

Temporal Connectives and Logical Form

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Temporal Connectives and Logical Form

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0.0 The infusion of logic into linguistic semantics has been both a bane and a salvation. Its rigor and its requirement that semantics must relate language to the world have lead to a clarity of purpose and important insights, but the tendency to abstract away from or ignore the intricacies and richness of natural language in favor of exploring more well-behaved formal languages has suggested to some that formal semantics is artificial and limited in its usefulness. But one must be careful here to distinguish limitation in practice from limitation in principle. Following Montague (1973) we reject the contention that important differences exist between formal and natural languages. The question to ask, then, is not whether language is like logic, but rather, what type of logic does language have?

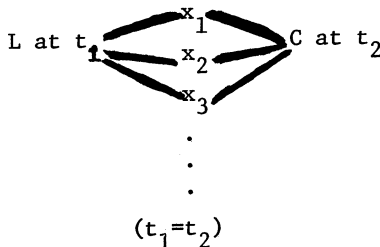
We assume that semantics proceeds by defining a translation relation between syntactic structure and representations in a disambiguated language called logical form (LF). LF's are then given an interpretation in a model. Our particular task is to give a truth-conditionally adequate semantics for certain adverbial clauses in English containing the adverbs when, before, and after in their use as temporal connectives. We also investigate the properties of Verbphrase Deletion (VPD) as it applies in temporal adverbial clauses.

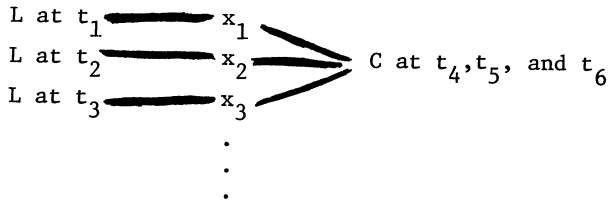
0.1 (1)-(3) present examples of the relevant data.

- (1) Leslie greeted everyone when Chris greeted everyone.
- (2) Leslie greeted everyone when Chris greeted 'em.
- (3) Leslie greeted everyone when Chris did.

Note that (1)-(3) are each ambiguous. (1) has two readings: one where Leslie gives one mass greeting to all involved at the same moment that Chris does, and a second where Leslie greets each member of the domain, and at each of these greeting times, Chris collectively greets everyone involved. These two readings, which we call group/group and individual/group respectively, are schematized in (4)-(5).

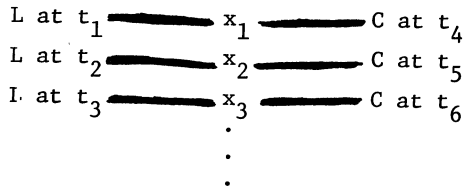
- (4) GROUP/GROUP READING



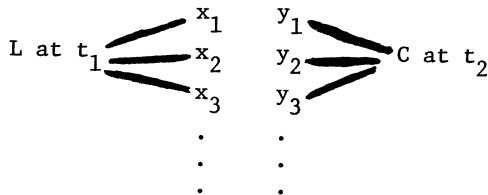
(5) INDIVIDUAL/GROUP READING

$$(t_1=t_4, t_2=t_5, t_3=t_6)$$

(2) introduces two new readings. On the first, (2) requires that Leslie and Chris each give individual, simultaneous greetings to everyone. On the second, Leslie gives one collective greeting to everyone at issue at the same time that Chris collectively greets some group which is contextually determined, perhaps by previous discourse. This second group may be identical to the group identified as "everyone" in the matrix clause, but it need not be. The two readings, which we call individual/individual and discourse Them readings, are schematized in (6) and (7), respectively.

(6) INDIVIDUAL/INDIVIDUAL READING

$$(t_1=t_4, t_2=t_5, t_3=t_6)$$

(7) DISCOURSE THEM READING

$$(t_1=t_2, \diamond x=y)$$

Finally, note that sentence (3) shares one reading with each of (1) and (2). It bears both the group/group and individual/individual interpretations. (8) summarizes the facts to be accounted for.

