

(A)temporal Complements

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1. Introduction

Untangling the factors that go into the temporal interpretation of complement clauses has provided work for formal semanticists for a number of years (Ladusaw 1977; Dowty 1982; Enç 1987; Ogihara 1989; Abusch 1994; von Stechow 1995b; Kusumoto 1999). Balancing the considerations of semantic innocence – that meanings be the same in root as in embedded contexts – with those of compositionality – that the meaning of the whole should be composed out of the meanings of the parts – has proved a difficult challenge. Much attention has been focussed on embedded finite clauses and the fact that the tense such clauses bear sometimes appears not to be interpreted. This is the so-called “sequence of tense” phenomenon. In this paper, however, I will be concerned with clauses that do not bear tense – infinitival clauses – and the fact that they sometimes appear to be interpreted as if they did. This might be called the “specification of tense” phenomenon.

The problem I will address can be presented in puzzle form, and the puzzle is this: Why, if (1b) is an acceptable variant of (1a), is (2b) not an acceptable variant of (2a)?

- (1) a. Fritz expects that Arnim will like his gift.
b. Fritz expects Arnim to like his gift.
- (2) a. Fritz believes that Arnim will like his gift.
b. Fritz believes Arnim to like his gift.

(1a), (1b) and (2a) can all be used to describe Fritz’s attitude toward a potential future situation, while (2b) can only be used to describe his attitude toward a current situation. More generally, verbs such as *expect*, *promise* and *predict* – what I will call “future-oriented” verbs – appear to require that their infinitival complements have a future interpretation, while verbs such as *believe*, *think* and *understand* – “present-oriented” verbs – require that their infinitival complements have a present interpretation.

In recent work, Abusch (to appear) has noted three properties which distinguish infinitival complements of future-oriented verbs from their present-oriented counterparts.

The first – illustrated by the contrast in (3) – is that infinitival complements of future-oriented verbs can be non-stative, while infinitival complements of present-oriented verbs must be stative (compare (2b) and (3b)).

- (3) a. Fritz expects Arnim to unwrap his gift.
 b. *Fritz believes Arnim to unwrap his gift.

The second – illustrated by the contrast in (4) – is that infinitival complements of future-oriented verbs can be modified by future time-frame adverbials, while infinitival complements of present-oriented verbs cannot be.

- (4) a. Monika expects Arnim to be in Tübingen tomorrow.
 b. *Monika believes Arnim to be in Tübingen tomorrow.

And the third – illustrated in (1) – is that infinitival complements of future-oriented verbs are equivalent with future-tensed complements, but infinitival complements of present-oriented verbs are equivalent with present-tensed (or sequence-of-tense past tense) complements. So while (2b) is not equivalent with (2a), it is equivalent with (5).

- (5) Fritz believes that Arnim likes his gift.

In short, infinitival complements of future-oriented verbs behave as if they are future-tense clauses, and infinitival complements of present-oriented verbs behave as if they are present-tense clauses.

To account for this contrast, Ogihara (1989) – in the first model-theoretic treatment I am aware of – took infinitival clauses to be ambiguous between a “present tense” interpretation and a “future tense” interpretation. The difference between future-oriented verbs and present-oriented verbs, then, is simply that future-oriented verbs select for future-tense complements and present-oriented verbs select for present-tense complements. For future-oriented verbs this account is quite appealing, as, in addition to selecting for a covert “future tense” in infinitival complements, these verbs select for an overt future tense in finite complements. As we see in (6), neither present-tense nor past-tense finite clauses can comfortably appear as complements of *expect*:¹

- (6) a. ??Arnim expects that Monika is writing a very long dissertation.
 b. ??Arnim expects that Monika was writing a very long dissertation.

¹ I am aware of dialects of English in which there is a sense of *expect* meaning ‘strongly believe’ which can appear with such complements. Insofar as non-future readings of *expect*’s infinitival complements are also available in these dialects, there is nothing of interest to say about them.

For these verbs, then, the interpretation of infinitival complements and the restriction on acceptable finite complements can be attributed to the same general selectional restriction: the complement clause must be future tensed.

For present-oriented verbs, however, such an ambiguity-plus-selection account is less attractive. Present-oriented verbs do not select for present-tense finite complement; they take future-tense complements and past-tense complements as well. Thus, the “present tense” interpretation of infinitival complements cannot be derived from general restrictions on the tense of complement clauses and must be independently stipulated. The complement must be “present tensed” if it is infinitival, but there are no restrictions on the tense if it is finite. This is clearly less than desirable.

In later work Ogihara (1996) adopted a “lexical” account which avoided this problem. On this account, a form of which Abusch also adopts, infinitival complement clauses are taken to have only a relative-present interpretation, with the lexical semantics of the embedding attitude verb specifying the time with respect to which the complement clause is to be interpreted: Present-oriented verbs specify a present time, and future-oriented verbs specify a future time. In essence, future-oriented verbs are taken to introduce into the semantics of the sentence a covert future-tense operator that “shifts” the evaluation time of the complement clause into the future. In fact, Abusch argues explicitly that – since a sentence of the form *x expects y to VP* is true exactly when the corresponding sentence of the form *x believes that y will VP* is – *expect* should be interpreted as *believe-will*. This lexical-future analysis runs into trouble, however, when it comes to the treatment of finite complements, as these complements aren’t future-shifted when, perhaps, they should be. More on this later.

