4] Even if ants are the only animals John fears in the actual world, 'Anteaters have the disposition of eating ants' does not mean 'Anteaters have the disposition of eating animals John fears.' The new observations support a conditional analysis of generics on the basis of possible worlds.

3 The Semantics of Generic Sentences

3.1. Language and Model

We deal with natural language, but it is clumsy to discuss the semantics of generics using natural language. So for convenience, we use a first-order language. For a basic first-order language L, we can assume an extended language L_g which includes two operators, $>$and $\triangleright$, related to generic sentences.

The intended meaning of '$\phi > \psi$' is that where ϕ holds, normally ψ holds, too. In general, a generic sentence in natural language involves universal quantification.

(12) Adults are (normally) employed.
$\forall x(A(x) > E(x))$

The English sentence is understood as saying that any adult is expected to be employed if (s)he is a normal adult. So the English sentence is translated into a sentence of universal quantification in L_g, as shown above. The generic sentence changes our expectation about a particular adult when we do not know for sure about whether (s)he is employed. Even though a generic sentence is truth-conditional, it is still a rule to follow in making an inference about a particular individual. For this inference, a new operator $\triangleright$ is used, as a monadic operator. The operator can be taken to be 'presumably' in English. '$\triangleright \phi$' is understood as saying that it is reasonably inferred in the current knowledge state that ϕ, though it is not logically entailed by the knowledge state. The reasonable conclusion is defeasible: as we get more knowledge of facts or default

4) One anonymous reviewer says that the objects in (10) should go into the Restrictor. Those readings are possible construals of the sentences, but they are not what I am interested in.

rules about the world, we may retract the former conclusion without being blamed for doing so.

3.2. The truth-condition of a generic sentence

In order for a sentence $\forall x(P(x) > Q(x))$ to be true, for every individual $a \in D$, if everything normal holds where $P(a)$ holds, then $Q(a)$ holds. To formalize the meaning of a generic sentence, we need to specify rigorously what normally holds where $P(a)$ holds for each individual a. For this purpose, a modal frame f is defined as follows:

Definition 1 For a possible world w, f_w is a function which, for each proposition ϕ, tells us what propositions (or default rules) normally hold in w.

According to the definition, $f_w(\phi)$ is a set of propositions, or (default) rules, which normally hold when ϕ holds. Here and below I do not distinguish a formula and its denotation formally. ϕ is sometimes a formula and sometimes a proposition. And a proposition is a set of possible worlds. If ψ is in $f_w(\phi)$, then it means that $\phi > \psi$ holds in w. So the truth condition of a generic sentence $\phi > \psi$ can be given as follows:

Definition 2 $\phi > \psi$ is true in w iff $\bigcap f_w(\phi) \subseteq \psi$.

Since $f_w(\phi)$ is a set of propositions, the intersection of $f_w(\phi)$ is a set of possible worlds. If ψ is in $f_w(\phi)$, the intersection is a subset of ψ.

We need to define the meaning of another operator $\triangleright$ 'presumably,' which is an operator used in making an inference. As I mentioned, making an inference is a matter of information. '$\triangleright \phi$' is what follows from a given set of facts and rules which is only determined by a context. It is independent of what the actual world is. Let's assume that k is a function which assigns to each possible world a set of propositions which are known to a (group of) individual(s) in that world. So the truth-condition of $\triangleright \phi$ can be roughly given as follows:

Definition 3 $\triangleright \phi$ is true in w iff ϕ reasonably follows from $k(w)$.

Here 'reasonably follow' must be more precisely specified. As previously

mentioned, however, making an inference in relation to generic sentences is nonmonotonic. To see how it works, it is necessary to see what happens when $k(w)$ changes. In this respect, it is of little significance to discuss the operator in static semantics. So I turn it over to the section for the dynamic interpretation of generic sentences below.

3.3. Conditions on frames

The truth condition of a generic sentence is defined with respect to a frame f_w determined by the generic sentences which hold in w. Generic sentences interact with each other, and if some generic sentences are true in w, another generic sentence must, or must not, hold in w. The function f_w must be constrained in such ways that it allows us to account for the relationships between generic sentences. A condition is that for any predicate P, $\forall x(P(x) > P(x))$ holds. In other words, sentences like *Students are normally students* are always true. Asher and Morreau (1995) call it factivity.

Factivity Condition: $\bigcap f_w(p) \subseteq p$.

This implies that for every domain p, $p \in f_w(p)$. This condition is trivial in a conditional analysis of generic sentences. When we evaluate a conditional sentence, we only consider possible worlds in which the antecedent of the conditional holds. So the factivity condition follows.

A second condition is that for a possible world w, the set of propositions $f_w(p)$ be consistent which normally hold where a proposition p holds in a world w. This means that no two incompatible generic sentences can be true at the same time in a world. Consider the following.

(13) Adults are responsible. Adults are irresponsible.
$(\forall x(A(x) > \mathrm{R}(x)); \forall x(A(x) > \neg R(x)))$[5]

If the two sentences were both true in w, then for any adult a, $f_w(A(a))$ could entail 'a is responsible' and 'a is irresponsible.' It is impossible.

5) A text consists of sentences, and punctuations are used between them. When a text is translated into predicate logic, I will use semicolons between formulas.

Things are a little more complicated. One generic sentence can be contradicted by the combination of more than one generic sentence.

(14) a. Adults are responsible. $(\forall x(A(x) > R(x))$
b. Men are not responsible. Women are not responsible either.
$(\forall x(M(x) > \neg R(x)); \forall x(W(x) > \neg R(x)))$

The inconsistency of the three sentences in (14) can be captured only by considering three domains together. The notion of "normal world" serves this purpose. Veltman (1996) defines normal world as follows:

Definition 4 For a frame f_w (of a possible world w), a possible world w' is a **normal world** in d iff for every domain $d' \subseteq d$ such that $w' \in d$, $w' \in \cap f_w(d')$.
For a frame f_w, $norm_{f_w}(d)$ is the set of normal worlds in a domain d.

A normal world in a domain d must conform not only to the rules in d but also to all rules in every subdomain of d. The Consistency Condition can be given in terms of normal worlds.

Consistency Condition (I):
For every $d \subseteq W$, $norm_{f_w}(d) \neq \emptyset$.