(8)	SENTENCES	READINGS			
		4	5	6	7
	1	+	+	-	-
	2	(+) ¹	(+)	+	+
	3	+	-	+	-

0.2 Our analysis of these facts proceeds as follows. Adopting in important respects the syntax of when-clauses suggested by Bresnan and Grimshaw (1978), we define a class of explicit translation rules which map from superficial syntactic structure onto logical form. The mapping disambiguates the English, providing a correct account of the number and type of readings inhering in sentences containing temporal adverbials. Second, we provide independent motivation for our conception of LF by demonstrating the manner in which VPD is sensitive to its syntax. As was first argued by Lakoff, the possibility of applying VPD to a sentence depends crucially on certain aspects of its logical structure. Following Sag (1976, forthcoming), we extend this insight by illustrating how VPD is sensitive to matters of quantifier scope and variable binding. The logical forms we assign to (1)-(3) lead to just the right predictions about where VPD can apply, hence providing additional support for our proposal.

0.3 If correct, our arguments support four conclusions: 1) We provide evidence for a surface structure oriented semantics as being developed in Montague Grammar, or, as we assume, through an integration of Montague Grammar and Transformational Grammar. 2) Our analysis supports a weakened version of Frege's principle of compositionality which allows that scope assignments may be assigned via a technique known as storage due to Robin Cooper. 3) The facts we examine prove to undermine the view that two unrelated identity conditions on VPD-- one syntactic and one logical-- apply. A single condition applying at logical form is argued to be sufficient and probably necessary as well. 4) Finally, as a consequence of our analysis, some, but not all pronouns must be represented as bound variables in the standard sense at logical form. In this way, our initial results concerning temporal connectives and logical form point to important consequences for a general theory of anaphora.

1.0 In a nutshell, we argue that when, before, and after translate as temporal operators at LF. Their semantics requires that two sentences in the scope of the temporal operator be true at times whose orientation to each other is determined by the choice of the temporal connective. Thus, a sentence of the form P when Q will translate into a formula of the form when(P,Q) which is true just in case P and Q are each true at the same moment of time.² On analogy, after(P,Q) is true iff P is true at a time which is later than a time at which Q is true, and before(P,Q) is true iff P is true at a time prior to a time at which Q is true. The different readings located in (1)-(3) can be described as resulting from the different scope possibilities obtaining between the quantifiers

which translate everyone and the operators which translate temporal connectives. That is, given the semantics for when just described, the following logical schemata correspond to the readings previously established.

- (9) $\text{when}((\forall x_0)P, (\forall x_1)Q)$ (GROUP/GROUP READING OF (1))
 $(x_0 \text{ free in } P, x_1 \text{ free in } Q)$
- (10) $(\forall x_0) \cdot \text{when}(P, (\forall x_1) \cdot Q)$ (INDIVIDUAL/GROUP READING OF (1))
 $(x_0 \text{ free in } P, x_1 \text{ free in } Q)$
- (11) $(\forall x_0) \cdot \text{when}(P, Q)$ (INDIVIDUAL/INDIVIDUAL READING OF (2))
 $(x_0 \text{ free in } P, Q)$
- (12) $(\forall x_0) \cdot \text{when}(P, Q)$ (DISCOURSE THEM READING OF (2))
 $(x_0 \text{ free in } P, f_0, \text{ a discourse variable, free in } Q)$

1.1 Given this background, the purpose of this section is to sketch the logical language we develop and to illustrate the nature of the translation process which maps superficial syntactic structures into LF.

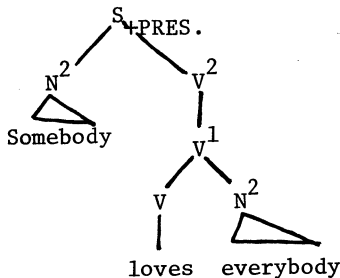
1.1.1 The syntax of our logical language is an extended version of standard predicate calculus. Modifications include the use of restricted quantification, the abstraction operator λ , and sentence operators which occur in the translations of tense and temporal connectives. The semantics of LF follows most recent standard treatments (eg. Montague, Cresswell, Davidson, etc.), except that we leave open the question of the role that intensions play in the interpretation. We exclude them with some malice aforethought, but one might suppose this to simply reflect their irrelevance for our present purposes. Thus, presuming a standard semantics for restricted quantifiers and the lambda operator, we include the following formal rules giving the semantics for past tense and the temporal connectives.