The interplay between the temporal interpretation of infinitival complements and the temporal interpretation of finite complements makes the puzzle presented by the data in (1) and (2) more challenging than it might at first seem, particularly if one is looking for a solution that respects compositionality considerations. In this regard, there are four properties that we would hope an ideal solution to our puzzle would exhibit:

- I. Infinitival clauses should have a uniform interpretation in all contexts.
- II. Finite clauses should have a uniform interpretation in all contexts.
- III. Attitude verbs should have a uniform interpretation in all contexts.
- IV. Attitude verbs should combine with their complements in a uniform manner.

As we have seen, the ambiguity analysis lacks the first property. As we will show later, the lexical analysis lacks at least one of the final two.

In what follows I will more thoroughly review the puzzle presented by the contrast in (1) and (2) and the problems that exist for solutions to it of the type Ogihara and Abusch have suggested. I will then sketch an account that avoids these problems and respects the compositionality considerations just mentioned. This will involve adopting a standard Lewis-style *de se* analysis of attitude verb meanings, generalizing it to the treatment of temporal interpretation, but significantly altering the anaphoric account of tenses that usually accompanies such a treatment. I instead adopt a two-dimensional

relational analysis of tense interpretation, embedded in a “dynamic” framework that allows tenses to act like predicates on the one hand and variables on the other, depending on their context of use. This would appear to be a radical departure from standard treatments of tense semantics, but, in fact, is in keeping with some of the most interesting recent proposals (von Stechow 1995a, Kusumoto 1999).

2. Tenses and Tensed Complements

The meaning of tensed sentence is usually factored into two components: the tense and the remainder of the sentence. This remainder has been called variously a “tenseless sentence” (Enç 1986), a “sentence radical” (Galton 1984), or a “basic proposition” (Katz 1995). Intuitively, the tenseless remainder is what the sentences (7a–c) all have in common.

- (7) a. Ede lived in Germany.
b. Ede lives in Germany.
c. Ede will live in Germany.

This remainder is invariably interpreted as that which must be combined with a tense to yield a tensed-clause meaning. I take it to be desirable, if not essential, that infinitival clauses be assigned the same types of meanings, since – at least pre-theoretically – this would seem to be what they are: clauses that lack tense.

But what is tense? Or, better, how are tenses interpreted? Are they sentential operators which “shift” the evaluation time of a sentence, as the traditional Montagovian analysis would have it (Montague 1974)? Or are they referential elements that fill a verbal argument role, as argued by Enç (1986) – perhaps with anaphoric properties (Partee 1973; Partee 1984)?

The referential-anaphoric account of tenses has become increasingly popular (Enç 1987; Abusch 1994; Heim 1994; Kratzer 1998; Kusumoto 1999). On this account, tenses refer to times, and may be “bound” by other time-denoting elements in the sentence or discourse. For example, the embedded tense in (8) may either be bound by the higher tense, as indicated in (9a), or interpreted freely (potentially to be discourse-bound), as in (9b).

- (8) Monika believed that Arnim was in Constance.
- (9) a. Monika PAST₁ believe that Arnim PAST₁ be in Constance.
b. Monika PAST₁ believe that Arnim PAST₂ be in Constance.

The logical form (9a) corresponds to the prominent “same time” reading of (8), on which Monika’s belief was that Arnim was in Constance at the time she had her belief,

while (9b) corresponds to the less-prominent “back shifted” reading, on which Monika’s belief was that Arnim was in Constance at a time before she had her belief. Tenses bear grammatical features – analogous to gender features associated with third-person pronouns – which reflect presuppositional requirements on their reference. “Sequence of tense” is simply taken to be an agreement phenomenon. The pastness of the embedded tense in (9a), for example, simply reflects the binding relation that holds between it and the main clause past tense. It need not indicate semantic anteriority.

As Arnim von Stechow (1984, 1995a, 1995b) has been careful to point out, however, it is a fundamental semantic error to bind variables in the complement clause of an attitude verb, as such binding improperly smuggles information into the content of the attitude that should not be there. In the case of temporal information, the problematic consequences of such illicit binding are quite clear. For example, if the coindexation in (9a) is interpreted as true coreference, then the sentence would attribute to Monika the belief (at some past time) that Arnim was in Constance at that time. The problem is that Monika may have had no idea what time it was or may have been mistaken about the time. To take an unlikely context, if Monika’s watch was running so slowly that when Arnim called from Constance at noon, she thought it was only eleven in the morning, (10a) might be true, but (10b) false.

- (10) a. At noon, Monika believed that Arnim was in Constance.
 b. At noon, Monika believed that Arnim was in Constance at noon.

The embedded tense cannot be taken to refer to the same time as the main clause tense in such constructions, or we risk predicting synonymy. But what, then, does it refer to?

One way of answering this question is to adopt a temporal analog of Lewis’ (1979) treatment of *de se* attitudes (von Stechow 1984; Ogihara 1989; Abusch 1994; Heim 1994; von Stechow 1995a; von Stechow 1995b). To review briefly, Lewis considers the problem of how to distinguish belief about the facts from indexical belief. In Kaplan’s famous sentence (11), for example, we need to distinguish the belief that Jones’ pants are on fire from the indexical belief – what Lewis calls the *de se* belief – that the believer has burning pants.

- (11) Jones thinks his pants are on fire.

If Jones is confused about his own identity, these two beliefs do not coincide. If he thinks that he is Smith, for example, we might want to deny that Jones has the belief that Jones’ pants are on fire while affirming his belief that his own pants are on fire.

