

7 The Semantic Enquiry Desk

A year working in Artificial Intelligence is enough to make one believe in God.

—Alan Perlis¹

7.1 Introduction

In this chapter, I will show how structural disambiguation may be added to the Paragram–Absity–Polaroid Words system. I will do this in two stages. First, I will consider the present version of the system and the structural ambiguities that it handles, a small subset of those that I listed in section 6.2. (Not all of the sentence types that I listed can even be parsed by the present Paragram grammar.) The disambiguation methods will include a synthesis of some of the ones that we saw in section 6.3, as well as my own. Then, second, I will consider methods for extending the system’s present limited range of abilities.

Although Paragram is basically a Marcus parser (*see section 1.3.2*), it has a somewhat different approach to semantics from that taken by Parsifal (Marcus 1980), which we saw in section 6.3.2. The two are similar in that they both assume the existence of a semantic process that they can ask for guidance when they need it. However, unlike Parsifal, Paragram is a trifle paranoid: it will never attach anything to anything, whether an ambiguity is possible or not, without first asking for permission from semantics. The semantic process that Paragram uses is called the SEMANTIC ENQUIRY DESK (SED); it is the operation of this process that we discuss in the remainder of this chapter.

At present, Paragram knows about two types of structural ambiguity for which it requires assistance from the SED: prepositional phrase attachment and gap finding in relative clauses. In the following sections, I will show how the SED handles each of these. We will see that the SED, in turn, gets considerable help from Polaroid Words.

¹ PERLIS, Alan J. “Epigrams on programming.” *SIGPLAN notices*, 17(9), September 1982, 7–13.

7.2 Prepositional phrase attachment

In this section, I consider those occasions on which the parser will require guidance from the SED to deal with a prepositional phrase.

7.2.1 Where prepositional phrases may be attached

Not all prepositional phrases really require the parser to send off for a semantic attachment decision, though Paragram asks anyway. English syntax prohibits VP attachment of PPs that occur between the subject and verb of a sentence or between the indirect and direct object:

(7-1) *Nadia for his birthday gave her secretary a gyroscope.

(7-2) *Nadia gave her secretary for his birthday a gyroscope.

PPs in these positions are always NP-attached:

(7-3) The gyroscope for Nadia's secretary gave him great pleasure.

(7-4) Nadia gave the secretary on the second floor a gyroscope.

and the SED reminds Paragram of this basic fact when necessary. English also prohibits restrictive PPs from being attached to NPs that consist of a proper name or a pronoun, or, in general, to NPs with a unique definite referent:

(7-5) The girl with brown hair didn't know what she wanted to prove.

(7-6) *Nadia with brown hair didn't know what she wanted to prove.

(7-7) Ross was rather amused by the girl with brown hair.

(7-8) *Ross was rather amused by her with brown hair.

This is not true, however, of non-restrictive PPs, whether appositive or not (*see section 3.8*):

(7-9) When I am sad and weary,
When I think all hope has gone,
When I walk along High Holborn
I think of you with nothing on.²

(7-10) Ross thinks of Nadia with nothing on.

(7-11) Nadia thinks of her house with a new coat of paint.

(7-12) Nadia thinks that her house, in Toronto's trendy Withrow Park area, is an architectural masterpiece of the early 1900s.

²MITCHELL, Adrian. "Celia Celia." [1] *Out loud*. London: Cape Goliard Press, March 1968. [2] *For beauty Douglas*. London: Allison and Busby, 1982. 128.

The SED rules that I will develop below will, however, always attach the PP to the VP if the NP has a unique definite referent and VP attachment is at all possible. In (7-9) and (7-10), this would incorrectly attach *with nothing on* to the VP as the MANNER case (an attachment that would be plausible in (7-10) but is probably not the preferred one). Except when commas are provided, determining the correct attachment in such cases is very difficult (as are the semantics of the attachment—see section 3.8), and I will have no more to say about it.

7.2.2 Determinants of prepositional phrase attachment

In a few lucky cases, the preposition itself will suffice to determine the PP attachment by having no meanings at all for one attachment or the other. Obviously, the pseudo-prepositions *SUBJ*, *OBJ*, and *INDOBJ* cannot be attached to NPs, for that would contradict the syntactic position they represent. This is also the case for some ordinary prepositions. For example, *into*, *onto*,³ and *despite* never⁴ have NP-attachment meanings.⁵ Other prepositions are precluded from VP-attachment by certain verbs; *with* cannot flag any case of *know*, for example:

(7-13) *With his microscope, Ross knew that the diamond was counterfeit.⁶

(7-14) *With care, Ross knew that the diamond was counterfeit.

(7-15) *With Nadia, Ross knew that the diamond was counterfeit.

Similarly, not many verbs have a case flagged by *of*.⁷ If the SED is given a case like one of these, it can easily return the correct answer to the parser, even if the PP complement remains undisambiguated.

But let us suppose that it is not a simple case. How is the SED to decide what to tell the parser? The SED will be given the PWs, which may or may not be fully disambiguated, for the following: the elements of the PP itself, the verb of the VP

³cf. Fowler 1965:420.

⁴Hirst 1981a[1]:86, fn.

⁵What, never? Well, hardly ever. Nominalized verbs CAN take these prepositions, but strictly speaking the attachment comes before the nominalization:

(i) The stealing of the gem despite the security measures mystified the police.

(ii) ?The attendance despite the rain was surprisingly high.

Compare:

(iii) The attendance was surprisingly high despite the rain.

⁶But:

(i) With his telepathic powers, Spock knew the thoughts of all the people on the space ship.

(Barbara Brunson, personal communication).

⁷Among the exceptions: *smell of*, *die of*, *talk of*, *approve of*, *know of*. All these verbs are intransitive, and *of* usually occurs right after the verb, so there is no ambiguity.

to which it might be attached, and the head noun of the NP or NPs for which it is a candidate.⁸ I will refer to this verb and these nouns as the potential attachment heads. In the following discussion, I will first assume that the PWs (other than, of course, the preposition) are disambiguated, later relaxing this assumption.