- (13) $\lceil \text{Past}(P) \rceil$ is 1 at t_i iff $\lceil P \rceil$ is 1 at t_j for some $j < i$.
- (14) $\lceil \text{when}(P, Q) \rceil$ is 1 at t_i iff $\lceil P \rceil$ is 1 at t_i and $\lceil Q \rceil$ is 1 at t_j .
- (15) $\lceil \text{after}(P, Q) \rceil$ is 1 at t_i iff $\lceil P \rceil$ is 1 at t_i and $\lceil Q \rceil$ is 1 at t_j for some $j < i$.
- (16) $\lceil \text{before}(P, Q) \rceil$ is 1 at t_i iff $\lceil P \rceil$ is 1 at t_i and $\lceil Q \rceil$ is 1 at t_j for some $j > i$.

1.1.2 The translation rules we employ to take superficial syntactic structures into LF function in a bottom-up fashion. That is, a verb translation applied to an NP translation yields a VP translation, an NP translation combines with a VP translation to yield an S translation, etc. A second important feature of the translation system is the use we make of storage. In certain cases, quantifiers and operators can attain wider scope at LF than they have at superficial syntactic structure. Although a simple bottom-up translation procedure requires identical scopes at both the syntactic and logical levels of a derivation, we allow quantifiers and temporal connectives

to be temporarily "stored" while the part of the syntactic tree in which they appear is translated, permitting them to be retrieved from storage and assigned wider scope at a later point in the translation procedure. Thus, schematically, we can represent how the use of the storage mechanism allows us to represent a crossed-scope reading of (17) where the quantifier translating everybody has widest scope at LF.^{2a}

(17)



$$N^2 \Rightarrow \langle \underbrace{x_1}_{\text{MAIN TRANSLATION}}, \langle \underbrace{(\forall x_1)}_{\text{STORAGE}} \rangle \rangle$$

$$\vdots$$

$$S \Rightarrow \langle \underbrace{(\exists x_2) \cdot \text{love}(x_2, x_1)}_{\text{MAIN TRANSLATION}}, \langle \underbrace{(\forall x_1)}_{\text{STORAGE}} \rangle \rangle \rightsquigarrow$$

$$\langle \langle \underbrace{(\forall x_1) (\exists x_2) \cdot \text{love}(x_2, x_1)}_{\text{MAIN TRANSLATION}}, \langle \underbrace{\emptyset}_{\text{STORAGE}} \rangle \rangle \rangle$$

In effect, the storage mechanism allows us to build up VP translations consisting of the translation of a transitive verb and a free variable, and that free variable becomes bound when the quantifier in storage is assigned scope at the sentence level of the translation. The other properties of the translation system and especially the translation rules we employ will be presented in detail as part of our analysis of temporal connectives.

2.0 Since all scope-taking expressions may be optionally put in storage and assigned a wider scope at LF than they exhibit at superficial syntactic structure, our translation procedure yields multiple representations for (1)-(3) at LF. In (1), for example, the universal quantifier translating the matrix direct object everyone may be assigned narrower scope than the translation of when as in (18) which schematizes the group/group reading of (1).

$$(18) \quad \underbrace{\text{when}}_{\text{main}} \langle \underbrace{(\forall x_0) \cdot \text{greet}(c, x_0)}_{\text{main}}, \underbrace{(\forall x_1) \cdot \text{greet}(k, x_1)}_{\text{main}} \rangle$$

On a second derivation the matrix universal quantifier remains in storage while the translation of when is assigned scope. (19) illustrates this stage.

$$(19) \underbrace{\langle \text{when}(\forall x_0) \cdot \text{greet}(C, x_0), \text{greet}(L, x_1) \rangle}_{\text{MAIN TRANSLATION}}, \underbrace{\langle \forall x_1 \rangle}_{\text{STORAGE}}$$

When $(\forall x_1)$ is retrieved and assigned scope, the result, given in (20), establishes wide scope for the matrix universal quantifier with respect to the translation of when, symbolizing the reading we call individual/group.