Lewis gives a clever account of the distinction by suggesting that the objects of attitudes are not normal propositions – sets of possible worlds – but rather properties, or “centered” propositions – functions from individuals to sets of possible worlds. The embedded expression *his pants are on fire* is not interpreted simply as the set of possible worlds in which Jones’ pants are on fire, but rather as the function from (male) individuals to the set of worlds in which that individual’s pants are on fire. The verb *believe*, then, is translated as a predicate of type $\langle\langle e\langle st \rangle\rangle\langle e\langle st \rangle\rangle$ with the following

(atemporal) interpretation (the function $\text{Dox}_{\text{atemporal}}$ returns, for each individual x and world w , the set of world-individual pairs that x entertains in w as possible alternatives for who he might be and what world he might be in, i.e., x 's doxastic alternatives in w).²

$$(12) \llbracket \text{believe}_{\text{atemporal}} \rrbracket(w, x, P) = 1 \text{ iff } \forall \langle x', w' \rangle \in \text{Dox}_{\text{atemporal}}(w, x) P(w', x') = 1$$

To derive the relevant sentence meaning from the syntactic structure, the index on the “bound” pronoun in the complement clause must be abstracted over at the level of Logical Form. The LF for (11), then, on the *de se* reading, is as in (13).³

$$(13) \text{ Jones}_1 \text{ believes } \lambda 1 [\text{his}_1 \text{ pants are on fire}]$$

After abstraction, the complement clause has the right semantic type to appear as the object of *believe*, since it is interpreted as a function from individuals to propositions. The *de se* truth conditions can be read off the structure of (13): (11) is true *de se* if and only if for all Jones thinks, he is in a world in which his own pants are on fire.

To maintain semantic uniformity in Lewis' system, in the case of propositional – *de re* – belief we must abstract vacuously, as in (14), so that the complement clause has the right semantic type to combine with the embedding attitude verb.⁴

$$(14) \text{ Jones}_1 \text{ believes } \lambda 2 [\text{his}_1 \text{ pants are on fire}]$$

Although the complement clause in (14) is interpreted as a function from individuals to propositions, the object of belief is effectively the proposition that Jones' pants are on fire, since, in this case, the function is a constant function, i.e., the abstractor doesn't bind anything. (11) is true *de re* if and only if for all Jones thinks, he is in a world in which Jones' pants are on fire.

As von Stechow, Ogihara, Abusch, and Heim have all shown, a Lewis-style *de se* analysis can be applied to the temporal interpretation of complement clauses. Consider the following example:

$$(15) \text{ At midnight Fritz believed it was raining.}$$

² We are assuming that verbs have an “extra” world argument position. In extensional contexts this is filled by the actual world, while in intensional contexts it is filled by alternative worlds. The composition of matrix verb and embedded clause is taken to be mediated by, e.g., Heim & Kratzer's (1998) Intensional Functional Application.

³ The syntactic and semantic mechanisms associated with this kind of abstraction have been discussed by Chierchia (1989).

⁴ We have, of course, simplified the *de re* treatment greatly, in that we have assumed simple coreference. A more adequate account would involve the introduction of acquaintance relations (cf. Cresswell & von Stechow 1982).

According to the anaphoric analysis of tense, this sentence is provided with the following LF (for the same-time interpretation).

(16) At midnight_t Fritz PAST₁ believe [it PAST₁ be raining]

As already mentioned, we don't want to claim that (15) means that Fritz believed it was raining at midnight, as the LF in (16) would suggest, because Fritz might not have known at midnight that it was midnight. Instead we want to say that Fritz's belief at midnight was that it was raining at whatever time he thought it was. We want to interpret the object of belief as a "temporally centered" proposition.

We will, then, translate the verb *believe* as a predicate of type $\langle\langle i\langle st \rangle \rangle e\langle i\langle st \rangle \rangle\rangle$ with the following temporal interpretation:⁵

(17) $\llbracket \text{believe} \rrbracket(w, t, x, P) = 1$ iff $\forall \langle w', t' \rangle \in \text{Dox}(w, t, x) P(w', t') = 1$

The function *Dox* here returns for each individual *x*, world *w*, and time *t* the pairs of worlds and times that *x* takes at *t* in *w* to be the viable alternatives for the actual world and the present time. Intuitively, (17) says that to believe *P* is to believe that you are in a world at a time at which *P* holds.

For a concrete illustration, assume that there are three worlds – *w*₁, *w*₂, and *w*₃ – and three times – 11:30pm, midnight, and 12:30am. Let us also assume that in *w*₁ it is raining at 11:30 and 12:30 but not at midnight, in *w*₂ it is raining only at midnight, and in *w*₃ it is raining only at 11:30. We can display this state of affairs graphically as follows:

be-raining	11:30pm	midnight	12:30am
<i>w</i> ₁	1	0	1
<i>w</i> ₂	0	1	0
<i>w</i> ₃	1	0	0

So if Fritz's only belief is that it is raining, and he is not sure what time it is, then his doxastic alternatives are $\langle w_1, 11:30\text{pm} \rangle$, $\langle w_1, 12:30\text{am} \rangle$, $\langle w_2, \text{midnight} \rangle$, and $\langle w_3, 11:30\text{pm} \rangle$. If, in addition, he thinks it is sometime before midnight, his doxastic alternatives are $\langle w_1, 11:30\text{pm} \rangle$ and $\langle w_3, 11:30\text{pm} \rangle$. If, on the other hand, his only belief is that it is exactly midnight, and he has no idea if it is raining or not, then his doxastic alternatives are $\langle w_1, \text{midnight} \rangle$, $\langle w_2, \text{midnight} \rangle$, and $\langle w_3, \text{midnight} \rangle$. Note that we have distinguished indexical belief – the time axis – from factual belief – the world axis.