If the SED is going to decide whether a given prepositional phrase is best attached to the VP of the sentence or to an NP, it must first know how that PP will function in each of its possible locations. Now, in the description of preposition Polaroid Words in section 5.3.1, I said that their meaning was either a case flag of one kind or another (in prepositional phrases attached to a verb phrase) or some appropriate slot of the noun (in PPs attached to a noun phrase).⁹ A preposition PW will work on both the set of VP-attachment meanings and the set of NP-attachment meanings until it knows where the PP is to be attached and can eliminate the inappropriate set.

Now, we saw in section 6.3 two types of strategy for deciding whether a PP should be attached to the verb head or the noun head. The first was Ford, Bresnan, and Kaplan's Final Expected Argument Principle (1982) (*section 6.3.3*), which says that (if semantics or pragmatics doesn't overrule it) the parser should attach PPs to the VP until no more cases are expected, after which point the current NP gets them. (The principle does not give a way of choosing between NP heads if there is more than one.) The second kind of strategy was pragmatic: Crain and Steedman's Principles of Referential Success, of Parsimony, and of A Priori Plausibility (1985) (*section 6.3.4*), which say that the attachment should be done so as to minimize the number of unsatisfied references and presuppositions while maximizing plausibility. While we were not wholly satisfied with either kind of strategy, we shall have the SED use a synthesis of the two to decide on PP attachments.

There are several things we must have before we can implement these strategies:

- An annotation on each verb sense as to which of its cases are "expected".
- A method for deciding on the relative plausibility of a PP attachment.
- A method for determining the presuppositions that would be engendered by a particular PP attachment, and for testing whether they are satisfied or not.
- A method for resolving the issue when the strategies give contradictory recommendations.

⁸At the point when the parser calls the SED for help, the parser will have just finished parsing the PP, which will be the first element of the buffer. The open NP to which it might be attached will be the current constituent on the parser's stack; the open VP will be above it on the stack. By the strict rules of Marcus parsing, the open VP should not be available for examination at this point (Marcus 1980: 41); however, Marcus breaks the rule himself (1980: 305), claiming (1980: 311) that case-frame semantics are not within the scope of the rules of strict determinism. Paragram is also unhappy about looking at the open VP, and an escape into Lisp code is required to do it.

⁹Recall from table 3.2 that in either case the semantic type of the translation of a preposition is *slot*.

7.2.3 Verb annotations

The first requirement, annotating verbs for what they expect, is straightforward once we have data on verb preferences. These data could come from textual analysis or from formal experiments on people's preferences, such as the one Ford, Bresnan, and Kaplan (1982) ran. (Connine, Ferreira, Jones, Clifton, and Frazier (1984) have presented a large set of suitable data.) However, for a small, experimental system such as ours, the intuitions of the author and his friendly informants suffice. We will classify cases as either COMPULSORY, PREFERRED, or UNPREFERRED (*cf. section 5.3.6*).

7.2.4 Plausibility

Now let's consider the use of plausibility to evaluate the possible attachments. Often, SLOT RESTRICTION PREDICATES (*see section 5.3.1*) will allow the preposition Polaroid Word to immediately eliminate many or all of its NP- or VP-attachment possibilities, even before the SED becomes involved. For example:

(7-16) Ross loves the girl with brown eyes.

The preposition *with* can be attached to a VP with *love* only as the MANNER case, but requires the filler to be a manner-quality, which eye isn't (*cf. Ross loves the girl with a passion*); when this is eliminated, only NP-attachment possibilities remain.

Slot restriction predicates are a simple form of plausibility testing. In the most general case, deciding whether something is plausible is extremely difficult, and I make no claims to having solved the problem. In the best of all possible worlds (*see section 2.2.2*), Frail would be able to answer most questions on plausibility. Slot restriction predicates would be DEFINED to guarantee plausibility. The predicate on INSTRUMENT, for example, would not require merely that it take a physical object, but that it take a physical object that could plausibly be used for the action in question. But, of course, we don't know how to specify that. What, for example, should the slot restriction for the INSTRUMENT of *cut* be (*cf. section 5.4*)? Some of the items in (7-17) are plausible, some are implausible, and some are difficult even for a human to decide upon the plausibility of:

(7-17) Ross cut the salami with a knife / a screwdriver / a pencil / a laser beam / an elephant / a sword / a chain saw / a computer / a dandelion / Fermat's last theorem / a pas de bourrée.

However, there are two easy methods of testing plausibility that we can use that, though non-definitive, will suffice in many cases. The first of these, which we just saw, is the slot restriction predicates that we do have in present-day Frail. Note that the work of handling these is already done for us by Polaroid Words—the SED will not even see possibilities that violate them (*see above*). While satisfying the predicates does not guarantee plausibility, failing the predicates indicates almost

certain implausibility. The second method is what we shall call the EXEMPLAR PRINCIPLE: an object or action should be considered plausible if the knowledge base contains an instance of such an object or action, or an instance of something similar.¹⁰ The SED can easily construct from the semantic objects supplied to it the Frail call to do this.^{11;12} For example, if the SED wants to test the plausibility of *a cake with candles* or *operate with a slug*, it looks in the knowledge base to see if it has run across such a thing before:

(7-18) (a ?x (cake ?x (attr=(some ?y (candle ?y))))))

(7-19) (a ?x (operate ?x (instrument=(a ?y (slug ?y))))))

If it finds an instance, it takes the attachment to be plausible. If no such item is found, the matter is unresolved.¹³ Thus the results of plausibility testing by the SED will be either EXEMPLAR EXISTS or CAN'T TELL.¹⁴

¹⁰Notice that the Exemplar Principle is simply a weak form of the Principle of Referential Success.

¹¹It is the SED rather than the preposition PW that does this because the PW is able to see only the heads of the NPs it deals with, not the whole NP. If this were to change, as it might in future versions, then PWs may take over this task from the SED.

¹²Frame determiners do not yet have a general frame matcher of the kind described by Finin (1980) or DG Bobrow and Winograd (1977), so calls such as (7-18) and (7-19) are taken more literally than they ought to be.

¹³Various recovery strategies suggest themselves. For example, the SED might try asking Frail for items similar to the one being tested by replacing one of the frames in the search with a sibling or ancestor in the ISA hierarchy. Thus, if *operate with a slug* draws a blank, it could try *operate with a coin* or *operate with a metal-stamping*. The problem with this, of course, is that it is hard to know where to stop if plausibility remains unproved. Also, there is the danger of turning an implausible search item into a plausible one, or vice versa.