$$(20) \underbrace{\langle \forall x_1 \rangle \cdot \text{when}(\forall x_0) \cdot \text{greet}(C, x_0), \text{greet}(L, x_1) \rangle}_{\text{MAIN TRANSLATION}}, \underbrace{\langle \emptyset \rangle}_{\text{STORAGE}}$$

Informally, the difference in truth conditions signalled by the different scopal relations in (18) and (20) turns on the fact that (18), but not (20), requires a single time at which both Chris's and Leslie's greetings take place. Since when's translation has wide scope in (18), the semantics requires simultaneous greetings. In (20), however, since $(\forall x_1)$ has widest scope, the truth conditions require that for all individuals, each time Leslie greets one of them must be a time at which Chris greets all of them. Thus, since $(\forall x_1)$ has narrower scope than the translation of when, Chris's greetings must be collective, but since $(\forall x_1)$ includes the translation of when inside its scope, Leslie's greetings may be individual.

The differences in the syntax of logical form established by our analysis produces different interpretations given our semantics, correctly describing the group/group and individual/group readings of (1). (21) and (22) give detailed derivations for each of these readings of (1) (on the next two successive pages).^{2b}

2.1 The individual/individual reading of (2) can be derived given the tradition assumption that pronouns whose antecedents are quantifiers translate as bound variables at LF. When the translation of the embedded VP in (2) is built up, greet 'em is represented as an open expression containing the free variable x_0 . By the final stage of the derivation, this free variable must be bound by the quantifier which translates everyone. Recall that the last two derivations demonstrated two scope possibilities for the matrix direct object, and these two scope possibilities are again produced.

$$(23) \text{when}(\text{greet}(C, x_0), \forall x_0) \cdot \text{greet}(L, x_0)$$

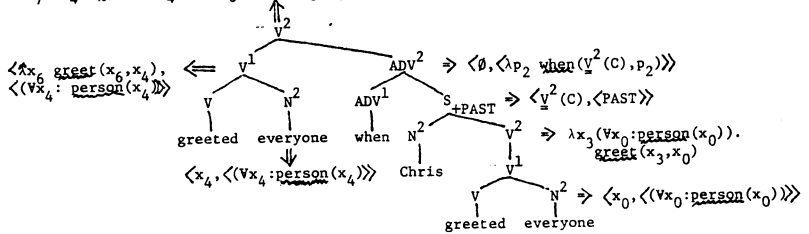
$$(24) \forall x_0) \cdot \text{when}(\text{greet}(C, x_0), \text{greet}(L, x_0))$$

Note that in (23) x_0 is free in the translation of the embedded sentence constituting an ill-formed expression in the logic. Thus, (24) is the only possibility here, and it follows that whenever the pronoun 'em translates as an individual variable, the quantifier translating the matrix direct object must take widest scope to

(21) Leslie greeted everyone when Chris greeted everyone. (Group/Group Reading)

$$\lambda x_8 [\lambda p_2 \text{ when } (\underline{V}^2(C), p_2)] (\lambda x_7 (\forall x_4 : \text{person}(x_4)) . \underline{\text{greet}}(x_7, x_4)] (x_8)$$

$$\langle \lambda x_7 (\forall x_4 : \text{person}(x_4)) . \underline{\text{greet}}(x_7, x_4) , \langle \lambda p_2 \text{ when } (\underline{V}^2(C), p_2) \rangle \rangle \rightsquigarrow$$

$$\langle \lambda x_7 (\forall x_4 : \text{person}(x_4)) . [\lambda x_6 \underline{\text{greet}}(x_6, x_4)] (x_7) , \langle \lambda p_2 \text{ when } (\underline{V}^2(C), p_2) \rangle \rangle =$$


$V^2 \Rightarrow$.

$$\lambda x_8 [\lambda p_2 \text{ when } ([\lambda x_3 (\forall x_0 : \text{person}(x_0)) . \underline{\text{greet}}(x_3, x_0)](C), p_2)]$$

$$([\lambda x_7 (\forall x_4 : \text{person}(x_4)) . \underline{\text{greet}}(x_7, x_4)](x_8))$$

$$= \lambda x_8 \text{ when } ([\lambda x_3 (\forall x_0 : \text{person}(x_0)) . \underline{\text{greet}}(x_3, x_0)](C),$$

$$[\lambda x_7 (\forall x_4 : \text{person}(x_4)) . \underline{\text{greet}}(x_7, x_4)](x_8))$$