Returning to the interpretation of (15), to generate an interpretable LF – one where the arguments are of the right semantic type to combine with the predicates – we must

⁵ To keep the discussion simple we have chosen to ignore the individual parameter from now on. A fully general analysis of *de se* belief would involve considering triples of worlds, times and individuals and abstracting over both times and individuals. The belief predicate would then have the interpretation: $\llbracket \text{believe} \rrbracket(w, t, x, P) = 1$ iff $\forall \langle w', t', x' \rangle \in \text{Dox}(w, t, x) P(w', t', x') = 1$.

abstract over the “bound” tense. Doing so yields the structure in (18a), which is interpreted as in (18b).^{6,7}

(18) a. At midnight₁ Fritz PAST₁ believe $\lambda 1$ [it PAST₁ be raining]

b. $\forall \langle w', t' \rangle \in \text{Dox}(w_0, \text{midnight}, \text{Fritz})$ **be-raining**(w', t') = 1

(15) is true, then, if at midnight Fritz located himself at a time in a world in which it was raining, that is, if Fritz’s doxastic alternatives at midnight were a subset of the set $\{\langle w_1, 11:30\text{pm} \rangle, \langle w_1, 12:30\text{am} \rangle, \langle w_2, \text{midnight} \rangle, \langle w_3, 11:30\text{pm} \rangle\}$. If, in addition, Fritz knew what time it was, then he located himself in world w_2 .

The *de se* analysis of the temporal component of attitude reports has become a standard accompaniment to the anaphoric treatment of tense (and *vice-versa*). The parallel it presents between pronouns on the one hand and tenses on the other is quite appealing, particularly in the context of the interpretation of “sequence of tense” past tenses. As we have seen, the same interpretive mechanisms can be applied to these bound tenses as are applied to bound pronouns in attitude complements (for discussion of these parallels, see Kratzer 1998). For us, however, the real appeal lies in the straightforward way this analysis can be applied to the treatment of infinitival complements of attitude verbs, as they can literally be interpreted as tenseless clauses.

3. Infinitival Complements

On the referential account of tense, interpreting infinitival clauses as tenseless means interpreting them as intensionalized properties of times. And as such, they are intrinsically of the right semantic type to appear as the clausal complement of *believe*. The infinitival complement clause in (19), for example, is interpreted as the predicate $\lambda t \lambda w. \text{be-raining}(w, t)$, which of course is simply the meaning of the VP *be raining*.

(19) Fritz believes it to be raining.

Combining this with our analysis of *believe* gives us the truth conditions in (20).

(20) $\forall \langle w', t' \rangle \in \text{Dox}(w_0, t_0, \text{Fritz})$ **be-raining**(w', t') = 1

In other words, (19) is true if and only if all the world-time pairs in Fritz’s doxastic alternatives are worlds and times at which it is raining. In the state of affairs we de-

⁶ It is an open question whether it is possible to have a *de re* interpretation of bound tense. While I think that it is, we will not consider that question here.

⁷ The distinguished variables w_0 and t_0 are taken – when free – to refer to the actual world and the speech time, respectively (Heim 1994; Stechow 1995b).

scribed above, (19) would be true if and only if Fritz' doxastic alternatives were a subset of the set $\{\langle w_1, 11:30\text{pm} \rangle, \langle w_1, 12:30\text{am} \rangle, \langle w_2, \text{midnight} \rangle, \langle w_3, 11:30\text{pm} \rangle\}$.

The belief attributed to Fritz in (19) and that attributed to him in (15), then, are identical. The fact that in one case the complement clause contains a *de se*-interpreted past tense and in the other case it is an infinitival clause doesn't play a role, since in both cases the temporal argument of the embedded predicate is filled by the temporal parameter of the doxastic alternative pair, i.e., by the believer's "subjective present." The only difference is that in the case of tensed clauses, the tense must be abstracted over before the embedded clause can be combined with the attitude verb. To put it another way, the "same-time" reading is what we call the interpretation on which the subjective present introduced by the attitude verb fills the temporal argument of the embedded verb. Tensed complements only have the same-time reading, of course, when the tense is interpreted *de se*, i.e., when it is abstracted over, and not when it is free. Infinitival complements, however, should always have a same-time interpretation. Our puzzle, of course, is that they don't. In contrast to (19), for example, (21) has a future shifted interpretation.

(21) Fritz expects it to be raining.

(21) is true if Fritz locates himself at a time in a world at which it will be raining later. How, then, do we explain the fact infinitival complements of future-oriented verbs such as *expect* have such a future-shifted interpretation?

Ogihara (1989) suggested that the difference between (19) and (21) lay in the meaning of the complement clause, and, in particular, in the meaning of the infinitive marker *to*. In (21) we have to_{fut} – a future tense operator – while in (19) we had to_{pres} – a present tense operator. In the introduction I pointed out one of the undesirable consequences of such an account, namely that we would need to stipulate that to_{fut} can never appear in the complement of present-oriented verbs such as *believe*. Since in principle *believe* can take future-tensed complements, there is no other way to prevent *believe*'s infinitival complements from getting a future-shifted reading. A further reason to doubt that the temporal interpretation of infinitival complements is tied to the interpretation of the infinitival marker *to* is that the same present/future contrast in interpretation exists for non-*to*-marked complements:

(22) a. Francis believes them lost.

b. Francis expects them late.