For a domain $d \subseteq W$, if $norm_{f_w}(d) = \emptyset$, then it means that for some generic sentence which holds in d, there are so many exceptions that there remains no world that conforms to that generic sentence.[6] The example in (14) is such a case. In this example, for any possible world w and any individual a, $norm_{f_w}(A(a)) = \emptyset$. In any world $w' \in \cap f_w(A(a))$, a is diligent. But the same world is in $M(a)$, or $W(a)$, and the same individual a must not be diligent here. No possible world can satisfy the two conditions.

6) Each generic sentence allows some degree of exceptionality, but it is hard to specify how much exceptionality they allow. In many cases exceptions come from the implicit assumptions on the range of individuals quantified over. For example, a sentence like *Chickens lay eggs* is uttered under the assumption that a chicken is female, not dead or sick, and mature enough. This is not part of the core meaning of a generic sentence. Male, dead or immature chickens should not be considered to be exceptions. This should be dealt with together with other sentences involving quantification in general.

The consistency condition above, however, is just a condition on possible worlds with respect to the frame generated by the set of generic sentences which hold in that world. If the frame f_w of a world w violates this condition, w is an impossible world. How (14) is consistent is shown in terms of the frame.

Suppose that there are five worlds from w_1 to w_5 in the model. For an individual a, $A(a)=\{w_1, w_2, w_3, w_4\}$, $M(a)=\{w_1, w_2\}$, $W(a)=\{w_3, w_4\}$, and $R(a)=\{w_1, w_3\}$. Then for a possible world w, the three sentences in (14) makes the following frame:

$$
\begin{array}{lllll}
f_w: & & \{\}_{12345} & & \\
\{\{w_1, w_3\}\}_{1234} & \{\}_{1235} & \{\}_{1245} & \{\}_{1345} & \{\}_{2345} \\
\{\{w_1, w_3\}\}_{123} \cdots & \{\}_{125} \cdots & \{\}_{135} \cdots & \{\}_{245} \cdots & \{\}_{345} \\
\{\{w_2, w_4, w_5\}\}_{12} \cdots & \{\{w_1, w_3\}\}_{23} \cdots & \{\{w_2, w_4, w_4\}\}_{34} \cdots & \{\}_{35} \cdots & \{\}_{45} \\
\{\}_1 & \{\{w_2, w_4, w_5\}\}_2 & \{\}_3 & \{\{w_2, w_4, w_5\}\}_4 & \{\}_5
\end{array}
$$

In the diagram $\{\{w_1, w_3\}\}_{1234}$ is meant to be $\{w_1, w_3\} \in f_w(\{w_1, w_2, w_3, w_4\})$: that is, $R(a) \in f_w(A(a))$. The number 1234 represents the domain of $A(a)=\{w_1, w_2, w_3, w_4\}$ and a rule $\{w_1, w_3\}$ is the proposition that a is responsible. Similarly, $\{\{w_2, w_4, w_5\}\}_{12}$ means that a freshman a is normally not responsible, and $\{\{w_2, w_4, w_5\}\}_{34}$ means that a non-freshman a is normally not responsible. If a generic sentence holds in a domain, it holds in its sub-domains. If adults normally are responsible *without exceptions*, then men would normally be responsible and a further specific group of men down to a specific man would normally be responsible.[7] That is why $\{w_1, w_3\}$ in the domain 1234 is also in the domains 123 and 23, and why $\{w_2, w_4, w_5\}$ in the domains 12 and 34 is in the domains 2 and 4. If a rule is not added to a subdomain, it is because the addition would make the set of normal worlds in the subdomain (or a super-domain) the empty set. That is why $\{w_1, w_3\}$ in the domain 1234 is not added to other subdomains of the domain 1234 and why $\{w_2, w_4, w_5\}$ in the domains 12 and 34 is not added to the domains 1 and 3. We can suppose that it is very difficult to decide whether or not a rule in a domain would be added to a certain

7) It is a contingent matter whether or not a rule in a domain holds in its subdomains. If a rule in a domain does not hold in a subdomain, it means that there is a exception. Here we assume that we have only a given set of generic sentences.

subdomain when there are a lot of other rules.

According to the Factivity Condition, we can assume that each domain d in a frame includes d as a proposition: $d \in f_w(d)$. $\{\{w_1, w_3\}\}_{1234}$ should have been $\{\{w_1, w_2, w_3, w_4\}, \{w_1, w_3\}\}_{1234}$ because adults are normally adults. I have not included such propositions in the frame above, but we should assume them in applying the Consistency Condition. So w_1 conforms to the rule in the domain 1234. It should conform to every rule in every sub-domain to which it belongs. Notice that w_1 belongs to the domains 123, 124, 134, 12, 13, 14, 15, 1. For each domain d of the domains 124, 134, 13, 14, 15, 1, d is the only member of $f_w(d)$. So $w_1 \in \bigcap f_w(d)$. w_1 conforms to the rule in the domain 123, but it is not a member of $\bigcap f_w(12) = \{w_2\}$. We can say the same thing about w_3. It conforms to $A(a) > R(a)$, but not to $W(a) > \neg R(a)$. So the set of normal worlds of the domain 1234 is the empty set.

There are cases where a frame is inconsistent but Consistency Condition (I) does not exclude it. There are two types of exceptions. One is a strong exception and the other is a weak exception. A generic sentence has one of the three forms:

(15) $\forall x(\phi > \psi)$ (affirmative)
$\forall x(\phi > \neg\psi)$ (internal negation)
$\neg\forall x(\phi > \psi)$ (external negation)

For a generic sentence of affirmative form, there are two types of negations; the internally negative form or the externally negative form. Similarly, for a generic sentence, there are two types of exceptions, each corresponding to the two negative forms (or their entailments) of the generic sentence. They are illustrated in the following:

(16) a. Adults are employed.
b. College students are not employed. (strong exception)
c. It is not the case that college students are employed. (weak exception)

I will call the internal negation a strong exception and the external negation a weak exception. A strong exception is just like an ordinary generic sentence except for the fact that it has another generic sentence to which it is an exception. Both divide a set of possible worlds into

normal and abnormal worlds. So I call them strong generics. I will call generic sentences of the externally negative form weak generics. Weak generics simply express lack of rules, and a weak exception to a strong generic partially nullifies the effect of discriminating possible worlds with respect to the strong generic.[8)]

Weak exceptions also can make a frame, thus a discourse, inconsistent, but Consistency Condition (I) above does not exclude such a case. Consider the following examples.

(17) a. Adults are responsible.
b. It is not the case that men are responsible.
c. It is not the case that women are responsible.

(18) a. Adults are responsible.
b. Men are irresponsible.
c. It is not the case that women are responsible.