REST OF DERIVATION: PASTf{ $x_8 \dots$ }(L)†

$$= \text{PASTf}\{\lambda x_8 \text{ when } ([\lambda x_3 (\forall x_0 : \text{person}(x_0)) . \underline{\text{greet}}(x_3, x_0)](C),$$

$$[\lambda x_7 (\forall x_4 : \text{person}(x_4)) . \underline{\text{greet}}(x_7, x_4)](x_8))\}(L) \dagger =$$

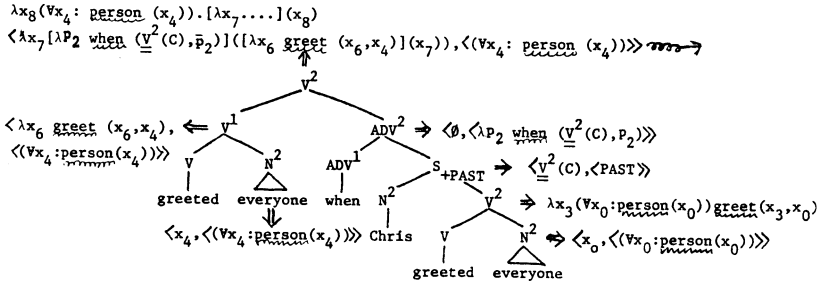
$$\text{PASTf}\text{when}([\lambda x_3 (\forall x_0 : \text{person}(x_0)) . \underline{\text{greet}}(x_3, x_0)](C),$$

$$[\lambda x_7 (\forall x_4 : \text{person}(x_4)) . \underline{\text{greet}}(x_7, x_4)](L)) =$$

$$\text{PASTf}\text{when}(\forall x_0 : \text{person}(x_0)) . \underline{\text{greet}}(C, x_0),$$

$$(\forall x_4 : \text{person}(x_4)) . \underline{\text{greet}}(L, x_4)) \dagger$$

(22) Leslie greeted everyone when Chris greeted everyone. (Individual/Group Reading)



$V^2 \Rightarrow \lambda x_8 (\forall x_4: \text{person}(x_4)). [\lambda x_7, [\lambda P_2 \text{ when } ([\lambda x_3 (\forall x_0: \text{person}(x_0)) \text{ greet}(x_3, x_0)](C), \underline{P}_2)]$
 $([\lambda x_6 \text{ greet}(x_6, x_4)](x_7))] (x_8)$
 $= \lambda x_8 (\forall x_4: \text{person}(x_4)). [\lambda P_2 \text{ when } ([\lambda x_3 (\forall x_0: \text{person}(x_0)) \text{ greet}(x_3, x_0)](C), \underline{P}_2)]$
 $([\lambda x_6 \text{ greet}(x_6, x_4)](x_8))$
 $= \lambda x_8 (\forall x_4: \text{person}(x_4)). \text{when}([\lambda x_3 (\forall x_0: \text{person}(x_0)) \text{ greet}(x_3, x_0)](C),$
 $[\lambda x_6 \text{ greet}(x_6, x_4)](x_8))$

- REST OF DERIVATION: $\text{PAST}\{[\lambda x_8 \dots](L)\}$
- $\text{PAST}\{[\lambda x_8 (\forall x_4: \text{person}(x_4)) \text{ when}([\lambda x_3 (\forall x_0: \text{person}(x_0)) \text{ greet}(x_3, x_0)](C), [\lambda x_6 \text{ greet}(x_6, x_4)](x_8))](L)\}$
 - $\text{PAST}\{(\forall x_4: \text{person}(x_4)) \text{ when}([\lambda x_3 (\forall x_0: \text{person}(x_0)) \text{ greet}(x_3, x_0)](C), [\lambda x_6 \text{ greet}(x_6, x_4)](L))\}$
 - $\text{PAST}\{(\forall x_4: \text{person}(x_4)) \text{ when}((\forall x_0: \text{person}(x_0)) \text{ greet}(C, x_0), \text{greet}(L, x_4))\}$

achieve proper binding. Furthermore, this implies that everyone will always have wide scope over the translation of when in such translations yielding the desired individual/individual reading, given the scope conventions of the system. (25) shows the derivation of (2) on the individual/individual reading in greater detail (see next page).^{2c}

