Chapter 5

Embedding the Grammar in a Comprehension Model

At last, we come to our own approach to comprehension. In chapter 3 we outlined some essential features of grammars relevant to the problem of comprehension. In chapter 4, we sketched how various contemporary models treat comprehension. Our conclusion is that any viable and behaviorally adequate model must have both an associative and a syntactic component. This chapter presents an architecture for the integration of the two kinds of information during comprehension.

5.1 Syntactic Derivations and Probabilistic Information in Comprehension

The syntactic component of a grammar represents the formal computational steps involved in defining the representation of sentences. We have outlined several enduring properties of syntactic structures and processes that are relevant for processing models:

- Lexical items are categorized syntactically. For example, there are nouns, verbs, and so forth.
- Lexical sequences are grouped hierarchically into categorized phrases, such as noun phrases and verb phrases.
- Syntactic operations can operate on phrasal categories.
- Syntactic operations include movement or computation of distant configurations of syntactic elements such as features and phrases.
- Syntactic operations are ordered and occur cyclically.

Consider the implications of these properties for models of comprehension. Our primary question is whether a syntactic structure can be constructed by direct left-to-right application of a grammar. We will conclude that it cannot. This conclusion motivates consideration of a model that "reconstructs" the syntactic derivation.

The first three syntactic properties above set constraints on any comprehension model. First, a comprehension model must quickly access the lexical category of each lexical item and the phrase type of each phrase. Ordinarily, both of these processes are thought of as "bottom up." In such a model lexical items are stored and recognized by matching. Based on the category of their content words, phrases are then "projected." In sentence (1), the first phrase—*the horse*—would be recognized in the following kinds of stages:

(1) The horse races.

1. Recognize *the* as initial noun phrase.
2. Recognize *horse* as a noun.
3. Construct the noun phrase (*the horse*).

Such processes can be compiled to build up a labeled phrase structure representation by proceeding from left to right. Having assigned *the horse* status as a noun phrase, the system can assign "verb" and "verb phrase" status to *raced* and put the whole hierarchy together as a syntactically well-formed sentence as the words are heard. Thus, the orderly application of syntactic knowledge seems adequate for at least the surface phrase structure involved in sentence comprehension.

However, it is often noted but rarely attended that lexical items in speech are not neatly segregated for auditory recognition. For example, the pronunciation of *the horse* might be something like *thuoarse*, with no pause and the /h/ dropped. Thus, recognition of words even in a simple phrase can involve much more than simple linear processing. Suppose sentence (2a) has the rough pronunciation of (2b):

(2) a. The horse races and wins.
   b. Thuoarserayseznwinz.

A listener might initially code *thuoarse* simply as an unrecognized noun phrase, based on the fact that it begins the sentence and the initial sequence *thu* is a reasonable pronunciation of *the*. This would allow for further processing. But then the *raysez* could either be a continuation of the noun phrase or the verb, requiring further suspension of a final analysis. In fact, the structure of the initial phrase is not really clear until the sequence *winz*, along with the fact that that is the end of the utterance. In certain instances, even the word *horse* may not be recognized until near the end of the sentence. Even worse, the sequence *winz* might be heard as the noun *winds*, in which case the entire sequence would be incorrectly analyzed as a noun phrase until its very end.

Simple cases like this show that the comprehension mechanism for auditory input cannot always work as the mere mechanical application of syntactic categories and frames from left to right. Rather, there must be a set of procedures for dealing with temporarily indeterminate information even at the acoustic level and using projected phrase and content information to guide comprehension both prospectively and retrospectively. That is, there must be a set of templates and processes that can predict likely sequences and structures from incomplete information.

This kind of information is partially structural, partially probabilistic. It is a structural fact that *the* introduces a noun phrase. But it is a probable fact that horses *race* more often than they *raise* or *ease*. Thus, in fast speech, sentence (3a) may be mistaken more often as (3b) than the reverse.

(3) a. The pony erased the competition.
  b. The pony raced the competition.

Because *horse* is animate, it is more likely an agent for a verb than not. And finally, it is more often the case that the initial noun phrase of a sequence is the subject of the verb than not. It would be functional for a comprehension system to utilize all these kinds of information during comprehension.

A second homely fact relevant for sentence comprehension is that normal speech is often defective. There are frequent mispronunciations, slips, false starts, and outright ungrammatical sentences. Any model that depends on completely recognizable well-formed units will not be adequate to the normal task of comprehension. Probabilistic knowledge may be important in dealing with this problem as well.