A generic sentence has only the weak exceptions, as in (17), or the combination of a strong and weak exceptions, as in (18). Neither case leads to a consistent frame. The notion of normal world in Definition 4 does not exclude these cases. Consider (17) first. It gives rise to the following frame.

f_w:		$\{\}_{12345}$		
$\{\{w_1, w_3\}\}_{1234}$	$\{\}_{1235}$	$\{\}_{1245}$	$\{\}_{1345}$	$\{\}_{2345}$
$\{\{w_1, w_3\}\}_{123}$ ⋯	$\{\}_{125}$ ⋯	$\{\}_{135}$ ⋯	$\{\}_{245}$ ⋯	$\{\}_{345}$
$\{\}_{12}$ ⋯	$\{\{w_1, w_3\}\}_{23}$ ⋯	$\{\}_{34}$ ⋯	$\{\}_{35}$ ⋯	$\{\}_{45}$
$\{\}_1$	$\{\}_2$	$\{\}_3$	$\{\}_4$	$\{\}_5$

The weak exception does not add a rule to a domain. (17b) does not add a rule to the domain 12 of $M(a)$ for an individual a. The exceptionality of men to the generic sentence *Adults are responsible* is represented by not adding the rule to the domain of $M(a)$=12 or its subdomains even though it is a subdomain of the domain 1234. The absence of a rule in a

8) Veltman's (1996) analysis of default rules cannot distinguish strong and weak generics. In Yeom (2000), I proposed a way of overcoming this problem within Veltman's analysis. But this does not allow him to avoid the problems discussed in section 2.

subdomain means that possible worlds are not discriminated by the rule with respect to normality in that subdomain. So normality is decided only by the rule in the domain 1234. Then we would conclude that the set of normal worlds of the domain 1234 is $\{w_1, w_3\}$, and that the frame is consistent. This should not be the case. Now consider (18). (18b) adds $\{w_2, w_4, w_5\}$ to the domains 12, 1, and 2. This would keep $\{w_1, w_2\}$ in the domain 1234 from applying to these domains. But this eliminates only w_2 from $norm_{f_w}(1234)$. So the frame is still predicted to be consistent.

From the discussion so far we have to introduce a slightly different notion than normal world. I will call the new notion N-world. It is defined considering weak exceptions as well as strong ones.

Definition 5 For a frame f_w, a possible world w' is a **N-world** in d iff w' conforms to every rule in every subdomain d' of d such that $w' \in d'$. $w' \in W$ **conforms to** a rule p in d' iff $w' \in p$ and there is a branch b in $BR(anch)(d', \{w'\})$ such that for every domain d'' in b, p is in $f_w(d'')$.[9] $BR(d, d')$ is a set of linearly-ordered maximal subsets of $\wp(d)$ in which d is the largest and d' the smallest member.

When a possible world w' conforms to a rule p, it should not be subject to the strong or weak exceptions to the rule. If there is a strong or weak exception to which w' is subject, then the rule is at least not in $f_w(\{w'\})$, and possibly not in $f_w(d'')$ for some super-domains of $\{w'\}$, in a branch. Therefore there is no branch with $\{w'\}$ as a member such that every domain in the branch includes the rule. So all possible worlds which are subject to strong or *weak* exceptions are excluded from the set of normal worlds.

One advantage with using the notion of branch is that it allows us to avoid the problem with (19).

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9) The definition of branch here is slightly different from that in Landman (1991), where the definition of chain is given as in (i), and a branch is defined as a maximal chain for a given set.

(i) A chain in T is linearly ordered subset of T.

Instead, in my paper, a branch is defined with respect to two sets.

(19) a. Birds fly. Penguins do not fly.
$(\forall x(B(x) > f(x));\ \forall x(P(x) > \neg F(x)))$
b. It is not the case that sparrows and penguins fly.
$(\neg \forall x((S(x) \vee P(x) > F(x)))$

When (19a) holds, we think that (19b) holds. That is, the domain $S(a) \vee P(a)$ does not include the rule $F(a)$. But we do not consider $S(a) \vee P(a)$ to be an exception domain. What we want to claim is that only $P(a)$ is an exception domain. For a possible world in which a is a sparrow, there is a branch every domain of which includes $F(a)$ from the domain $B(a)$ down. That branch does not include the domain $S(a) \vee P(a)$, so this domain does not play a role in determining whether the possible world is a normal world or not.

Based on the new definition of N-world, we can specify the consistency condition again.

Definition 6 In the frame f_w for a possible world w, $N_{f_w}(d)$ is the set of N-worlds in a domain $d \subseteq W$.

Consistency Condition (II):
For every $d \subseteq W$, $N_{f_w}(d) \neq \emptyset$.

This condition excludes the frame in which a default rule in a domain is completely negated by a strong exception and/or nullified by a weak exception.

Asher and Morreau (1995) claim that a constraint is required on the function f, considering the following example.

(20) Tomatoes contain vitamin C.
Potatoes contain vitamin C.
Tomatoes and Potatoes contain vitamin C.

If the first two sentences hold in a possible world w, the third one must hold in w, too. This does not mean that a generic sentence in a domain must hold in a larger domain too. Look at example (21).

(21) Adults are employed. College students are not employed.

The second sentence is a strong exception to the first one, and it cannot hold in the domain for the first sentence. If it did, it would be concluded that adults are normally not college students. Our intuition says of a employed college student that (s)he is a normal adult and an abnormal college student.[10] Considering these cases, Asher and Morreau (1995) propose the condition that $\bigcap f_w(p \cup q) \subseteq \bigcap f_w(p) \cup \bigcap f_w(q)$ for the case in (20).

The condition is not right in two respects. First, it does not hold for the case in (19). Sparrows fly and penguins do not fly, but it is not the case that sparrows and penguins do, or do not, fly. In this case, $\bigcap f_w(p \cup q) \supseteq \bigcap f_w(p) \cup \bigcap f_w(q)$. Second, a condition in terms of the intersection of default rules in a domain is not adequate for capturing the relationships between domains in a frame. The condition must be specified with respect to each default rule in a domain, not with respect to the intersection of default rules in a domain. This is illustrated in the following example.