Ideally, the SED should also be able to see if the entailments of an attachment lead to an implausibility or contradiction. For example, the AGENT of an action is usually located at the same place that the action occurs; thus attachment of the PP to the VP would lead to a contradiction in (i):

(i) The women discussed the dogs on the beach.

if it were known that the women were not at the beach.

What we really need is a theory of implausibility that could prove a Frailframe statement implausible. One component of such a theory would be the construction of "mental images" of things whose plausibility is to be tested (*cf.* Waltz 1978). I believe, however, that the exemplar principle is what people use most of the time; their enormous knowledge bases permit a conclusion of implausibility to be drawn when a modest amount of searching fails to find an exemplar for plausibility.

¹⁴With a large knowledge base it may be possible to assign ratings based on the number of exemplars found; an item that has a hundred exemplars would be considered more plausible than one with only one exemplar, other things being equal. It would be necessary to take into consideration how many instances can be found of the frame with slot values DIFFERENT from those sought. If only one *cake* could be found with (attr=flowers), but a hundred without, a *cake with flowers* on it could be considered plausible but unusual. On the other hand, if there were just one *cake* known, but with (attr=flowers), then *flowers on cakes* would be considered perfectly normal.

Once an instance has been determined to be either common or unusual, it could be marked as such for future reference. A marking of *unusual* would have to be revised if too many more instances like it turn up. Intuition suggests that people operate in this way.

7.2.5 Testing for presupposition satisfaction

The next requirement is a method for deciding whether a particular PP attachment would result in an unsatisfied presupposition. I will show that the Principle of Referential Success (*section 6.3.4*) suffices. We observe the following.¹⁵ First, a definite NP presupposes that the thing it describes exists and that it is available in the focus or knowledge base for felicitous (unique) reference;¹⁶ an indefinite NP presupposes only the plausibility of what it describes. Thus, *a blue chipmunk* presupposes only that the concept of a **blue chipmunk** is plausible; *the blue chipmunk* further presupposes that there is exactly one blue chipmunk available for ready reference. Second, the attachment of a PP to an NP results in new presuppositions for the new NP thus created, but cancels any uniqueness aspect of the referential presuppositions of both its constituent NPs. Thus, *the ocelot with the blue chipmunk* presupposes that there is just one such ocelot available for reference (and that such a thing is plausible); the plausibility and existence of an **ocelot** and a **blue chipmunk** continue to be presupposed, but their uniqueness is no longer required. Third, the attachment of a PP to a VP creates no new presuppositions,

¹⁵The proof of the generality of these observations is by absence of counterexample. If the reader has a counterexample, she or he should notify me promptly.

¹⁶When I say “exists” here, I am conflating two things: actual existence in the world, represented by an instance in the knowledge base, and conceptual existence, which is not quite so straightforward. For example, one can say:

- (i) The conference on linguistic meteorology will not be held this year.

apparently denying the existence of the entity whose existence is seemingly (*cf. chapter 4, footnote 16*) presupposed by the sentence’s own subject NP! But there is no paradox; what the NP really presupposes is the existence of the conference AS A CONCEPT. If (i) is uttered to someone who had heard of the plans of the conference, it would be a perfectly valid reference to the concept, in their knowledge base, of the conference, in exactly the same manner as I describe above for entities with represented real-world existence. If (i) is uttered to someone who has not heard of the conference, the presupposition is still there, albeit unsatisfied. The problem of representing non-existence of a particular instance of a generic frame, or of any instance of it, is left to the knowledge base designer. [I am grateful to Yorick Wilks, Xiuming Huang, and Dan Fass for drawing my attention to this problem; see Wilks, Huang, and Fass 1985.]

When I say “available” here, I am also conflating two things: being already explicitly represented in the knowledge base, and being implicitly represented, that is able to be generated from available information. An example of the latter: the NP

- (ii) The address of my brother who lives in Melbourne

(*cf. Winograd 1972: 156, Ritchie 1980: 103*) might not refer to an existing node in the knowledge base, but if my brother is known and it is known that people have addresses, then the existence of the presupposed address may be inferred and is thus available in the knowledge base. This suffices to satisfy the presupposition.

It should be emphasized that nothing I am saying here denies that definite NPs can introduce new information, as Ritchie (1980: 103) has pointed out. My point is only that, even in such cases, there is a presupposition (unfulfilled) of prior knowledge. Such usage is not in any way pathological.

but rather always indicates new (unpresupposed) information.¹⁷

These observations allow us to “factor out” most of the presupposition testing: the candidate attachments will always score equally for unsatisfied presuppositions, except that VP attachment wins if the NP candidate is definite but NP attachment would result in reference to an unknown entity. On the other hand, if NP attachment would result in a felicitous definite reference, the number of unsatisfied presuppositions will remain the same for both attachments, but by the Principle of Referential Success we will prefer the NP attachment.¹⁸ Testing for this is particularly easy for the SED because of the property of Absity that the semantic objects associated with the syntactic constituents are all well-formed Frail objects (or, to be precise, Polaroid Word “pictures” of them). The SED can therefore just put them into a call to Frail to see whether the mooted NP-attachment entity exists in the knowledge base or not. (The entity may be there explicitly, or its existence may be inferred; that is up to Frail.) If the entity is found, the presupposition is SATISFIED, and the PP should be attached to the NP; otherwise, if the presupposition is UNSATISFIED or if NO PRESUPPOSITION WAS MADE, the VP gets the PP.

As an example, let’s suppose the SED needs to decide on the attachment of the PP in (7-20):

(7-20) Ross saw the man with the telescope.

It will have the semantic objects for *the man* and *with the telescope*, the latter having two possibilities:

(7-21) (the ?x (man ?x))

¹⁷This is not quite true; sentences asserting a change of state presuppose that the new state did not previously hold. For instance, (i):

(i) Ross flew to New York.

presupposes that Ross isn’t already in New York. Such presuppositions can be the complement of the presuppositions engendered by NP attachment of the PP:

(ii) Throw the ring in the tub.

The PP of (ii) can be NP-attached, implying that the ring is in the tub, or VP-attached, implying, conversely, that the ring is not (yet) in the tub. [I am grateful to Eugene Charniak for these examples and for discussion of these points.] I will ignore these complications; but note that the PP-attachment procedure to be discussed below will nevertheless handle most of these cases correctly.