Thus, prima facie, it appears that the probabilistic modelers are right: Comprehension models must include devices that can quickly apply many kinds of probabilistic knowledge as well as assign syntactic structure. Such models might be able to account for the rapid assignment of some syntactic structures as sentences are heard. Indeed, we saw in the previous chapter that connectionist models are excellent at "pattern completion" when there is only partial input. Thus, an adequate comprehension model includes both an implementation of rule-based grammar and an implementation of associative information.

However, this kind of "hybrid" model is not sufficient by itself. Syntax not only involves left-right orderings arranged into hierarchical structures, it also involves cyclic, successive upward movement and other computational relations between distant elements. Therefore, each sentence has a derivational history that ranges over its entire structure. How are we to recover the cyclic stages involved while computing sentences from left to right?

The computational problem is that if the movements are ordered and cyclic, recovering the initial input form by "reversing" the derivation presents too many computational paths. Of course, if traces had actual phonetic form and wore their indexes in their pronunciation, recovering the source trees of a sentence would be a great deal easier. But traces are inaudible and generally have no phonetic effect. Even when they are explicitly instantiated in pronouns, they do not intrinsically indicate how they are coindexed. Thus, the comprehension system has to recover the source sequence of structures by undoing operations and moving phrases back to their source positions without having any explicit marks that locate the source positions or the relations to their particular derived positions. To compute this would require an inverse system to keep track of multiple possibilities, which expand exponentially with each level of embedding. It cannot be proved that this is *impossible*, only that it is computationally overwhelming with even fairly simple sentences.

5.2 Analysis by Synthesis

We perceptually organize speech as made up of discrete sounds and higher-order units. But the process of talking obscures the boundaries between the units. Producing speech is like taking an ordered lineup of different kinds of eggs, breaking them so each overlaps with its neighbors, then scrambling them up a bit so there is a continuous egg belt, and then cooking them. Comprehension is analogous to the problem of figuring out how many eggs there were originally, exactly where each was located, and what kind it was. This is a hard problem for any template-matching system that is ordered as below:

(4) Input → sequence of sounds → words → phrases

The problem of acoustic analysis is even harder. Each physical speech sound is perceived in the context of a particular speaker with a particular vocal tract. This means that certain sounds are perceived differently depending on who utters them. For example, Ladefoged and Broadbent (1957) demonstrated that a vowel sound acoustically between /i/ and /e/ is perceived clearly as one or the other, depending on who the speaker is that introduces it. This deepens the importance of an active perceptual model.

Of course, the problem is made somewhat easier by the fact that in language the units are not lined up in arbitrary ways. Each language has phonetic, phonological, lexical, and syntactic constraints that severely limit the possible sequences. But the problem remains of how to bring such grammatical knowledge to bear on the input signal.

Theories of the perception of phonemes—speech sounds at the most elementary level—offer a model for our consideration. Two distinct kinds of proposals converge on the same idea. In a long series of theoretical and research papers, the Haskins Laboratory group has outlined a "motor theory" of the perception of speech sounds (for example, Liberman et al. 1967). Separately, Halle and Stevens (1964) suggested that speech perception could proceed in an "analysis-by-synthesis" framework. The essential feature of both proposals is that an initial preliminary analysis of the input is used to trigger the mechanism that generates grammatically possible forms in the language. The candidate output of the grammar is compared with the speech input. When there is a match, the system assigns the grammatical representation used to provide the match. Figure 5.1 shows the Halle and Stevens model.