(22) a. Adults are normally employed.. $(\forall x(A(x) > E(x)))$
b. College students are normally unemployed. $(\forall x(CS(x) > \neg E(x)))$
c. College students are normally responsible. $(\forall x(CS(x) > R(x)))$
d. Other people than college students are also normally responsible.
$(\forall x(\neg CS(x) > R(x)))$

(20c, d) entail that adults are normally responsible, but this is not guaranteed by Asher and Morreau's condition. Due to (20a, b), $\bigcap f_w(A(a) \subseteq \bigcap f_w(CS(a)) \cup \bigcap f_w(\neg CS(a))$ for any world w and any individual a, regardless of whether (22c, d) apply to the domain of $A(a)$. To avoid these problems, the condition between domains would have to be specified with respect to each rule. I call them Disjunction Conditions.

Disjunction Conditions:
(i) If $p \in f_w(d)$ and $p \in f_w(d')$, then $p \in f_w(d \cup d')$;
(ii) If $p \notin f_w(d)$ and $p \notin f_w(d')$, then $p \notin f_w(d \cup d')$.

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10) Pelletier and Asher (1997) and Asher and Morreau (1991) propose another constraint called specificity condition:

If $p \subseteq q$ and $\bigcap(f_w(p) \cup f_w(q)) = \emptyset$, then $\bigcap f_w(q) \cap p = \emptyset$.

This implies that from the two sentences in (21) it follows that normal adults are not college students. As I pointed out, this condition seems to be against our intuition.

However, these conditions essentially follow from Consistency Condition. The following examples are cases where the Disjunction Conditions are violated:

(23) (i) Men are responsible. Women are responsible. It is not the case that adults are responsible.
(ii) It is not the case that men are responsible. It is not the case that women are responsible. Adults are responsible.

In (23i) and (23ii) the first two sentences together are contradictory with the last. So the two Disjunction Conditions can be reduced to Consistency Condition. But our Consistency Condition (II) only covers case (ii). I could revise the Consistency Condition so that it could cover case (ii). But I do not pursue this revision. Instead I will propose proposition 1 below which ensures to satisfy Disjunction Condition (i). Notice that Consistency Condition is more general because it excludes cases where a frame is inconsistent within one domain as well as cases where a frame is inconsistent due to relations between two or more domains.

A more serious problem with the Disjunction Conditions is that it will make a wrong prediction. We know that penguins do not fly, but that birds normally fly. In this situation, we do not say that penguins and sparrows normally fly. Similarly, we do not say that penguins and swallows normally fly, nor that penguins and parrots do not normally fly. This can continue until all birds that can fly are mentioned. Then the Disjunction Condition (ii) would require that birds do not normally fly. So the Disjunction Conditions are not correct.

4. Information States and Inferences

4.1. Dynamic Interpretation of Generic Sentences

In dynamic theory of meaning, a sentence is assumed to be a function from information states to new information states. In this paper, it is assumed that a generic sentence is truth-conditional, just like episodic sentences. So it is not necessary to assume a special update rule for generic sentences. An information state is normally assumed to be a set of possible worlds, each of which is taken to be an alternative of the actual world in view of what is known. A new utterance eliminates

possible worlds in which the sentence uttered is false. We assume that [ ] is a dynamic interpretation function and $\| \ \|$ is the (static) interpretation function in the truth-conditional semantics.

Definition 7 For an information state $s \subseteq W$,
$s[P(a)]=\{w \in s \mid V_w(a) \in V_w(P)\}$ (or equivalently, $s \cap \| P(a) \|$)
$s[\neg \phi]=s \setminus s[\emptyset]$ (or $s \cap \| \neg \phi \|$)
$s[t_1 \wedge t_2]=s[t_1][t_2]$
$s[\phi > \psi]=\{w \in s \mid \bigcap f_w(W[\phi])[\phi]=\bigcap f_w(W[\phi])\}$ (or $s[\phi > \psi]=s \cap \| \phi > \psi \|$)

Note that in the update with a generic sentence $\phi > \psi$, W is updated with the antecedent ϕ to decide the domain for evaluating the consequent of the generic sentence. This implies that update with a generic sentence is not affected by the current information state s. The interpretation of a generic sentence has the form of dynamic semantics, but essentially the meaning of a generic sentence is static. $s[\phi > \psi]$ is equivalent to $s \cap \| \phi > \psi \|$), just like episodic sentences.[11)]

The main purpose of introducing information models is to give interpretation to the operator $\triangleright$. This is an operator for making an inference only from a given set of facts and default rules, regardless of what other generic sentences are true in a world in s. But all we have for evaluating a inference is the function f which is defined with respect to each world regardless of what is known at the moment. One difficulty with using the frames of the possible worlds in an information state is that the frame of a possible world in an information state is likely to contain more rules than are known in the current information state, and reasoning with default rules is nonmonotonic. For this reason Asher and Morreau (1995) introduce a separate process called normalization of an information state. One defect of their analysis is that the meaning of the operator $\triangleright$ is not directly related to the interpretation of generic sentences. The function f, which is expressed by a frame, is not considered at all in evaluating an inference. As a result, the analysis cannot consider interactions between generic sentences inherently

11) Furthermore, update with generic sentences is permutation invariant: $s[\phi_i > \psi_i][\phi_j > \psi_j]$ is the same as $s[\phi_j > \psi_j][\phi_i > \psi_i]$. And the dynamic meaning of a generic sentence is stable: for any two information states s and s' such that $s \subseteq s' \subseteq W$, if $s'[\phi > \psi]=s'$ then $s[\phi > \psi]=s$.

embedded in the frame.[12] In this section I am going to use the notion of minimality and interpret the operator with respect to a group of minimal frames in which only the known rules hold.

4.2. Determination of Minimal Worlds and the Meaning of 'presumably'

Consider the following example.

(24) a. Birds normally fly.
b. Tweety is a penguin.
c. Penguins are birds.

Suppose that these are all we know. Then we conclude that presumably Tweety flies. But once we learn that penguins do not fly, we retract the previous conclusion and get to a new conclusion that presumably Tweety does not fly. If we are to evaluate an inference in an information state *s* based on the frame of a possible world, we have to consider only the frame of a possible world which contains only the known generic sentences. We call such a world a minimal world, and its frame a minimal frame.

In order to determine a minimal world, we need to see what happens to a frame when a new generic sentence is uttered. I propose that a minimal frame and minimal world can be selected by comparing the number of N-worlds from the largest domain *W* down. Suppose that we are given a set of generic sentences before a new generic sentence is uttered. In this information state, if a strong generic $\phi > \psi$ is uttered which is not an exception to any given generic sentence, it simply reduces the number of N-worlds in the domain of ϕ, and also the number of N-worlds in the domain of *W*.