Clearly in (22a) we have a present interpretation, while in (22b) we have a future interpretation. Whatever is responsible for the present/future contrast, then, must be unrelated to the infinitival marker.

Accordingly, following Ogihara (1996) and Abusch (to appear), we will provide infinitival clauses themselves with a univocal meaning and derive the differences in complement-clause interpretation from the lexical semantics of the embedding attitude verbs. In particular, we will take *expect* and other future-oriented verbs to introduce

lexically a time-shifting future-tense-like operator into the semantics of the sentence. We (provisionally) translate *expect*, then, as a predicate of type $\langle\langle i\langle st \rangle \rangle \langle e\langle i\langle st \rangle \rangle \rangle$ – the same type as *believe* – but with the following interpretation:⁸

$$(23) \llbracket \text{expect}_{\text{prov}} \rrbracket(w, t, x, P) = 1 \text{ iff } \forall \langle w', t' \rangle \in \text{Dox}(w, t, x) \exists t'' [t'' > t' \ \& \ P(w', t'') = 1]$$

Whereas to believe *P* is to locate oneself at a world and time at which *P* holds, to expect *P* is to locate oneself at a world and a time at which *P* will come to hold. For *expect* the complement clause is applied to a time that the attitude holder takes to be in his future, not, as in the case of *believe*, to a time he takes to be his present. The truth conditions for (21) are, then, as follows:

$$(24) \forall \langle w', t' \rangle \in \text{Dox}(w_0, t_0, \text{Fritz}) \exists t'' [t'' > t' \ \& \ \text{be-raining}(w', t'') = 1]$$

In other words, (21) is true if and only if in each of his belief worlds Fritz locates himself at a time before a time at which it is raining. In the state of affairs described above (21) would be true if and only if Fritz's doxastic alternatives were a subset of the set $\{\langle w_1, 11:30\text{pm} \rangle, \langle w_1, \text{midnight} \rangle, \langle w_2, 11:30\text{pm} \rangle\}$.

The advantages of this type of analysis are clear. It confines the difference between present-oriented verbs and future-oriented verbs to the lexical semantics of the verbs themselves, it involves no stipulated ambiguity, and, at least to a first approximation, it captures the intuitive relationship between *believe* and *expect*: To expect something is simply to believe that it will happen. Such an analysis runs into trouble, however, when it is applied to tensed complements.

As is well known, a present tense clause in the scope of a future tense can have a future-shifted reading, as in (25).

(25) Arnim will buy a fish that is alive.

So, the fish might be alive at the (future) time at which it is bought but not (yet) alive at the time of speech. If the lexical semantics of *expect* truly contains a future-shifting operator, then we would expect this operator also to shift the interpretation of present-tense clauses in its scope. Consider, however, sentence (26):

(26) ??Fritz expects that it is raining.

It is clear that the complement clause does not have a future-shifted reading, even for those speakers who take the sentence to be acceptable. Unfortunately, the theory as so far outlined provides (26) with exactly such a future-shifted interpretation.

⁸ In order to capture the fact that one can have misconceptions about the temporal relationships that hold between times, the temporal ordering relation should be parameterized with respect to the world of evaluation, i.e., $t'' > t'$ should read $t'' >_w t'$. We simplify for readability's sake.

Following the *de se* analysis of tensed complements we presented in the last section (26) would be assigned the LF in (27).

(27) Fritz PRES₁ expect λ I [it PRES₁ be raining]

As we noted above, when the embedded tense is abstracted over, the tensed complement clause is interpreted as a property of times, i.e., it has the same interpretation as an infinitival clause. This means that when the complement clause in (27) is combined with a future-oriented matrix verb such as *expect*, the complement clause should be future-shifted by the covert temporal operator associated with the verb. The truth conditions for (26), then, should be as in (28).

(28) $\forall \langle w', t' \rangle \in \text{Dox}(w_0, t_0, \text{Fritz}) \exists t'' [t'' > t' \ \& \ \mathbf{be-raining}(w', t'') = 1]$

(26) should mean that Fritz thinks it will rain. But, of course, it doesn't.

Both Ogihara (1996) and Abusch (to appear) handle this problem by simply stipulating that the covert future-shifter is only introduced when the complement clause is an infinitival. Such a stipulation, however, violates one of the basic compositionality conditions that we are trying to hold to. It effectively means that attitude verbs are provided with different interpretations depending on whether or not their complement clause is tensed. In addition, such a stipulation makes it impossible to relate the future-shifted interpretation of infinitival complements of *expect* to the selectional restrictions on *expect*'s finite complements.

To treat future-oriented verbs in more satisfactory way we will need to adopt a more sophisticated analysis of tensed complement clauses than the one which we have been assuming. We can no longer assume that embedded tenses are simply interpreted as variables. We need to confront the fact that tenses have semantic content.

4. A New Semantics for Tensed Complements

In our earlier discussion of embedded tenses I made a slight omission when I suggested that the back shifted reading of a sentence such as (29) is a case of a "free" tense.

(29) Fritz believed that Arnim climbed Monta Rosa.

This is not really correct. A tense embedded under an attitude verb is rarely, if ever, free.⁹ Even if it is not bound, it is typically still interpreted with respect to the attitude holder's subjective present. On the back-shifted reading of (29), for example, the embedded past tense is interpreted with respect to the time Fritz thought it was when he

⁹ Potential exceptions are *de re* interpretations of tense such as the so-called "double access" interpretations of sentences like *John said that Mary is pregnant* (Ogihara 1989, Abusch 1994).

had his belief. The sentence is interpreted to mean that Fritz located himself at a time after a time at which Arnim climbed Monta Rosa.