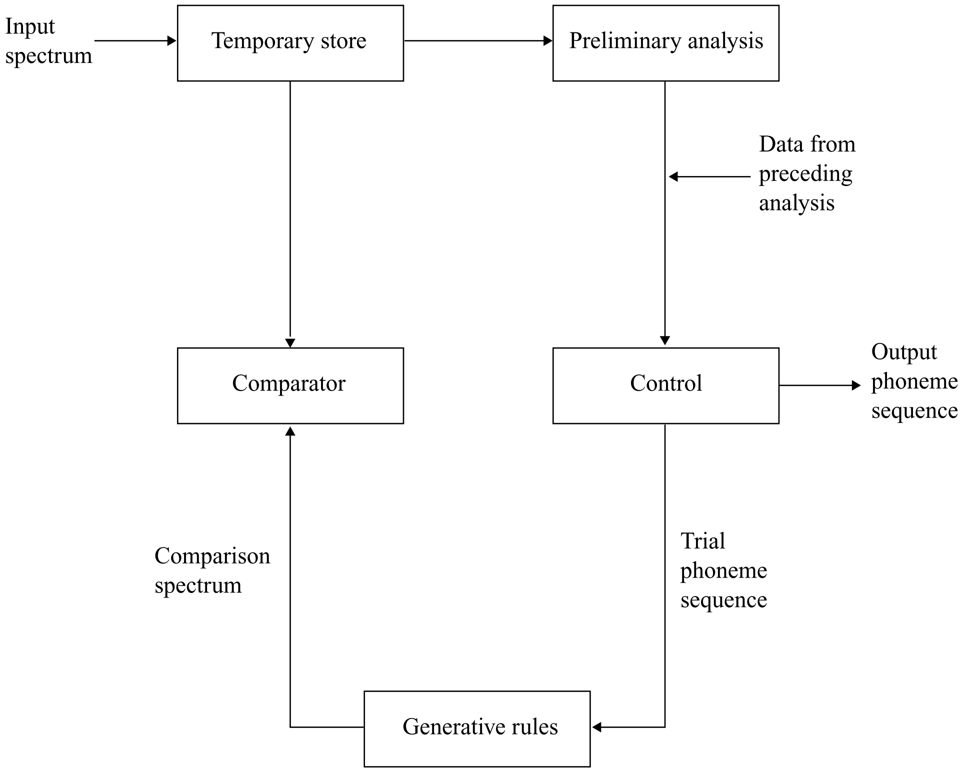

Figure 5.1
Halle and Stevens's analysis-by-synthesis model for speech recognition (from Halle and Stevens 1964:608).

It is clear how such a scheme approaches the scrambled-egg problem. In terms of our scrambled-egg analogy, the analysis-by-synthesis model starts with a particular hypothetical egg sequence, scrambles and cooks them in a virtual kitchen, and then compares the resulting virtual omelet with the actual input. When the virtual omelet matches the actual omelet, the input and cooking sequence producing the virtual omelet is confirmed as the correct analysis. The analysis-by-synthesis model has considerable appeal at the phonetic level. One reason is that the physical basis for speech production ensures that phonemes are realized in different ways, depending on their context. Thus, /k/ between two /i/s is made with the tongue farther forward in the mouth than between two /a/s; /a/ between two /k/s is made with quite a different tongue shape than /a/ between two /t/s. Hence it is difficult to find constant acoustic features for many speech sounds. The analysis-by-synthesis model solves the problem by generating the surface from an input sequence, which is not ambiguous initially.

The analysis-by-synthesis model can also apply at higher levels of analysis (see Neisser 1967 for further examples). Consider the word-level recognition of the sentence-initial phrase, assuming for the moment that a phonetic analysis has been performed:

(5) Thuoarse . . .

The preliminary sounds *Thu* can be recognized as a potential instance of *the*, which is also recognized as a noun phrase initial word, with a head noun somewhere:

(6) $[[\text{the}]_{\text{Det}}[\text{oarse}]_{\text{N}}]_{\text{NP}}$

The problem now is to find a noun corresponding to the monosyllable *oarse*, but there is no such noun. Enlarging the search to monosyllabic nouns that end in *oarse* reveals a few: *course*, *horse*, *Norse*, *force*, *source*, and so on. Trying to fit each of these candidates to the input phonetic sequence, the grammar would generate:

(7) a. the Norse . . .
b. the force . . .
c. the course . . .
d. the source . . .

Each of those cannot match the input because of the initial consonant. But in trying *the horse*, and optional process of rapid speech in American English can drop initial /h/, as in:

(8) a. If /h/ is internal to a sequence, then /h/ → 0.
b. But he found his bat . . . → buteefoundizbat

Thus, one of the derivable pronunciations of *the horse* is, in fact, *thuoarse*, creating a match to the input.

This simple example clarifies the importance of grammatical derivations in motivating an analysis-by-synthesis scheme. Suppose perception proceeded entirely by recognition schemes: such a scheme might recognize *thu* as *the*, but *oarse* does not occur anywhere in the lexicon. Only after application of the /h/-dropping rule is there a match to the input.

One could list all such alternate pronunciations of each word, but this would create massive duplication of information. Maintaining a normal lexicon and having a framework in which normal grammatical processes can apply both represents and greatly simplifies the role of grammatical constraints in recognition.

Such information duplication might be conceivable at the lexical level, but it would be intractable at the phrase and sentence levels, because there are too many of them. Figure 5.2 represents how the entire analysis-by-synthesis architecture might look at the clause level.