Things are different when the additional generic $\phi > \psi$ is a strong exception to one of the given generic sentences $\phi' > \psi'$. First, it will reduce the number of N-worlds in the domain of $\| \phi' \|$. This will lead to the reduction of N-worlds in *W*, too. On the other hand, a new set of N-worlds is added in the domain of $\| \phi \|$. So simple comparison of the

12) A result from resorting to normalization is that the analysis cannot account for so-called graded normality, which is discussed below.

whole set of N-worlds cannot determine a minimal world. But notice that the domain of $\| \phi' \|$ is larger than $\| \phi \|$ and that the number of N-words in the larger domain gets smaller with the addition of a new generic sentence.

When the additional generic statement is a weak generic like $\neg(\phi > \psi)$ and it is exceptional to none of the given generic sentences, it is simply ignored because it just asserts that there is no discrimination between possible worlds with respect to normality. But when it is a weak exception to one of the given generic sentences $\phi' > \psi'$, then it reduces the number of N-worlds in the domain of $\| \phi' \|$. And it reduces the number of N-worlds in W unless there is an exception domain between W and $\| \phi' \|$. On the other hand, the number of N-worlds in $\| \phi \|$ expands compared with the frame before the new weak generic is added. So the total number of N-worlds may increase with the addition of the new weak generic. But notice again that the number of N-worlds in $\| \phi' \|$ reduces and that $\| \phi' \|$ is a larger domain than $\| \phi \|$. From these observations we can see that in order to get a minimal world we have to compare the numbers of N-worlds from larger domains to smaller ones. So a minimal frame can be defined as follows:

Definition 8 A frame $f_{w \in s}$ is a minimal frame with respect to an information state s iff there is no frame $f_{w' \in s}$ such that for every branch $b \in BR(W, \{w''\})$ such that $w'' \in W$, if there is a domain d in b such that $N_{f_w}(d) \not\subseteq N_{f_{w'}}(d)$, then there is a domain $d'(\supset d)$ in b such that for every $d'' \supseteq d'$, $N_{f_w}(d'') \subset N_{f_{w'}}(d'')$.
A minimal world is a possible world with a minimal frame.

A minimal frame must have a larger number of N-worlds from larger domains to lower domains. This can be expressed by the notion of branch. For every branch from W to each possible world in W, if a domain in the branch does not have the largest set of N-words, then there must be a larger domain in the branch that has a larger set of N-words than any other frame in the current information state.

But we have to consider the possibility that there is more than one minimal frame/world. Let's consider an example. If there are two generic sentences which are incompatible in some domain, it is not expected for either of them to hold in that domain. This is illustrated in the following:

(25) Greens do not like cars.
AAA members like cars.

The two sentences are incompatible in the domain in which an individual is a green and a AAA member. If both held in that domain, it would make the world an impossible one since the set of N-worlds in the domain becomes the empty set. And if an individual is a green and AAA member, then it is not necessarily the case that (s)he normally does or does not like cars. It is a contingent matter whether an individual who is a green and AAA member does or does not like cars, given only the two generic sentences. Among the two options, the condition of "more N-worlds in a larger domain" does not select either of them as a minimal one. That is, the two options are incomparabilities. For this reason, a minimal world is defined as a world which has no world with more N-worlds from the domain W down than that minimal world.

So far I have not talked about a domain which is not a sub-domain of a generic sentence. For a generic sentence $\phi > \psi$, I have only considered the sub-domains $d \subseteq \| \phi \|$, but the generic sentence also has the effect of discriminating worlds in which both ϕ and $\neg\psi$ hold from those in which ϕ does not hold. Consider the following example:

(26) a. Adults are normally employed.
b. Tim is not employed.
$(\forall x(A(x) > E(x)); \neg E(t))$

In this example, the current information state $s \subseteq \| \neg E(t) \|$ is not a sub-domain of $A(t)$. But from the two sentences, we expect that presumably Tim is not an adult.[13] This shows that (26a) somehow holds in the domain $\| \neg E(t) \|$, which is not a sub-domain of $A(t)$. So we can say that a generic sentence differentiate worlds into normal and abnormal worlds, and all worlds in $\| \phi_a \wedge \neg\psi_a \|$ are taken to be abnormal and the rest, that is, those in $\| \neg\phi_a \wedge \psi_a \|$ are taken to be normal worlds. So it has non-trivial effect on domains $d \not\subseteq \| \phi_a \|$. The following specifies when a generic sentence in a domain holds in other domains. It also covers cases

13) This does not mean that when the two sentences are true it is necessarily true that Tim is normally not an adult. Whether or not this is true depends on what other rules hold in the same world.

where a generic sentence holds in its sub-domains.

Proposition 1 For a generic sentence $\phi_a > \psi_a$, there is no domain $d \subseteq W$ such that $\| \neg \phi_a \vee \psi_a \| \in f_w(d)$ and for some $d' \supseteq d$ $N_{f_w}(d') \cap \| \neg \phi_a \vee \psi_a \| \cap d = \emptyset$

According to this proposition, a generic sentence is added to any domain unless the domain and its super-domains contain a rule which is incompatible with the generic sentence. This allows (26a) to apply to the domain in which Tim is not employed. On the other hand, it keeps an exception from applying to the domain for a more general rule, as in (21).

(27) a. Adults are employed. (= (21))
b. College students are not employed.

The two sentences are incompatible in the domain in which the same individual is an adult and a college student. In this case neither sentence applies to the domain for the other sentence. If the second generic sentence applied in the domain for the first sentence, it would make a frame in which it is predicted to be true that adults are (normally) not college students. To me it seems false. We can think of an individual who is a normal adult but abnormal college student.

In making an inference, a weak exception does not play a significant role. Consider the following case where a strong generic has a weak exception.

(28) Adults are employed.
It is not the case that graduates are normally employed.
Tim is an adult.

From this we expect that Tim is presumably employed, despite the weak exception. Compare this with the following.

(29) Birds fly. Penguins do not fly. Tweety is a bird.
$(\forall x(B(x) > F(x));\ \forall x(P(x) > \neg F(x));\ B(t))$

From these we expect that presumably Tweety flies and is not a penguin.

This shows that only a strong exception changes inference, and that the semantics of the operator 'presumably (or $\triangleright$)' must be defined with the notion of normal world, instead of N-world. The set of N-worlds in $\| A(t) \|$ and the one in $\| B(t) \|$ in (28) and (29) respectively are the same, regardless of whether the exception is weak or strong.