This relativity of interpretation has the effect that sometimes an embedded past tense doesn't end up referring to a past time at all. In (30), for example, the embedded past tense is interpreted with respect to Wolfgang's future doxastic alternatives and might therefore refer to a time that, while in the past with respect to this future time, is actually after the speech time.

(30) Wolfgang will believe that the students turned in their papers on time.

Relative tense interpretation presents well-known problems for the anaphoric analysis of tense meaning, since it shows that tenses do behave (at least sometimes) like "shifting" operators. In what follows, I would like to develop on a suggestion made by von Stechow (1995a) for how to treat relative tenses in the context of an anaphoric theory and show how this new account will help us address the problems raised above with the interpretation of tensed complements of future-oriented verbs.

Von Stechow suggested that tenses be treated as relational operators. A tense takes three arguments: two times – the perspective time and the event time – and a temporal predicate. The perspective time is the time with respect to which the truth of the clause as a whole is evaluated – usually either the speech time or the subjective present of the attitude holder – and the event time is a time which satisfies the open temporal argument of the predicate. Formally, tense operators will be subscripted with two indices. The left index is interpreted as the perspective time and the right index as the event time. The interpretations for the tenses given in (31) should make this clear.

- (31) a. $[[i\text{PRES}_j]]^g(w, P) = 1$ iff $g(j) = g(i)$ and $P(w, g(j)) = 1$
 b. $[[i\text{PAST}_j]]^g(w, P) = 1$ iff $g(j) < g(i)$ and $P(w, g(j)) = 1$
 c. $[[i\text{FUTR}_j]]^g(w, P) = 1$ iff $g(j) > g(i)$ and $P(w, g(j)) = 1$

Semantically, then, tenses require that a particular temporal relation hold between the perspective time and the event time and that the temporal predicate be applied to the event time. Under this view of tense interpretation, tensed clauses are treated as formulae with possibly free variables. The indices on a tenses may be bound by other time-denoting elements in the sentence or discourse, and may themselves act as binders. Although highly non-standard, this proposal is very much along the lines of the analysis put forward recently by Kusumoto (1999).

There are two operations that can apply in the course of the derivation to bind the otherwise free variables (or to rebind those that are improperly bound): existential closure and abstraction. These will be taken to be operations on LFs, as indicated in (32).

- (32) a. Existential Closure: $\text{CP}[v] \Rightarrow [\exists v \text{CP}[v]]$
 b. Abstraction: $\text{CP} \Rightarrow [\lambda v \text{CP}]$

Existential Closure must bind a free variable. Abstraction need not. Abstraction applies – as we have seen – in order to avoid type-clashes. Existential closure simply provides a strategy for interpreting otherwise unbound variables (as has become standard since Heim 1982). Both operations are clause-bound.

With respect to abstraction, note that variables bound by operators outside the CP must be abstracted over when the CP is a complement of an attitude verb in order to avoid the semantic problems associated with binding into an opaque context. We follow von Stechow in adopting the convention that that these variables are abstracted over last. Vacuous abstraction is not ruled out, and, as we mentioned above, in the case of normal propositional belief vacuous abstraction must apply in order to preserve interpretability. We will, however, rule out vacuous abstraction when there are free variables that could be abstracted over. In other words, if abstraction applies, then it should bind a variable if there is one to bind. Existential closure applies after abstraction to bind any variables that remain unbound. Note that variables which are deictically bound, such as the indexical pronouns and the speech time variable 0 are not bound by existential closure.

While this may seem an *ad hoc* set of principles, in fact what we see is that the temporal variables associated with the tenses are being treated as indefinite pronouns, analogous to those Chierchia (2000) has recently been investigating in the nominal domain. When they are not bound, they are treated like indefinites, and when they are bound they are treated like pronouns. Since abstraction and existential closure are used to treat *de se* pronouns on the one hand and indefinite noun phrases on the other, it is not surprising that both operations end up playing a role in tense interpretation.

Von Stechow assumed that tense operators were ambiguous between a relative interpretation and an anaphoric interpretation. I will instead treat all tenses as relative and incorporate a kind of sequence-of-tense rule into the syntax, in the style of Stowell (1993). That is, I assume that the actual morphological spell-out of a tense operator is determined by two factors: the identity of the tense operator itself, and whether or not it is marked with the morphological feature [past]. The [past] feature is lexically associated with the PAST operator, and is passed on to other tense operators whose perspective time index is “bound” by the event time index of a [past]-marked operator. This feature passing is accomplished via the Tense Agreement Rule given in (33).

(33) Tense Agreement Rule

$$[\dots \text{TNS}[\text{past}]_i \dots [\dots {}_i \text{TNS} \dots] \dots] \Rightarrow [\dots \text{TNS}[\text{past}]_i \dots [\dots {}_i \text{TNS}[\text{past}] \dots] \dots]$$

The tense operators themselves are spelled out morphologically as indicated below:

(34) The Tense Operators

PRES[past] → *-ed*
 FUTR[past] → *would*
 PAST[past] → *-ed*
 PRES → \emptyset
 FUTR → *will*

Presumably, English morpho-syntax takes care of the proper spellout of these abstract morphemes.

To illustrate the workings of the analysis, let us consider the treatment of (35).

(35) John believed that Bill would leave.

The LF for (35), which indicates the operators and their binding relations, is (36).