2.2 There is a final derivation of (2) which differs only minimally from the one just sketched. Instead of translating 'em as an individual variable, we can also translate it as the discourse variable δ_0 . δ_0 , unlike x_0 , may appear free in well-formed expressions at LF. Furthermore, the extension of δ_0 is determined by extra-semantic factors-- context, for example. Therefore, alongside (24), we also generate (26).

$$(26) (\forall x_0) \cdot \text{when}(\text{greet}(C, \delta_0), \text{greet}(L, x_0))$$

This allows the discourse Them reading of (2) since δ_0 is free to take as its value a group different from that signified by everyone. Except for the variable notation, the derivation of the discourse Them reading of (2) is as illustrated in (25) (again, please see the next page).

Thus far we have presented the analysis of (1)-(2). The next section presents some of our assumptions about the nature of VPD. Then we give an account of (3) which supports our approach and which focusses several interesting claims about deletion and anaphora.

3.0 As we noted in the introduction, (3) shares the group/group reading with (1) and the individual/individual reading with (2). We could give a principled account of these facts were we to use VPD to derive (3) from each of (1) and (2). In addition, notice that (3) does not have any of the other readings supported by (1) or (2). Therefore, an adequate account of the facts requires that (1) and (2) each correspond to structures underlying (3), but only on one of their readings.

Consider the statement of VPD given in (27).⁴

(27) VPD (SYNTACTIC VERSION)

$$W_1 \text{--} V^2 \text{--} W_2 \text{--} [+AUX] \text{--} V^2 \text{--} W_3$$

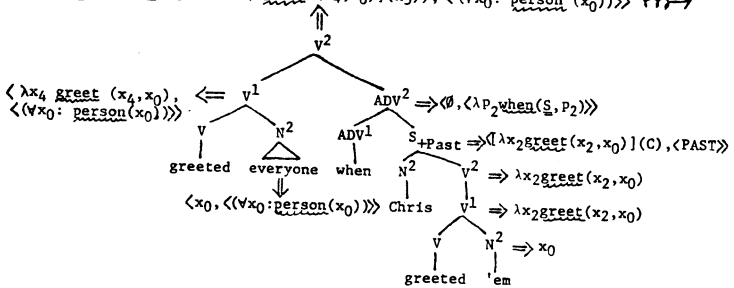
1	2	3	4	5	6
1	2	3	4	∅	6

CONDITION: 2=5

It is the identity condition requiring syntactic identity between controller and target VP's-- a standard feature of syntactic accounts of VPD-- which runs afoul of the facts just described. Neither (1) nor (2) correspond to syntactic structures which sanction the application of VPD to derive (3). One problem is that (1) and (2) are apparently⁵ antecedent-contained deletions since the target VP is part of the controller. Thus, the identity

(25) Leslie greeted everyone when Chris greeted 'em. (Individual/Individual Reading)

$\lambda x_6 (\forall x_0: \text{person}(x_0)). [\lambda x_5 [\lambda p_2 \text{ when } (\underline{S}, p_2)] ([\lambda x_4 \text{ greet } (x_4, x_0)](x_5))](x_6)$
 $\langle \lambda x_5 [\lambda p_2 \text{ when } (\underline{S}, p_2)] ([\lambda x_4 \text{ greet } (x_4, x_0)](x_5)), \langle \forall x_0: \text{person}(x_0) \rangle \rangle \rightsquigarrow$



$v^2 \Rightarrow \lambda x_6 (\forall x_0: \text{person}(x_0)). [\lambda x_5 [\lambda p_2 \text{ when } ([\lambda x_2 \text{ greet } (x_2, x_0)](C), p_2)] ([\lambda x_4 \text{ greet } (x_4, x_0)](x_5))](x_6)$