¹⁸A corollary of this is that a PP is never attached to an indefinite NP if VP attachment is at all possible, except if the Final Expected Argument Principle applies. This seems too strong, and the rule will probably need toning down. The corollary is not completely out of line, however, as definiteness certainly influences attachment. For example, the preference for NP attachment in (i) is changed to a VP preference in (ii) just by making the NP indefinite (even though the Final Argument Principle still applies!):

(i) The women discussed the dogs on the beach.

(ii) The women discussed dogs on the beach.

(7-22) (instrument=(the ?y (telescope ?y))
 (attr=(the ?y (telescope ?y)))

It therefore constructs the Frail statement (7-23) for the NP attachment:

(7-23) (the ?x (man ?x (attr=(the ?y (telescope ?y))))))

If this returns some instance, `man349` say, then the SED knows that presupposition considerations favor NP attachment; if it returns `nil`, then it knows they favor VP attachment.

7.2.6 Making the attachment decision

The SED's last requirement is a method for deciding on the PP attachment, given the results of verb expectation and presupposition and plausibility testing. If all agree on how the attachment should be made, then everything is fine. However, as Ford, Bresnan, and Kaplan (1982) make clear, verb expectations are only biases, not absolutes, and can be overridden by conflicting context and pragmatic considerations. Therefore, the SED needs to know when overriding should occur. Table 7.1 shows a decision algorithm for this. The algorithm assumes (unrealistically) that there are one VP and one NP available and that implausibility judgments can be made; we will get rid of these assumptions in a moment. The algorithm gives priority to ruling out implausible readings, and favors NP attachments that give referential success (referential success is tried first, since it is the stronger condition); if these tests don't resolve matters, it tries to use verb expectations.¹⁹ If these don't help either, it goes for VP attachment (*i.e.*, Minimal Attachment; *see sections 1.1.3 and 6.3.4*), since that is where structural biases seem to lie, but it is more confident in its result if an unsatisfied presupposition contraindicates NP attachment.

Now, table 7.1 makes two assumptions that it shouldn't. The first is that we can recognize plausibility with some confidence at the SED level, whereas we saw earlier that the best we can really do is say "yes" or "maybe". We shall therefore rearrange the priorities to take account of this. The second assumption is that there is only one NP candidate for attachment. We will amend this by adding a preference in NP attachment for the most recent NP, that is, a preference for Low Right Attachment (*see section 1.1.3*) when there is more than one NP available.²⁰ The

¹⁹We saw in section 1.1.3 that some sentences, such as (i):

(i) The landlord painted all the walls with cracks.

show verb expectations prevailing over plausibility. Ideally, the SED would react to this sentence the way most people do; however, the procedure we present tends to err on the side of common sense.

²⁰When checking for referential success in the attachment of a PP to an NP that is, in turn, part of a PP attached to an NP, we check the entire matrix NP; however, for plausibility exemplars, we only check the immediate attachment. For example, suppose we wish to attach the underlined PP in (i), where *in*

Table 7.1. Decision algorithm for restrictive PP attachment (one VP and one NP)

[Referential success]

if NP attachment gives referential success
then attach to NP

[Plausibility]

else if VP attachment is implausible
then attach to NP
else if NP attachment is implausible
then attach to VP

[Verb expectations]

else if verb expects a case that the preposition
could be flagging
then attach to VP
else if the last expected case is open
then attach to NP

[Avoid failure of reference]

else if NP attachment makes unsuccessful
reference
then attach to VP
else sentence is ambiguous, but prefer VP
attachment anyway.

amended algorithm is shown in table 7.2. It is simpler than it looks. Its priorities are referential success, known plausibility, verb expectations, and avoidance of unsatisfied presuppositions, and there is an “inner loop” with these same priorities for handling the final expected argument.

Sentences for which the algorithm gives the correct answer are shown in table 7.3. I also show a few sentences on which the algorithm fails. That the algorithm is a little ragged around the edges, especially in its more desperate clauses towards the end, is not bothersome; it seems to me that the fault is not in the algorithm but rather in the system’s inability to use world knowledge for disambiguation as well as people do. I can’t believe that people have some sophisticated mental algorithm that tells them how to attach PPs in those awkward cases where several different possibilities all rate approximately the same (*cf. section 1.4*); rather, they use a simple algorithm and lots of knowledge, and in the rare awkward (and, probably, artificial) case, either ask for clarification, choose an attachment almost at random

the park has already been attached to *the man*:

(i) the man in the park with the chain saw

The two entities we check for referential success will be *the man with the chain saw* and *the man in [the park with the chain saw]*. For plausibility, we will check *a man with a chain saw* and *a park with a chain saw*.

Table 7.2. Decision algorithm for restrictive PP attachment (one VP and more than one NP; imperfect plausibility judgments)

[Referential success]

if some NP attachment gives referential success
then attach to most recent such NP

[Plausibility]

else if there is exactly one attachment known to be plausible
then make that attachment

[Verb expectations]

else if verb expects a case that the preposition could be flagging
then attach to VP

else if the last expected case is open or past
then if there is an NP attachment known to be plausible that
 doesn't give referential failure
then make the rightmost such attachment
else if VP attachment is known to be plausible
then attach to the VP
else if there is an NP attachment that doesn't give referential failure
then make the rightmost such attachment
else attach to the rightmost NP

[Avoid failure of reference]

else if there is an NP attachment known to be plausible that
 doesn't give referential failure
then make the rightmost such attachment
else if there is an NP attachment that doesn't give referential failure
then make the rightmost such attachment
else sentence is ambiguous, but prefer VP attachment anyway.

(perhaps using a stochastic technique; cf. Heidorn 1982, Fujisaki 1984), or use conscious higher-level inference (perhaps the kind used when trying to figure out garden paths) to work out what is meant.

The algorithm does not treat the case where there are two verbs available for the PP to be attached to. It seems that the verb closer to the PP is preferred, other things being equal. To see this, consider the following sentences,²¹ in which it must be decided whether the final PP is attached to the main verb, *put*, or to the verb of the relative clause, *read*:

(7-24) Ross put the book Nadia had been reading in the study.

(7-25) Ross put the book Nadia had been reading behind the couch.

Most people experience a mild garden-path effect with (7-24), initially attaching *in the study* to *read*, and then backing up after they find that this leaves *put* without

²¹The examples are from Marilyn Ford (personal communication).