(36) $\text{John}_0 \text{ PAST}[\text{past}]_1 \text{ believe that } [\text{Bill}_1 \text{ FUTR}[\text{past}]_2 \text{ leave}]$

The [past] feature on the FUTR operator indicates that this operator is (syntactically) bound by a [past]-marked matrix tense. Note that the [past] feature does not carry any semantic value.¹⁰ To “break” the binding relation between the higher tense and the lower tense, abstraction must apply to (36), yielding the structure in (37).

(37) $\text{John}_0 \text{ PAST}[\text{past}]_1 \text{ believe that } \lambda 1 [\text{Bill}_1 \text{ FUTR}[\text{past}]_2 \text{ leave}]$

Note that had we abstracted over the free variable 2 instead of 1, the illicit binding relation between the higher and the lower tense would remain. Were we to abstract over both 1 and 2, then we would have an object of the wrong semantic type to appear as the object of *believe*. Only the structure in (37) satisfies our conventions concerning abstraction and is interpretable.

Interpreting the LF in (37) – applying existential closure at each clausal level but not to the distinguished variable 0 – gives us the truth conditions in (38).

(38) $\exists t [t < t_0 \ \& \ \forall \langle w', t' \rangle \in \text{Dox}(w_0, t, \text{John}) \exists t'' [t'' > t' \ \& \ \text{leave}(w', t'', \text{Bill}) = 1]]$

In other words, the claim is that at some time in the past John located himself in a world at a time at which Bill subsequently left. This seems correct.

We might note at this point that we have already accounted for part of our puzzle, namely the fact that (2a) and (2b) cannot be synonymous. Since infinitival complements of *believe* are always applied directly to the believer’s subjective present, but, as we have just seen, future-tense complement clauses are always future-shifted with respect to the subjective present, a *believe*-sentence with an infinitival complement can never be synonymous with the corresponding sentence with a future-tense complement. The real puzzle, of course, is to account for the fact that for *expect* this is not the case.

Before we turn to this, however, let me illustrate how my treatment of sequence of tense works by deriving the two interpretations of the ambiguous sentence (39).

¹⁰ As Kusumoto has noted, on accounts in which *would* is decomposed into a PAST operator plus a FUTR operator (cf. Abusch 1988), there is no explanation for the fact that *would* never gives rise to a “back shifted” reading, i.e., that (35) never means *John thought that Bill had been going to leave*. This problem does not arise here, as *would* only appears when its perspective index is bound by a higher PAST operator, as explicitly indicated in (36).

(39) Fritz believed it was raining.

As is typical for sequence-of-tense analyses, the LF for the same-time interpretation contains an embedded present tense operator, while that for the back-shifted interpretation contains an embedded past tense operator:

- (40) a. Fritz ₀PAST[past]₁ believe λ 1 [it ₁PRES[past]₂ be raining]
 b. Fritz ₀PAST[past]₁ believe λ 1 [it ₁PAST[past]₂ be raining]

Note that both PRES[past] and PAST[past] are spelled out by the same morpheme. The truth conditions for (40a) and (40b) are different, of course, as we see in (41a) and (41b).

- (41) a. $\exists t [t < t_0 \ \& \ \forall \langle w', t' \rangle \in \text{Dox}(w_0, t, \text{Fritz}) \ \exists t'' [t'' = t' \ \& \ \text{be-raining}(w', t'') = 1]]$
 b. $\exists t [t < t_0 \ \& \ \forall \langle w', t' \rangle \in \text{Dox}(w_0, t, \text{Fritz}) \ \exists t'' [t'' < t' \ \& \ \text{be-raining}(w', t'') = 1]]$

(40a) has an underlying present tense operator, so the perspective time index and the event time index must refer to the same time, but (40b) has an underlying past tense operator, so the event time index must refer to an earlier time.

We are now in a position to give a new semantics for future-oriented verbs that does not run afoul of the problems that we raised above for the simple lexical account.

5. Tensed Complements of Future-Oriented Verbs

I propose that future-oriented verbs differ from present-oriented verbs not just in their temporal orientation, but in the logical type of their clausal complements. As we have seen, to interpret tensed complements of present-oriented verbs such as *believe* we need only abstract over the perspective time index. The event time index is typically otherwise bound, usually existentially. To interpret future-oriented verbs such as *expect*, however, it appears that we need to abstract over both the perspective time and the event time. I propose, then, that *expect* be translated as a predicate of type $\langle\langle i \langle i \langle st \rangle \rangle \rangle \langle e \langle i \langle st \rangle \rangle \rangle$ with the following interpretation:

- (42) $\llbracket \text{expect} \rrbracket (w, t, x, P) = 1$ iff $\forall \langle w', t' \rangle \in \text{Dox}(w, t, x) \ \exists t'' [t'' > t' \ \& \ P(w', t'', t') = 1]$

Whereas previously *expect* took as its clausal argument an intensionalized property of times, now it takes an intensionalized property of properties of times. *Expect* and *believe* now differ in the logical type of their complement clauses. In addition, *expect* specifies the temporal relation that holds between the times that fill the complement clause's temporal argument positions.

It may be easiest to understand how this new semantics for *expect* combines with our system for tensed-clause interpretation by way of example. Consider (43a), the logical form of which is given in (43b).