Let a possible world w in s be a minimal world in s and $f_{m(s)}$ a minimal frame. The operator $\triangleright$ 'presumably' is interpreted as follows:

$$s[\triangleright \phi] = \begin{cases} s \text{ if } norm_{f_{m(s)}}(s)[\phi] = norm_{f_{m(s)}}(s) \text{ for every } f_{m(s)} \\ \varnothing \text{ otherwise} \end{cases}$$

As the rule shows, $\triangleright$ is a test operator. It just checks an information state as to whether we can conclude that presumably ϕ at the current information state. The information state may pass or fail the test. If there is at least one minimal world in which an inference does not follow, it means that the inference is not guaranteed in the current information state. This is illustrated in (25), where more than one minimal world is allowed and a green and AAA member is expected to like cars in some minimal worlds but not in others.

Minimal worlds in an information state are removed as a new nontrivial generic sentence is added to that information state. This is why an inference statement is not stable, so nonmonotonic. Suppose that an inference statement is verified in an information state. It means that it follows from the minimal frames of minimal worlds in that information state. When a new generic statement is uttered, those minimal worlds are eliminated and new minimal worlds are considered in evaluating the previous inference statement.[14] The introduction of a new generic sentence changes the relationships between domains in the minimal frame, and the new frame could falsify the previous inference. When the newly-added information is factual, the minimal frame does not change. But the set of normal worlds in the current information state can change because the domain under consideration changes. Generic sentences which held in the domain of the previous information state may not hold in the domain of the new information state. This ensures that when

14) There is an exceptional case where all minimal worlds are eliminated with the addition of a new rule. If there are incomparabilities, as in (25), the new rule can only select some of the incomparabilities.

new information is added we get to a different inference. Nonmonotonicity is captured by the change of minimal worlds and of the domain considered in evaluating an inference statement.

5. Nonmonotonic Reasoning

So far I have discussed constraints on frames and minimal frames. I have also given the interpretation rule for $\rhd$. In this section, I will show how different inference patterns can be accounted for using the rules I have introduced.

5.1. Defeasible Modus Ponens

This is the simplest pattern of reasoning. Consider the following example:

(30) Birds fly. Tweety is a bird. Then presumably Tweety flies.
$(\forall x(B(x) > F(x));\ B(t);\ \rhd F(t))$

When W is updated with the first two sentences, the current information state becomes $s = W[\{\forall x(B(x) > F(x)),\ B(t)\}] \subseteq W[B(t)]$. In the frame of a minimal world the set of normal worlds in the domain of s is the set of worlds in which all birds fly. So $\| F(t) \| \in f_{m(s)}(s)$. $norm_{f_{m(s)}}(s) \subseteq \| F(t) \|$. So presumably Tweety flies.

This holds when only irrelevant information is added. Unless the new information entails that Tweety does not fly, s will be reduced further but still the normal worlds in the domain s are those in which Tweety flies. If the new information is a rule, then it simply reduces $norm_{f_{m(s)}}(s)$ unless it prevents the rule that birds fly from applying to the domain of the new information state. So it still holds that $norm_{f_{m(s)}}(s) \subseteq \| F(t) \|$.

5.2. Defeasible Modus Tollens

Consider the following discourse:

(31) a. Adults are normally employed. $(\forall x(A(x) > E(x)))$
b. Tim is not employed. $(\neg E(t))$
c. Then presumably Tim is not an adult. $(\rhd \neg A(t))$

After (31a, b) update the minimal state W, $s = W[\{\forall x(A(x) > E(x)), \neg E(t)\}] \subseteq W[\neg E(t)]$. In the worlds in s, Tim could, or could not, be an adult. But in the minimal frame $f_{m(s)}$, $norm_{f_{m(s)}}(s) \subseteq \| \neg A(t) \|$, because $\| \neg A(t) \vee E(t) \|$ can be added to $f_{m(s)}$ without making the frame inconsistent, as discussed in (26). So we can conclude that presumably Tim is not an adult.

There are cases where Defeasible Modus Ponens and Defeasible Modus Tollens compete. In this case the former wins:

(32) a. Students are normally adults. $(\forall x(S(x) > A(x)))$
b. Adults are (normally) not students. $(\forall x(A(x) > \neg S(x)))$
c. Tim is a student. $(S(t))$
d. Presumably Tim is an adult. $(\rhd A(t))$

By Defeasible Modus Ponens, we get the inference that Tim is presumably an adult. But by Defeasible Modus Tollens, we are supposed to infer that Tim is not an adult. The two inferences are contradictory. Our intuition says that Tim is presumably an adult. How do we get this? When the minimal state W is updated with (32a-c), we get $s = W[\{\forall x(S(x) > A(x)), \forall x(A(x) > \neg S(x)), S(t)\}] \subseteq \| S(t) \|$. If both $\neg S(t) \vee A(t)$ and $\neg A(t) \vee \neg S(t)$ hold in the domain s, the set of normal worlds in s becomes the empty set. If (32a) did not hold in $\| S(t) \| (\supseteq s)$, the frame would become inconsistent. Consistency Condition requires that $\| S(t) \|$ have a non-empty set of $A(t)$-worlds. If (32a) did not hold in the subdomain s of $\| S(t) \|$, there should be some exception to it. But we are considering only minimal frames which do not include any extra exception. On the other hand, Consistency Condition does not require that (32b) be applied to the domain of $\| S(t) \|$, nor to its subdomains including s. So (32a) wins.

A slightly different case is the following:

(33) Birds fly. Penguins do not fly. Tweety is a bird. (=(29))
$(\forall x(B(x) > F(x)); \forall x(P(x) > \neg F(x); B(t))$

In this case Defeasible Modus Ponens and Defeasible Modus Tollens apply in a series. In a minimal frame, $norm_{f_{m(s)}}(s)$ only consist of possible worlds in which Tweety is a bird and not a penguin. So presumably Tweety is a bird and not a penguin. This is a case where Defeasible

Modus Ponens and Defeasible Modus Tollens apply without canceling each other.

Let's consider a case where a weak exception involves.

(34) a. Adults are employed. ($\forall x(A(x) > E(x))$)
b. It is not the case that graduates are normally employed. ($\neg \forall x(G(x) > E(x))$)
c. Tim is an adult. ($A(t)$)

The notion of normal world only considers strong generics. So (34b) does not reduce the set of normal worlds in the domain $s \subseteq \| A(t) \|$. Our analysis predicts that Tim is presumably employed, but not that Tim is presumably not a graduate student. This seems intuitively correct.