Table 7.3. PPs that are and aren't correctly attached

PPS THAT ARE CORRECTLY ATTACHED	
The women discussed the dogs <u>on the beach</u> .	
<i>NP-attached.</i>	
The women discussed the tigers <u>on the beach</u> .	
<i>NP-attached if there are tigers on the beach, but VP-attached if tigers on the beach is not found plausible and discussed on the beach is.</i>	
The women discussed tigers <u>on the beach</u> .	
<i>VP-attached if tigers on the beach is not found plausible.</i>	
Ross bought the book <u>for Nadia</u> .	
<i>NP-attached if there is a book for Nadia available for reference, and VP-attached otherwise.</i>	
Ross included the book <u>for Nadia</u> .	
<i>NP-attached.</i>	
Nadia saw the man in the park <u>with the telescope</u> .	
<i>Attached to in the park if there is a park with a telescope with a man in it, or if there is a park with a telescope even if there is a man with a telescope; attached to the man if there is a man with a telescope but no park with a telescope; attached to the VP otherwise.</i>	
<hr style="width: 20%; margin: 0 auto;"/>	
PPS THAT ARE NOT CORRECTLY ATTACHED	
The women discussed dogs <u>on the beach</u> .	
<i>NP-attached because dogs on the beach is plausible and doesn't fail referentially, though VP attachment seems to be preferred by informants.</i>	
The women discussed the dogs <u>at breakfast</u> .	
<i>NP-attached like the dogs on the beach, because the subtle implausibility of the dogs at breakfast as a topic of conversation is not detected.</i>	
The landlord painted all the walls <u>with cracks</u> .	
<i>NP-attached (contra informants) if walls with cracks are deemed plausible; otherwise, VP-attached (contra common sense) by lexical expectations.</i>	

its obligatory LOCATION case. No such effect is felt with (7-25). The verb *read* can take a PLACE modifier, and, in (7-24), grabs the PP accordingly—an error that results in the garden path. In (7-25), the PP is judged an implausible PLACE for reading, and so is left for attachment to *put*. The implication is that local attachment is preferred, but is subject to plausibility considerations. The SED does not yet handle PP attachment problems with two competing verbs.

7.2.7 Muffling combinatorial explosions

The preceding discussion assumed that while the meaning of the preposition of the PP whose attachment is to be decided may be unresolved, the potential attachment

heads and the prepositional complement were all either lexically unambiguous or already disambiguated. Now let's consider what happens if they are not, that is, if the Polaroid Words that must be used by the SED to decide on an attachment are not yet fully developed. We will see that the SED's decision will often as a side effect allow the PWs to become disambiguated as well.

In principle, the number of combinations of meanings of the undisambiguated words could be large. For example, if the two potential attachment heads, the preposition, and the prepositional complement all have three uneliminated senses, then 81 (*i.e.*, 3^4) combinations of meanings could be constructed. In practice, however, many combinations will not be semantically possible, as one choice will constrain another—the choice for the verb will restrict the choices for the nouns, for example. Moreover, such multiple ambiguities are probably extremely rare. (I was unable to construct one that didn't sound artificial for use as an example in this paragraph.) It is my intuition that verbs are almost always disambiguated by the prepositional phrase (possibly *OBJ*+ NP) that immediately follows them, before any PP attachment questions can arise, thereby reducing substantially the number of combinations. Moreover, the SED could use the strategy that if the verb remains ambiguous when PP attachment is being considered and combinatorial explosion seems imminent, the Polaroid Word for the verb is REQUIRED by the SED to resolve itself forthwith, even if it has to guess (*cf. section 5.3.4*).²² (This is in accord with Just and Carpenter's (1980:340) model of reading, in which combinatorial explosion is avoided by judiciously early choice of word senses.)

Given, then, a manageably small number of lexical ambiguity combinations, structural disambiguation by the SED may proceed as before. Now, however, each attachment must be tried for each combination. The type of attachment that scores best for some combination is then chosen, thereby also choosing that combination as the resolution of the lexical ambiguity. For example, if combination *A* suggests NP attachment on the basis of referential success, thus beating combination *B*'s suggestion of VP attachment on the basis of plausibility, then both NP attachment and the word senses in combination *A* are declared winners. Ties are, of course, possible, and may well indicate genuine ambiguity; the SED has at present no mechanism for handling them. One possible resolution method would be (as discussed above) to force the PWs involved to make a guess one by one about their meanings until a clear solution is apparent; this obviously risks being overzealous if the ambiguity is genuine. Of course, if all or a majority of the tied combinations agree on what the PP attachment should be, there is no problem for the SED even if the PWs are left none the wiser.

²²This strategy is not implemented in the SED at present.

To shrink with horror from ending [a clause] with a preposition is no more than a foolish superstition.
—H. W. Fowler²³

7.3 Gap finding in relative clauses

7.3.1 *Why gap finding is difficult*

As I mentioned in section 6.2.2, there is an interaction between ambiguities of relative clause attachment and of gap finding: the former requires deciding what the relative pronoun refers to, and the latter requires deciding where to put it. Unfortunately, just finding the gaps in relative clauses is a source of severe difficulty for Marcus parsers such as Paragram and Parsifal. To see the problem, consider (7-26) and (7-27):²⁴

(7-26) The mansion that the Hearsts moved \diamond to California was monstrous.

(7-27) The mansion that the Hearsts moved to California for \diamond was monstrous.

Both Paragram and Parsifal try to place the *wh*- as soon as they find a potential gap that their semantic consultants will let them use. Thus (7-27) will be treated like (7-26), with the *wh*- placed after the word *moved*, despite the fact that the correct gap occurs later in the sentence. Even if the parsers tried to look out for such cases (which they don't), their deliberately limited lookahead would often prevent them seeing the later gap, since it can be arbitrarily far from the "false" gap (though there does seem to be a performance limitation):

(7-28) the mansion that the Hearsts moved to California last summer for \diamond

(7-29) the mansion that the Hearsts moved to California last summer against the advice of their attorneys for \diamond

Because of this problem, we will not be able to use Ford, Bresnan, and Kaplan's (1982) proposals for applying lexical preference to gap finding (section 6.3.3); the parser requires a decision to be made on whether or not to use an apparent gap before it is known whether an expected case will turn up later.²⁵ The system, therefore, will have a systematic bias towards erroneously early placement of *wh*-s, and this seems unavoidable in a (present-day) deterministic system.²⁶

Paragram and Parsifal are also a little overeager in deciding which constituent the *wh*- should be bound to; both take the most recent NP on the parser's stack. For example, in (7-30):

²³Fowler 1965: 626.