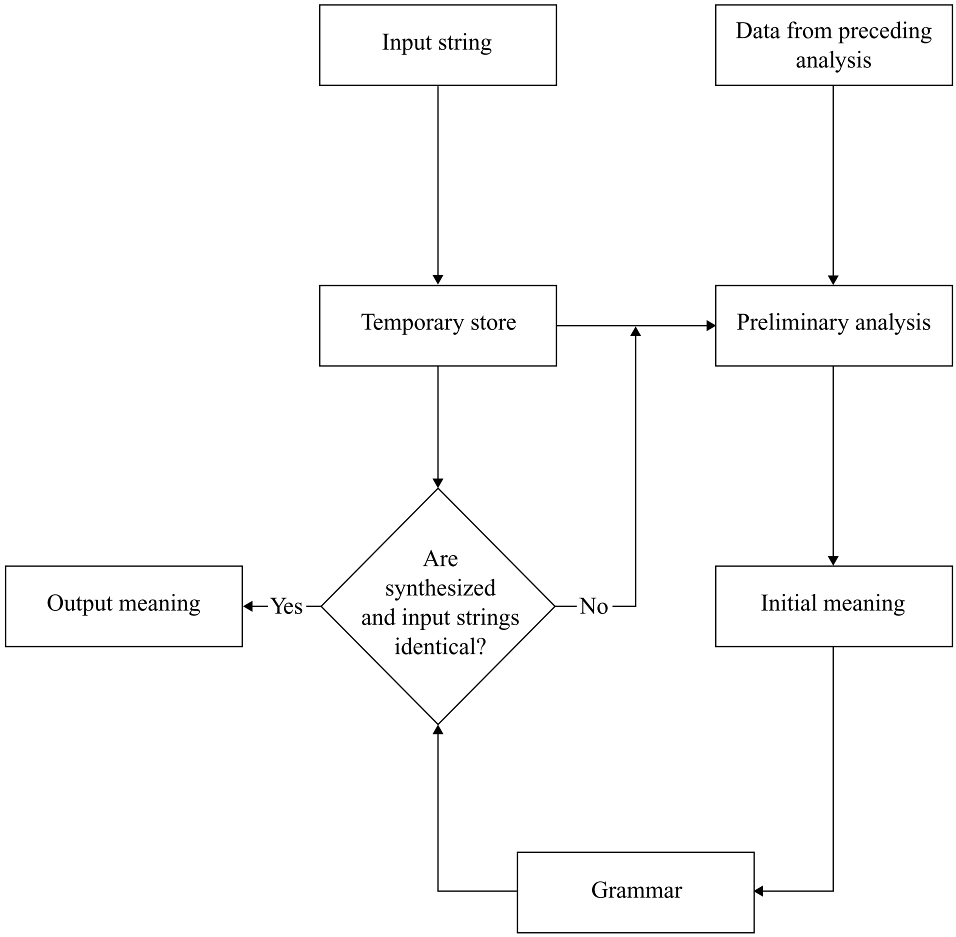

Figure 5.2
An analysis-by-synthesis model at the sentence level.

According to the model shown in figure 5.2, a quick-and-dirty parse is initially elicited, assigning major phrases and setting them in conceptual relation to each other. This preliminary analysis uses a variety of surface schemata in conjunction with verb argument and control information to organize an initial hypothesis about meaning. From that, a complete parse may be accessed that computes a derivation and fills in the remaining syntactic details. In this view, one purpose of assigning a complete syntactic parse is to make sure that the initial statistically and lexically based initial meaning is consistent with a syntactically well-formed parse. The model articulates three major steps in comprehension:

1. Assign a likely meaning.
2. Map that onto a syntactic structure and derive a surface structure.
3. Check the output of step 2 against the input.

This model also resolves the major difficulty in how to interrelate syntactic structures with processing models. Put crudely, an initial structural and associative system isolates a candidate analysis based on surface cues, and syntactic processes check that the analysis can derive the sequence. The difficulty for such models is to limit the initial hypothesized search space of potential syntactic structures. If the input to that stage included a specification of the thematic roles of the words and phrases, it would limit the generated hypotheses to sentences that have the indicated words with just those underlying structure roles that typically correspond to the conceptual thematic roles. It is a subsidiary result of that claim that the syntactic parse usually follows the initial semantic analysis. We suggest further that if the parse characteristically follows an initial semantic analysis, this solves the problem of limiting the search space.