- (43) a. Fritz expects that Arnim will laugh.
 b. Fritz₀ PRES₁ expect [Arnim₁ FUTR₂ laugh]

In order that the clausal argument of *expect* have the right semantic type, we need to abstract twice. First we abstract over the free variable 2, since an abstractor should bind a variable if there is one to bind. Then we abstract over the improperly bound variable 1, since it must be abstracted over, and by convention it must be abstracted over last. This yields the structure in (44):

- (44) Fritz₀ PRES₁ expect $\lambda 1 \lambda 2$ [Arnim₁ FUTR₂ laugh]

This structure can be interpreted, and the truth conditions for it are given in (45).

- (45) $\forall \langle w', t' \rangle \in \text{Dox}(w_0, t_0, \text{Fritz}) \exists t'' [t'' > t' \ \& \ \text{laugh}(w', t'', \text{Arnim}) = 1]$

Note here that the existential force associated with the variable t'' – the time at which Arnim laughs – is contributed by the lexical semantics of the predicate *expect*. Furthermore, note that the relationship between the subjective present – t' – and this time of laughter is doubly specified, once by the lexical semantics of the attitude verb itself and once by the tense.

This double specification accounts for the requirement that tensed complements of *expect* must be future-tense clauses. If the complement were a present- or past-tense clause, the temporal specification associated with the attitude verb would be in conflict with that associated with the tense.¹¹ Consider, for example, (46a), whose logical form is (46b).

- (46) a. ??Fritz expects that it is raining.
 b. Fritz₀ PRES₁ expect $\lambda 1 \lambda 2$ [it₁ PRES₂ be raining]

While (46b) is formally interpretable, it is necessarily false, since the temporal relation introduced by *expect* and that introduced by the embedded present tense are in conflict. This can be seen by inspecting the computed “truth conditions” given in (47).

- (47) $\forall \langle w', t' \rangle \in \text{Dox}(w_0, t_0, \text{Fritz}) \exists t'' [t'' > t' \ \& \ t'' = t' \ \& \ \text{be-raining}(w', t'') = 1]$

¹¹ It might be the case that these specifications have somewhat different force. The marginal acceptability of non-future tensed finite complements indicates that the temporal specification associated with the lexical entry for *expect* might, in fact, be some sort of default presupposition, which an overt tense can override.

Naturally, no time can be both after t' and identical with it. Thus the lexical specification account explains the fact that only future-tense clauses can appear as complements of future-oriented verbs.

As desired, the same account explains the future-shifted interpretation of infinitival complements. Again, let us take an example. Consider an infinitival version of (43a):

(48) Fritz expects Arnim to laugh.

Given our new semantics, the infinitival clause is of the wrong type to appear as the complement of *expect*. Infinitival clauses are interpreted as properties of time, but *expect* needs a complement that is a property of properties of time. In order to get the right type, then, we need to apply vacuous abstraction. The logical form of (48), then, is (49).

(49) Fritz₀ PRES₁ expect $\lambda 2$ [Arnim to laugh]

The binder variable 2 , like those variables introduced by Lewis for non-*de se* belief, will play no role in the specification of the truth conditions of the sentence, as it will not bind anything. The complement clause meaning will first be applied to the subjective present variable t' , which will, in a sense, disappear. Then it will be applied to the future time introduced lexically by *expect*, and it is this time that will be interpreted as the laughing time. The truth conditions for (48), then, are those given in (50).

(50) $\forall \langle w', t' \rangle \in \text{Dox}(w_0, t_0, \text{Fritz}) \exists t'' [t'' > t' \ \& \ \text{laugh}(w', t'', \text{Arnim}) = 1]$

This, of course, is identical with (45). In the course of calculating (50), however, the temporal relation between t' and t'' is specified only once, and this is by the lexical semantics of the attitude verb. Thus the lexical requirements of the embedding verb simultaneously account for the future-shifted interpretation of infinitival complements and the selectional restrictions on finite complements.

Going back to our puzzle, we now have accounted for the synonymy of (1a) and (1b) and the non-synonymy of (2a) and (2b). And, since we have explicated the meanings of *expect* and *believe* with the same *Dox* operator, we have also accounted for the synonymy of (1a–b) and (2a). Furthermore, our account appears to have each of the properties we enumerated at the outset that a compositional account should have. Both verbs are given univocal interpretations, as are both classes of complement clauses, and the mechanism of verb/complement-clause combination is uniform. Only the flexibility which we have built into this mechanism might be seen as not-quite-compositional. It is precisely this flexibility, however, that allows us to relate the temporal interpretation of infinitival complements to the selectional restrictions on finite complements, this being the final desideratum that we had hoped our analysis would satisfy. I would venture to suggest, then, that the brute empirical facts surrounding the temporal interpretation of complement clauses might simply show us how necessary a flexible, dynamic approach to natural language semantics is.

6. Conclusion

Deriving the temporal interpretation of finite and non-finite clausal complements of attitude verbs such as *believe* and *expect* presents many challenges for a compositional semantic theory. Owing to the groundbreaking work of von Stechow, Heim, Ogihara, Abusch, and others, we have been able to come to grips with the scope of these challenges. The simple facts that need to be accounted for – that infinitival complements of *believe* have a present interpretation while infinitival complements of *expect* have a future interpretation and that finite complements of *believe* can be past, present, or future tensed, but finite complements of *expect* must be future tensed – do not, in the end, appear amenable to a classical analysis. We have been forced to adopt a more sophisticated approach, on which tenses display both anaphoric and operator-like properties. This may appear to many to be quite strange. I hope that the strangeness isn't off-putting and that the considerations that have led us to adopt the analysis are convincing. After all, superficial oddity should not trouble us – here of all places – if the account can be shown to be motivated and to work.

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