²⁴These examples are from Frazier, Clifton, and Randall (1983), who use them to make a different point.

²⁵Experiments by Clifton, Frazier, and Connine (1984), Stowe (1984) and Tanenhaus, Stowe, and Carlson (1985) suggest that lexical expectations are used; see exercise 5.10 in section 9.5.

²⁶Sometimes it will erroneously AVOID early placement; see next section.

(7-30) the lions in the field that ...

the NP that the *wh-* will be bound to is *the field* (PP attachment of *in the field to the lions* will not have occurred yet). This choice is made as soon as the *wh-* occurs (cf. section 7.4.2).

In what follows, I will limit the discussion to fairly simple cases. I will consider only the case of one filler and one gap, and look for gaps only in the top level of the relative clause. (Neither Paragram nor Parsifal can handle subsentential gaps or multiple gaps.) Examples of cases that we won't look at:

(7-31) the boy whom the girl wanted \diamond to die²⁷ [*gap in subsentence of relative clause*]

(7-32) the boy_i whom the girl_j wanted \diamond_j to die for \diamond_i [*two gaps and fillers*]

(Notice that the gap after *wanted* takes *the boy* in (7-31), but *the girl* in (7-32); this creates a problem similar to that in examples (7-26) and (7-27).)

7.3.2 How to find gaps

Some of the principles that we used for prepositional phrase attachment will also serve for finding the gap in a restrictive relative clause. The gap location is constrained by plausibility and a preference for avoiding unsatisfied presuppositions, just as PP attachments are, and the tests can be done in the same way, with the Exemplar Principle and the Principle of Referential Success. We will also rely on preposition Polaroid Words to screen out wildly implausible hypotheses with the aid of slot restriction predicates, as they did in PP attachments.

Initially, we will assume that the binding of the *wh-* is lexically unambiguous. If the gap is in the subject position, it is immediately apparent, and English requires that it be taken without question:

(7-33) the cat that \diamond sat on the mat

(7-34) *the cat that sat \diamond on the mat

After the verb, gap finding gets more complicated. Either there is a noun phrase following the verb or there isn't. If there isn't, then there are two possibilities:

- the *wh-* is the object of the verb: *the company that Ross moved \diamond to California*;
- there is no object of the verb, and the gap is somewhere later in the sentence: *the company that Ross moved to California for \diamond* .

(We have already seen that the second possibility will not be considered unless the first is semantically inadmissible.) If a noun phrase does follow the verb, then that may be the object of the verb, and the first possibility above is eliminated; but if the verb is one that can take an indirect object, then there are four possibilities (cf. Marcus 1980: 226–228 for the first three; see also section 6.3.2):

²⁷From Frazier, Clifton, and Randall 1983, with syntax corrected.

- the NP is the indirect object, and the *wh-* is to be used as the direct object: *the book that Ross gave* \diamond *the girl*;
- the NP is the direct object, and the *wh-* is to be used as the indirect object: *the girl that Ross gave* \diamond *the book*,²⁸
- the NP is the direct object, there is no syntactic indirect object, and the gap is somewhere later in the sentence: *the girl that Ross gave the book to* \diamond ;
- the NP is the indirect object, a direct object will follow, and the gap is somewhere later in the sentence: *the book that Ross gave the girl the money for* \diamond .²⁹

The decision in each case is, of course, made by the Semantic Enquiry Desk by asking Polaroid Words to check the acceptability of slot-fillers and by testing for referential success and exemplars.

Suppose that we have (7-35), that the parser has just finished analyzing *the girl*, and that the words are all unambiguous:

(7-35) the book that Ross sold the girl

The competing parses are these:

(7-36) Ross sold INDOBJ the girl OBJ the book

(7-37) Ross sold INDOBJ the book OBJ the girl

(7-38) Ross sold OBJ the girl

(7-39) Ross sold INDOBJ the girl

Notice that the second two are weak versions of the first two. The SED sets up HYPOTHETICAL PWs for *INDOBJ* and *OBJ* corresponding to the first two parses (that is, two different *INDOBJ* PWs and two *OBJ* PWs), and looks to see whether there are any total failures. In this case, there will be a failure in parse (7-37), because the slot restriction predicates of *sell* require that *INDOBJ* flag a destination that is *hanim* (a “higher animate being”);³⁰ (the *?x* (book *?x*)) fails this test, leaving *INDOBJ* with no possible meaning. On the other hand, parse (7-36) succeeds; parses (7-38) and (7-39) are therefore not considered (despite, as already mentioned, the possibility of error).

Now let’s consider an example in which slot restriction predicates don’t give the answer and other tests must be used:

²⁸This construction varies widely across idiolects in acceptability. Some people, including most speakers of non-North American English, disallow this construction, and allow only the form given as the third possibility. Marcus (1980: 226–228) provides an analysis of the idiolectic variation; see also Langendoen, Kalish-Landon, and Dore 1973. A computer NLU program should be able to handle a wide variety of idiolects.

²⁹Neither Paragram nor, I think, Parsifal, can parse this.

³⁰Ambiguities can result with things like companies that are both *hanim* and *salable*; for example, *the company that Ross sold IBM* could be parsed like (7-36) or like (7-37).