= $\lambda x_6 (\forall x_0: \text{person}(x_0)). [\lambda p_2 \text{ when } ([\lambda x_2 \text{ greet } (x_2, x_0)](C), p_2)] ([\lambda x_4 \text{ greet } (x_4, x_0)](x_6))$

= $\lambda x_6 (\forall x_0: \text{person}(x_0)). \text{when } ([\lambda x_2 \text{ greet } (x_2, x_0)](C), [\lambda x_4 \text{ greet } (x_4, x_0)](x_6))$

REST OF DERIVATION: $PAST\{[\lambda x_6 \dots](L)\} = .$

$PAST\{[\lambda x_6 (\forall x_0: \text{person}(x_0)). \text{when } ([\lambda x_2 \text{ greet } (x_2, x_0)](C), [\lambda x_4 \text{ greet } (x_4, x_0)](x_6))](L)\}$

= $PAST\{(\forall x_0: \text{person}(x_0)). \text{when } ([\lambda x_2 \text{ greet } (x_2, x_0)](C), [\lambda x_4 \text{ greet } (x_4, x_0)](L))\}$

= $PAST\{(\forall x_0: \text{person}(x_0)). \text{when } (\text{greet } (C, x_0), \text{greet } (L, x_0))\}$

condition is not satisfied, and the VPD is incorrectly blocked. Assuming this problem could be overcome, (2) will still fail to provide a source for (3) since the matrix VP [_{VP} greet everyone] is not identical to the embedded VP [_{VP} greet 'em]. Finally, note that even if this problem were overcome, a purely syntactic analysis which derives (3) from both (1) and (2) fails to predict that (3) shares only one reading with each of its sources.

3.1 All three of these difficulties with VPD-- its antecedent-contained structure, the non-identity of [_{VP} greet everyone] and [_{VP} greet 'em], and the semantic relationship between the elliptical sentences and their sources-- disappear given the logical theory of deletion proposed by Sag (1976, forthcoming). Next we sketch the leading ideas of this analysis and then we return to the analysis of (3).

3.1.1 The version of VPD we adopt is given roughly in (28).

(28)	<u>VPD</u>	(INCLUDED IN THE LOGICAL THEORY OF DELETION)
	$W_1 \text{--} [+AUX] \text{--} V^1 \text{--} W_2$	
	1 2 3 4	
	1 2 \emptyset 4	

In lieu of a syntactic identity condition, our analysis of VPD falls under a recoverability principle stated in the metatheory. We maintain that VPD is possible only when the translation of the VPD target is redundant at LF. That is, VPD will delete a target VP only when the λ -expression which translates the VP finds a second λ -expression with the same semantic value at LF as reflected by a parallelism of internal structure and identity of free variables. Given this approach, we are in a position to make two predictions: 1) syntactic identity is neither a necessary nor a sufficient condition for the application of VPD, and 2) insofar as the different readings a sentence supports translate into distinct LF, it is possible for a sentence to sanction deletion on one of its readings but not on another. These predictions, we maintain, lead to just the right mechanism to account for (3).

3.2 Let us first examine how our analysis predicts that (1) is a source for (3) on its group/group reading. The boxed line in (21) represents the complete translation of the matrix VP. The $\lambda x_3(\dots)$ expression is the translation of the embedded V^2 , and since this has the same semantic value as $\lambda x_7(\dots)$, we predict that VPD is possible on this reading. Note that although the embedded V^2 is contained within the matrix V^2 , the relevant lambda expressions are disjoint at LF, hence the problem with antecedent-contained deletion is avoided.

We can also successfully block the derivation of (3) from (1) when (1) bears the individual/group reading. As the boxed line in (22) shows, the logical structure of the second reading of (1) does not satisfy the logical identity condition on VPD. Here, $\lambda x_6(\dots)$, which translates the matrix V^1 has x_4 bound by a quantifier external

al to the lambda expression while the only potentially redundant lambda expression, $\lambda x_3(\dots)$, which translates the embedded V^2 , has all of its variables bound internally. VPD is not possible in this case, and we correctly predict that (1) is a source for (3) only on its group/group reading.