5.3. Partial and Complete Incompatibility

One of the interesting features of generic sentences is that an exception takes precedence over a more general sentence than that. Consider the following example.

(35) a. Animals do not fly.
b. Birds fly.
c. It is not the case that insects normally fly.
d. Birds and insects are animals.
e. Tweety is a bird.
f. Bimby is an insect.

(35a) and (35b) are incompatible, and neither applies to the domain for the other. Tweety is also an animal, but it is not subject to the rule (35a), but to (35b) because the latter is more specific than the former. Similarly, Bimby is also an animal and (35a) and (35c) are incompatible. (35c) is more specific, so we cannot conclude that Bimby presumably flies. We can come to a conclusion that presumably Tweety flies. This can be explained easily: a more general generic sentence does not hold in the domain of its exception in the frame. Unless the current information state is not in the exception domain of the second sentence, we are led to come to our conclusion. On the other hand, we cannot conclude either that Bimby presumably flies or that Bimby presumably does not fly. The

relevant exception is weak and does not say whether or not a particular insect is expected to fly.

There is a case where two generic sentences are incompatible only in a certain domain.

(36) a. Greens do not like cars.
b. AAA members like cars.
c. Tim is a green and a AAA member.
d. *Presumably Tim does not like cars/*Presumably Tim likes cars.

The domain in which Tim is a green and a AAA member or its subset is an exception domain to one or both of the two generic sentences. If we want to get minimal worlds, we have to assume that one of the two holds in that domain and the other does not. We can get minimal worlds in which Tim likes cars and ones in which Tim does not. So we cannot come to one conclusion or the other, as discussed in (25).

Let's look at a case where two generic sentences are incompatible in a domain, but one of them is a weak generic.

(37) a. AAA members like cars. ($\forall x(AM(x) > LC(x))$)
b. It is not the case that car dealers like cars. ($\neg\forall x(CD(x) > LC(x))$)
c. Tim is a car dealer and AAA member. ($CD(t) \wedge AM(t)$)
d. Presumably Tim likes cars. ($\triangleright LC(t)$)

A minimal world is one in which (37a) has the least number of exceptions. (37b) is a weak generic and is not an exception to any strong generic. So it simply expresses the lack of a rule. When we derive minimal worlds, we do not consider such weak generics. So in a minimal world (37b) does not apply to the domain $\| CD(t) \wedge AM(t) \|$. The current information state s is the subset of $\| CD(t) \wedge AM(t) \|$, and the set of normal worlds in s is a subset of $\| LC(t) \|$.

5.4. Graded Normality

We know that we have to constrain frames with respect to each generic sentence. This makes the analysis much more complex, but it enables us to explain the following:

(38) a. Adults normally are employed.
b. Adults normally know how to drive a car.
c. Students normally are not employed.
d. Students normally are adults.
e. Tim is a student.
f. Presumably Tim knows how to drive a car.

(38c) is an exception to (38a), so the latter does not hold in the domain in which Tim is a student. But this does not mean that Tim is completely not a normal adult. In a minimal frame, (38b) does hold in the domain in which Tim is a student, regardless of whether (38a) applies to the same domain, because there is no rule incompatible with it.

Veltman (1996) claims that the analysis of generic sentences using selection functions is not expressive enough to capture the principle of Graded Normality. In his theory, for every domain d, $f_w(d)$ is not just a bipartition of worlds in d into normal worlds and abnormal worlds. Worlds that conform to more propositions in $f_w(d)$ are more normal than those that conform to less propositions. In my analysis, a domain is assumed to have a set of propositions which could be used to express graded normality. I exploit a set of propositions in a domain as a means to constrain a frame and a means to select a minimal world. Note that Consistency Condition is simply a condition on possible worlds. So we do not need to impose that condition independently since we only deal with possible worlds. The only remaining condition on frames is the Factivity Condition, which does not require considering the relationships between rules conveyed by generic sentences. So sets of propositions in a frame are necessary only to select minimal worlds in the current information state. If a minimal world can be determined without mentioning individual propositions, then a selection function is sufficient to evaluate an inference from generic sentences.

For a world w and a proposition p, a selection function ξ gives us a set of possible worlds which conform to every rule in the domain of p. That is, $\xi(w, p)=\cap f_w(p)$. The interpretations of the two operators can be given as follows:

$\phi > \psi$ is true in w iff $\xi(w, \| \phi \|) \subseteq \| \psi \|$.

$$s[\triangleright \phi] = \begin{cases} s \text{ iff forevery minimal workd } w \text{ in } s, & norm_{f_w}(s)[\phi] = norm_{f_w}(s) \\ \text{otherwise } \emptyset \end{cases}$$

$norm_{f_w}(s) = \{w' \in s \mid \text{for every } d \subseteq s \text{ such that } w' \in d,\ w' \in \xi(w, d)\}$

Graded Normality is simply a matter of whether a generic sentence can hold in a certain domain when other rules are considered which hold in the same world.

6. Conclusion

I have shown that generics can be truth-conditional without losing the explanatory power of other non-truth-conditional analyses in predicting reasonable inferences in relation to generic sentences. I also deal with weak generics, which are not discussed seriously in other analyses. In doing this, I have introduced the notion of N-world, which is comparable to the notion of normal world but slightly different in that the notion is defined considering weak exceptions as well as strong exceptions. For each possible world, a frame is defined based on the set of default rules that hold in that possible world. The frame is restricted by the Consistency Condition, which is based on the notion of N-world. In making an inference, a set of default rules in each possible world does not help because inference is nonmonotonic. We have to consider only a set of default rules that are known at the moment. For this, I have introduced the notion of minimal world or minimal frame. I claim that correct inferences are guaranteed based on a minimal world or minimal frame.

In this paper, I basically assume that a generic sentence is just like a conditional semantically, and that the truth-condition is based on a selection function. But this assumption can be accepted only when the notion of minimal world or minimal frame can be defined without mentioning each default rule. I am not sure if it is possible. But the notion of minimality is exploited in an analysis like McCarthy's circumscription. In that analysis, the notion can be defined in a different way. Minimality can be defined from a model-theoretic perspective. This implies that the use of the notion of minimality is on the right track, and

that there can be other ways to define minimality.