(7-40) the book that Ross gave the girl

Let's assume that the destination of *give*, unlike *sell*, need not be *hanim* (e.g., it could be a dog), so the counterparts of both (7-36) and (7-37) will succeed. The SED then constructs the Frail objects that correspond to these parses and tries for referential success.

```
(7-41) (the ?x (book ?x
        (a ?y (give ?y
              (agent=Ross)
              (patient=?x)
              (destination=(the ?z (girl ?z)))))))
```

```
(7-42) (the ?x (book ?x
        (a ?y (give ?y
              (agent=Ross)
              (destination=?x)
              (patient=(the ?z (girl ?z)))))))
```

If one of these succeeds referentially, the corresponding possibility is chosen. If neither does, then the SED constructs calls to look for exemplars of the concepts. (If both succeed, the discourse is an extremely weird one.) The calls that search for exemplars are made by ABSTRACTING the previous calls. Continuing the example:

```
(7-43) (a ?x (book ?x
        (a ?y (give ?y
              (agent=(a ?w (person ?w)))31
              (patient=?x)
              (destination=(a ?z (girl ?z)))))))
```

```
(7-44) (a ?x (book ?x
        (a ?y (give ?y
              (agent=(a ?w (person ?w))
              (destination=?x)
              (patient=(a ?z (girl ?z)))))))
```

In the exemplar search, the *thes* have been replaced by *as*. (This is not entirely satisfactory; see below.) If these also both fail, the third and fourth possible parses are tried, with the *wh-* not being used in the present position. If they both had found exemplars, the one that found the greatest number would be preferred (*cf. footnote 14*); this would happen, for instance, in cases like Marcus's *dragon-knight-boy* example.³²

The last case to consider is when early use of the *wh-* has been rejected. In this case, the *wh-* is necessarily used at the site of the next preposition that is missing

³¹This is the "indefinite" form of *Ross*, since *Ross* is an instance of a person.

³²*the dragon that the knight gave the boy [cf. (6-83)].*

its complement and that can possibly accept it.³³ If no such gap eventuates, then the *wh*- should have been used earlier; recovery, however, is not possible, and the parser has been garden-pathed.³⁴

Now let's relax the assumption that the words involved are lexically unambiguous and suppose that some are, instead, undeveloped Polaroid Words. In this case, each of the words' remaining meanings will have to be included in the semantic tests, as with lexical ambiguity in PP attachment (*see section 7.2.7*). If only one sense of a word gives good results, the gap is used, and, as a side effect, the PW is disambiguated appropriately. If more than one sense is good, the gap is chosen, but the PW continues to look for disambiguation cues (*cf. section 5.3.5*). Again, as with PP attachment, some of the PWs should, if necessary, be forced to make an early decision, but this is not yet implemented. Similar principles could be used in deciding between alternative bindings for the *wh*- when a method of obtaining the possibilities is provided (*see above and section 7.4.2*).

We now return to the problem of exactly what should be sought when looking for exemplars to prove plausibility. When the SED is testing for referential success, no problem arises—it just looks for the exact semantic object specified. However, if this does not succeed, the SED has to look for “something similar”. For prepositional phrase attachment (*see section 7.2.4*), this is not so difficult, since the semantic object is simply a frame with a specified slot value; the question of “similarity” doesn't really arise.³⁵ Relative clauses describe more complex and specific situations than PPs, and it would be silly to require an exemplar to match exactly; rather, a suitable abstraction needs to be created. For example, the plausibility of *the book that Ross gave the girl* should not rest on knowing of some book that some person gave some girl; people accept as plausible *the sewing machine that Ross gave the librarian*, but not *the escalator that Ross gave the baby*, though they

³³It is necessary to distinguish such prepositions from particles, but at the moment we don't—we always take loose prepositions as indicative of a gap if a gap is sought; *see section 7.4.1*.

³⁴These garden paths do not seem to have psychological reality. For example, (i) would give the system a garden path:

(i) Ross likes the horse that Nadia knitted \diamond on Monday.

but people don't seem to have any trouble analyzing (i) and deciding that the horse was a knitted toy. Compare:

(ii) Ross likes the horse that Nadia knitted near \diamond on Monday.

(iii) #Ross fed the horse that Nadia knitted \diamond on Monday.

Note that (iii) can be parsed by people, even though it is nonsensical.

³⁵But *see footnote 13*. Notice also that in the VP-PP plausibility tests, the SED does not test for implausibility in the entire case structure. For example, in testing the attachment of *with the telescope* to *saw* in (i):

(i) The squirrel saw a man with a telescope.

the SED looks only for an exemplar of **see with a telescope**, not **squirrel see with a telescope**, and makes the obvious mistake.

are unlikely to have an example of either in their knowledge bases. They do, however, have exemplars of giving something suitable as a gift to something suitable as a gift recipient—a concept very hard for us to characterize in Frail—and use knowledge and inference in attempting to make a match in the knowledge base. Ideally, the SED should have a principled method of abstracting from a semantic object to an exemplar search pattern, and also the necessary inference mechanisms for the search; this is a matter for further research.

The two kinds of relative clause, to one of which “that” and to the other of which “which” is appropriate, are the defining and the non-defining; and if writers would agree to regard “that” as the defining relative pronoun and “which” as the non-defining, there would be much gain both in lucidity and in ease.
—H. W. Fowler³⁶

I have spoken above solely of restrictive relative clauses. The problems of gap finding are similar in non-restrictive relative clauses:

(7-45) The mansion, which the Hearsts had moved \diamond to California, was monstrous.

(7-46) The mansion, which the Hearsts had moved to California for \diamond , was monstrous.

The Principle of Referential Success, however, does not apply in testing for gaps in such clauses, because (by definition) the clause contains new information about the *wh*-. The SED is therefore limited to weaker methods, such as the Exemplar Principle, to test for plausibility in non-restrictive relatives.

7.4 Methods for other structural ambiguities

To deal with all the different types of structural ambiguity listed in section 6.2 is a large task, and the Semantic Enquiry Desk presently handles only two of them, albeit two particularly important ones. In this section I give some preliminary thoughts on how some of the other ambiguities might be handled.

7.4.1 Particle detection

There are three classes of verb in English that take particles: PREPOSITIONAL VERBS, PHRASAL VERBS, and PHRASAL-PREPOSITIONAL VERBS. Each class has a different syntactic behavior, varying in the movements the particle may make with respect to the verb and its object; see Quirk, Greenbaum, Leech, and Svartvik 1972: 811–819 or Cowie and Mackin 1975 for a detailed discussion of the classes, their syntax, and their distinguishing characteristics. A verb usually has a distinct sense when

³⁶Fowler 1965: 625–626.

```

[look (verb):
  [look-deliberately
    agent      SUBJ
    patient    at
    direction  up, down, out, ...
    ... ]

  [search-for-info
    PHRASAL    up
    agent      SUBJ
    patient    OBJ
    ... ]

  [be-wary-of
    PHRASAL    out
    agent      SUBJ
    patient    for
    ... ]]

[up (prt)]
[out (prt)]

```

Figure 7.1. Partial Polaroid Words for *look* with particles, and *up* and *out* as particles.

used with a particle—compare *look* and *look up [a phone number]*, for example—so particle detection is closely related to lexical disambiguation.