We also predict that (2) is a source for (3) on its individual/individual reading. As the boxed line in (25) shows, the lambda expression $\lambda x_2(\dots)$, which translates the embedded V^2 , has the same semantic value as $\lambda x_4(\dots)$. In particular, both contain the variable x_0 which is bound externally by the universal quantifier. Thus, despite the fact that (2) fails to meet the syntactic identity condition, (which we reject), our logical theory of deletion does derive (3) from (2). Finally, note that in the other derivation of (12), where δ_0 appears instead of x_0 in the translation of the embedded V^2 , $\lambda x_2(\dots)$ will not be redundant for the free variable δ_0 will not match x_0 in $\lambda x_4(\dots)$. Thus VPD will be blocked in this case.

This completes the analysis of the data. All objections to the standard approach to VPD have been surmounted, and the convergence of our theory of VPD with the truth conditionally adequate semantics already provided for the data lends independent support to our account. 4.0 Although the present analysis presents but a splinter of a fragment of English, we nevertheless believe that our work endorses several important conclusions. First, we show that it is possible to give a precise characterization of certain ambiguities reflected by sentences containing temporal connectives in English. The characterization utilizes the standard technique of scope variation between universal quantifiers and the logical operator which translates the temporal connectives. Second, our analysis crucially requires that certain pronouns translate both as bound variables and as discourse variables. Third, there is a smooth interface between our multiple scope theory of temporal ambiguities and current work on logical theories of deletion. In particular, our analysis predicts the observed set of readings for (1)-(3). Finally our analysis illustrates how the use of a highly structured logical language whose syntax is determined in important respects by superficial syntactic structure can form the core of an interesting semantic theory. We conclude that the facts we discuss provide strong evidence for a surface semantic analysis based on an independently motivated syntax. Thus, our analysis militates against semantic representations of the sort suggested by transformational grammarians of many persuasions where no particular structural connections are established between the syntactic and semantic levels of representation.

NOTES

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¹ When the discourse variable is assigned as its value the same set signified by everyone, the possibility of a group/group and an individual/group reading for (2) emerges. Although there are no problems we know of for our analysis lurking in this domain, we will ignore these possibilities, for the most part, in what follows.

² Words with squiggly underlining are expressions in the logic which translate the orthographically related English lexical items. In this paper we ignore certain natural extensions of our analysis to comprehend a much wider range of data. For example, the temporal connectives can also have a semantics where the operators which translate them orient two propositions in intervals of time rather than with respect to moments of time. There also may be a possibility of construing temporal connectives more like universal quantifiers rather than giving them the strictly existential force we do here. These possibilities are investigated in some detail in Weisler (1978a,b)

^{2a} This storage mechanism is developed by Cooper (1975, ms.) within a Montague Grammar framework. Our use of it differs only slightly from his.

^{2b} We use the notation "σσσσ" to indicate retrieval of stored elements. Note that in (21), (22), and (25), storage retrieval is proceeding up the page. Two other notational quirks should be pointed out. We are using restricted quantification. Thus $(\forall x_4: \text{person}(x_4))$ is a restricted quantifier, syntactically on a par with $(\forall x_4)$. Finally, $\underline{\forall}^2$ is a shorthand for "the translation of \forall^2 ".

^{2c} It may be possible to do away with our distinction between discourse and individual variables. For a detailed discussion of this point, see Cooper (to appear).

³ Since $\underline{\mathcal{D}}_0$ is a discourse variable which need not be bound in well-formed expressions at LF, the analogue of (23) with $\underline{\mathcal{D}}_0$ substituted for the free appearance of \underline{x}_0 is well-formed, and a new reading is derived for (2). See note 1 for discussion.

⁴ Many features of this purported analysis may be straw-like in fiber, but the criticisms we make challenge most syntactic approaches to VPD of which we are aware. However, see Weisler (1978c) for an attempt to give a purely syntactic analysis of antecedent-contained deletion.

⁵ We say apparently because most interesting analyses of antecedent-contained deletion involve a level of analysis at which the two VP's involved in the transformation (or their translations) are, in fact, disjoint. See Sag (1976, forthcoming) and Weisler (1978c) for discussion.

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