The analysis in this paper is not new in that it follows the tradition of analyzing a generic sentence as a conditional. But it makes a good contribution in showing how problems with previous truth-conditional analyses can be solved. Restrictions on frames are minimized. The only significant restriction is the Consistency Condition. But this is just a condition for possible worlds. This means that no significant restriction is imposed on frames and that inference is not based on any restriction on frames. This does not mean that for a possible world w, the frame f_w is not determined. A possible world consists of a set of propositions which hold in that world. The set also includes a set of default rules. If a frame were arbitrary, a new default rule which is not in the original set of default rules would hold in that frame, and so in that possible world. This leads to a contradiction. Therefore, a frame for a possible world must be a minimal one for the set of default rules which hold in that possible world. In this respect, a frame is not restricted, but the frame for a possible world is determined in a non-arbitrary way.

Another contribution is that this analysis needs no other device than the already given set of frames for making correct inference. In Asher and Morreau (1991, 1995), reasoning with generics is based on a separate process called normalization, in addition to the frames for the interpretation of each generic sentence. In our analysis, the result of interpreting a set of sentences is a set of possible worlds and their frames, and inferences are made only on the basis of those possible worlds. In this respect, our analysis is dynamic in its real sense.

Reference

Antoniou, G. (1997). *Nonmonotonic Reasoning.* Cambridge: MIT Press.

Asher, N. and M. Morreau. (1991). Commonsense entailment: A modal theory of nonmonotonic reasoning. *Proceedings of the 12th IJCAI,* 387-392. San Mateo, Cal.: Morgan Kaufmann.

Asher, N. and M. Morreau. (1995). What some generic sentences mean. In G. N. Carlson et al. eds., *The Generic Book* (pp. 300-338). Chicago: University of Chicago Press.

Boutilier, C. (1994). Conditional logics of normality: A modal approach. *Artificial Intelligence* 68, 87-154.

Carlson, G. N. (1977). *Reference to Kinds in English.* Ph.D. dissertation, University of Massachusetts, Amherst. Published 1980 by Garland Press, New York.

Carlson, G. N. (1982). Generic terms and generic sentences. *Journal of Philosophical Logic* 11, 145-181.

Carlson, G. N. (1988). Truth conditions of generic sentences: Two contrasting views. In M. Krifka, ed., *Genericity in Natural Language,* (pp. 31-51). SNS-Bericht 88-42, University of Tübingen.

Carlson, G. N. (1989). On the semantic composition of english generic sentences. *Properties, Types and Meaning* 2, 167-192.

Cohen, A. (1999a). *Think Generic.* Stanford, California: CSLI.

Cohen, A. (1999b). Generics, frequency adverbs, and probability. *Linguistics and Philosophy* 22, 221-253.

Delgrande, J. (1987). A first-order conditional logic for prototypical properties. *Artificial Intelligence* 33, 105-130.

Groeneveld, W. and F. Veltman. (1994). Inference Systems for Update Semantics. Institute for Logic, Language and Computation, Department of Philosophy, University of Amsterdam. *Dyana Deliverable Report,* 229-273.

Heim, I. (1982). *The Semantics of Definite and Indefinite Noun Phrases.* Ph.D. dissertation. University of Massachusetts, Amherst.

Heyer, G. (1985). Generic descriptions, default reasoning, and typicality. *Theoretical Linguistics* 11, 33-72.

Heyer, G. (1990). Semantics and knowledge representation in the analysis of generic descriptions. *Journal of Semantics* 7, 93-110.

Kratzer, A. (1979). Conditional necessity and possibility. In R. Bäuerle, U. Egli, and A. von Stechow (eds.), *Semantics from Different Points of View.* Springer-Verlag: New York.

Kratzer, A. (1981). Partition and revision: The semantics of counterfactuals. *Journal of Philosophical Logic* 10, 201-216.

Kratzer, A. (1989). An investigation of the lumps of thought. *Linguistics and Philosophy* 12, 607-653.

Krifka, M. (1987). *An Outline of Genericity.* partly in collaboration with Claudia Gerstner. SNS-Bericht 87-23, University of Tübingen.

Krifka, M. (1995). Focus and the interpretation of generic sentences. In G. N. Carlson et al., eds., *The Generic Book* (pp. 358-382). Chicago: University of Chicago Press.

Landman, F. (1991). *Structures for Semantics.* Dordrecht: Kluwer.

Lewis, D. (1973). *Counterfactuals.* Oxford: Basil Blackwell.

Lewis, D. (1981). Ordering semantics & premise semantics for counterfactuals. *Journal of Philosophical Logic* 10, 217-34.

Link, G. (1995). Generic information and dependent generics. In G. N. Carlson et al., eds., *The Generic Book* (pp. 358-382). Chicago: University of Chicago Press.

McCarthy, J. (1980). Circumscription - A form of non-monotonic reasoning. *Artificial Intelligence* 13, 27-39.

Moore, R. C. (1984). Possible world semantics for autoepistemic logic. In R. Reiter, ed., *Proceedings of the Workshop on Non-Monotonic Reasoning* (pp. 344-354).

Morreau, M. (1992). *Conditionals in Philosophy and Artificial Intelligence.* Ph.D. dissertation, University of Amsterdam.

Pelletier, F. J. and N. Asher. (1997). Generics and defaults. In Johan van Benthem and Alice ter Meulen, eds., *Handbook of Logic and Language* (pp. 1125-1177). Amsterdam: Elsevier.

Reiter, R. (1980). A logic for default reasoning. *Artificial Intelligence,* 12, 81-132.

Rooth, M. (1985). *Association with Focus.* Ph.D. dissertation, University of Massachusetts, Amherst.

Rooth, M. (1995). Indefinites, adverbs of quantification, and focus semantics. In G. N. Carlson et al, eds., *The Generic Book* (pp. 265-299). Chicago: University of Chicago Press.

Schubert, L. and F. J. Pelletier. (1989). Generally speaking, or using discourse representation theory to interpret generics. *Properties, Types and Meaning* 2, 193-268. Dordrecht: Kluwer.

Stalnaker, R. (1968). A theory of conditionals. In N. Rescher, ed., *Studies in Logical Theory* (pp. 98-112). Oxford: Blackwell.

Thomason, R. H. (1997). Nonmonotonicity in linguistics. In Johan van Benthem and Alice ter Meulen, eds., *Handbook of Logic and Language* (pp. 777-831). Amsterdam: Elsevier.

Veltman, F. (1996). Defaults in update semantics. *Journal of Philosophical Logic* 25, 221-261.

Yeom, J.-I. (2000). Semantics for default rules. *Language and Information* 4(2), 69-92.

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