To handle particles, we must first, obviously, add to the grammar rules that will recognize the possibility that a word is functioning as a particle and will ask the SED for an opinion if necessary. Listed in the Polaroid Word for each verb will be the words that can act as particles with that verb; thus the PWs for *look*, *up*, and *out* may appear in part as shown in figure 7.1. (Notice that particles are taken as being semantically empty; this does not threaten Absity's compositionality if they are suitably typed.)

Let's suppose that the parser is working on (7-47) or (7-48):

(7-47) Ross looked up the number.

(7-48) Ross looked the number up.

The parser notes that *up* in these positions could be a particle. It therefore asks the SED whether *look up the number* is better regarded as verb–particle–object-NP, or as verb–PP. The SED decides that no sense of *number* makes a good direction and reports accordingly. As a side-effect, the PW for *look* is resolved. (No PW process is created for *up*.)

Ideally, the SED should be able to take context and plausibility into account in such decisions. It is, however, restricted by the parser's limited lookahead, and would probably analyze (7-50) erroneously as being like (7-49):

- (7-49) Ross looked up the elevator shaft.
 (7-50) Ross looked up the elevator shaft in the inventory of the building's conduits.

7.4.2 Relative clause attachment

To determine the attachment of a relative clause, the possible ambiguity of the *wh*- must be added to the SED's gap-finding methods. First, of course, it must be determined what the possibilities for the *wh*- are. We saw in section 7.3.1 that Marcus parsers always immediately assume it to be the most recent NP on their stack, but there is no reason why the decision couldn't be delayed and all possibilities considered in conjunction with the content of the relative clause. This would, however, require the SED to figure out exactly what *wh*-s could be constructed from constituents on the stack, in effect doing some of the parser's work for it, which might be considered inelegant.

The best way to handle ambiguity in the *wh*- seems to be to make it a Polaroid Word once its syntactic possibilities are discovered. It can then be disambiguated with no need of extra mechanisms or rules, except that at the end of the clause the SED will have to look at its result in order to tell the parser where to attach the relative clause.³⁷

7.4.3 Adverb attachment

Adverb and adverb phrase attachment is conditioned by both lexical preferences and the position of the adverb in the sentence. Some adverbs insist on being attached always to the sentence or always to the VP, and these may be handled easily by the SED if they are so marked in the lexicon:

- (7-51) Fortunately, the bad guys couldn't get across the river.
 (≠ *The bad guys were fortunate that they couldn't get across the river.*)
- (7-52) One day, when Princess Mitzi was out in the garden, hopefully kissing frogs . . .³⁸
 (*i.e., Princess Mitzi was kissing frogs in a hopeful manner; ≠ It is hoped that Princess Mitzi was kissing frogs*³⁹ or *#The fact that Princess Mitzi was kissing frogs was full of hope.*)

³⁷It might be objected that even this is unnecessary, as once the *wh*- is disambiguated, the attachment of the relative clause is of no further interest. This is not true in all cases, since the attachment of the clause may result in the closure of intermediate constituents, and thus affect later attachment possibilities.

³⁸MONTY PYTHON. *Monty Python's previous record*. Charisma, 1972.

³⁹My tolerance for a wide range of idiolects (*cf. footnote 28*) does not extend to the discourse-comment use of *hopefully*. "Such use is not merely wrong; it is silly" (Strunk and White 1979: 48).

Webster (1983) attempts to defend the admissibility of the use of *hopefully* as a discourse comment by the following amazing argument: *interestingly* can be used as a sentence modifier; therefore, so can *hopefully*. This is both a non sequitur and an ignoratio elenchi. Whitley's arguments (1983), though at least informed, are also unconvincing.

Adverbials that admit both attachments are sensitive to their position in the sentence. Generally, clause-initial position implies sentence attachment, and clause-final implies VP attachment; compare:

- (7-53) In accordance with the law, Ross ate his breakfast.
(*i.e.*, *The law obliged Ross to eat his breakfast, and he did so.*)
- (7-54) Ross ate his breakfast in accordance with the law.
(*i.e.*, *The particular way that Ross ate his breakfast was legal.*)

However, adverbials are easily moved about. The following examples mean the same as (7-53); note that (7-56) differs from (7-54) only in its comma:

- (7-55) Ross, in accordance with the law, ate his breakfast.
- (7-56) Ross ate his breakfast, in accordance with the law.

This suggests the following rule for the SED: an adverbial modifies the sentence if set off from the clause by commas (and if lexically permitted to do so).⁴⁰ This assumes that adverbials such as *in accordance with the law* may be reliably distinguished from ordinary prepositional phrases, for otherwise the rule will be erroneously applied to preposed PPs such as (7-57):

- (7-57) On Monday, Ross ate his breakfast.

I hypothesize that such adverbials are a small (but not closed) class concerning obligation and happenstance, and are flagged by constructions such as *in accordance with*, *as instructed by*, *as predicted by*, and the like.

Unfortunately, there are a few adverbs for which the rule does not work and for which the SED will need to use something more subtle. Sentence (7-58) admits both attachments:

- (7-58) Happily, Nadia frolicked in the meadow.

Such sentences cannot be reliably disambiguated without inference on the context.

⁴⁰ Discourse comment adverbials (*i.e.*, those not attached at all) behave rather as sentence modifiers do:

- (i) Frankly, I don't like him. (*discourse comment*)
- (ii) I don't like him, frankly. (*discourse comment*)
- (iii) He gave his opinion frankly. (*VP-attached*)
- (iv) He frankly gave his opinion. (*VP-attached*)

Note, however, the use of *literally* in (v):

- (v) Ross and Nadia literally fell over with laughter. (*discourse comment*)
(*i.e.*, *Ross and Nadia fell over with laughter, and I mean that literally*)
- (vi) I mean that literally. (*VP-attached*)

7.5 Conclusion

The Semantic Enquiry Desk gains its power from the design of Absity and Polaroid Words. It is able to make semantic judgments with Frail because the constituents with which it works have already been assigned well-formed semantic objects by Absity. Even if the correct choice of object for an ambiguous word is not yet known, the alternatives will be well-formed and easily accessible from the Polaroid Word.