The idea that a sentence may be initially "understood" before a complete and correct parse is assigned sets one limit on how the formation of levels of representation might be integrated. Of course, there may be natural situations in which the initial pass at assigning the meaning is incorrect, or simply not complete enough to constrain the syntactic parse. Under those circumstances, assignment of the syntactic parse may actually precede the correct semantic representation; thus, our most basic claim is that the two levels of representation are computed independently. Before turning to some examples of how the model works out, we review the different components in some detail. First, the model assigns a likely meaning and form. The initial stage of assigning a likely meaning/form involves what we call *pseudosyntax*. This component assigns lexical categories, segments major phrases, isolates their heads, and assigns likely argument relations between the heads of major phrases. Pseudosyntax is largely passive and bottom up. Since it relies on statistical properties of the ecology of language and specific lexical information, it is a probabilistic analysis of the meaning and form. Its ultimate output is:

- A list of likely lexical items
- A list of likely heads
- An arrangement of heads into a syntactic structure that relates arguments to predicates

On the basis of this pseudosyntax, a likely candidate meaning or conceptual structure is assigned.

Second, the model forms a candidate real syntax. This process takes the candidate meaning/form from pseudosyntax and maps it onto a corresponding set of structures that serve as the input to a syntactic derivation. The mapping principles are partly statistical, applying first the most likely syntactic structures corresponding to the output of the pseudosyntax. The mapping principles are also partly structural, constrained by lexical subcategorization information and syntactic well-formedness constraints.

Third, the model generates and matches the syntax. This stage derives a complete surface structure from the input and compares it to the stored sequential input.

Now consider each stage in even more detail.

1. *Assign a likely meaning*. This process involves isolating lexical items and phrases, relating them in a likely syntactic structure, and assigning a meaning to that. As a largely passive process, there is no principled reason why the different aspects of this kind of structure cannot be assigned partially in parallel. But for expository purposes we discuss the different aspects of structure as though they were ordered bottom up.

a. *Lexical recognition*. As we discussed above, sometimes lexical pronunciation is distinct and unique enough to allow for immediate segregation and recognition. At other times, there is no segmentation, and local encoding effects may obscure and blur isolated word recognition, so that it depends on a larger context. A salient part of that context is the phrase.

b. *Phrase segregation*. Not only is isolation of phrases an important aid to recognition of individual words, it is a logical prerequisite to assignment of arguments to predicates. All languages include a small number of function words and morphemes that give some cues to phrase boundaries and phrase types. In English, such words tend to begin phrases. For example, if we segmented and categorized each phrase in the sentence before last, using a simple strategy of segmenting before each function word, we would see:

(9) a. All languages . . .
all = quantifier
quantifier phrase
b. can include . . .
can = modal
verb phrase
c. a small number . . .
a = determiner
determiner phrase
d. of function words . . .
of = preposition
prepositional phrase
e. and morphemes . . .
and = conjunction

f. which give . . .
which = relative pronoun
relative clause
g. some cues . . .
some = quantifier
quantifier phrase
h. to phrase boundaries . . .
to = preposition
prepositional phrase
i. and word types.
and = conjunction

Once a skeletal segmentation of this sort occurs, isolation of individual lexical items becomes simpler. The typology of each phrase based on its leading function word also constrains identification of its head. Furthermore, many local phonetic encoding processes that obscure words are contained within major phrases. Thus, the initial segmentation of phrases, identification of phrase types and heads, and recognition of words all are mutually supportive, and all can rely in large part on simultaneous passive recognition processes.

c. *Assign a configurational syntactic structure*. Meaning is compositional and depends on some structural form that specifies possible arguments in relation to possible predicates. Isolated phrases must be integrated within a higher-order framework to arrive at a candidate conceptual interpretation of sentences. This, too, can in part depend on passively accumulated and applied statistical generalizations. The most salient example is that a noun phrase preceding and agreeing in number with a verb is taken as the subject of that verb—that is, the noun phrase has the subject relation in a phrase structure tree. Similarly, a noun phrase following a verb is taken to be the object of the verb; in other words, it falls within the same verb phrase. Assigning a configurational syntactic structure to the sample sentence above would yield:

(10) (All languages) ((can include) (a small number)) . . .

Prepositional phrases, conjuncts, and relative clauses can be initially interpreted as locally attached, yielding:

(11) (All languages) ((can include) (a small number (of function words and phrases))) (that give cues (to phrase boundaries and word types))

So far, we have developed quite a rich structure based entirely on superficial cues and likely phrase organizations with no appeal to meaning. The logically final operation of this stage is to project a likely conceptual interpretation onto the hypothesized syntactic configuration. A well-grounded set of generalizations accounts for a large proportion of such hypothesized structures:

(12) N . . . (V . . . (N . . .) (N . . .)) = agent, action ((patient) (recipient))

(13) HEAD (adjunct) = adjunct modifies head

2. *Forming the syntax.* So far so good. But as the reader is sure to have thought, the system cannot count on always being presented with statistically dominant structures and meanings. There has to be some mechanism to check that the initially hypothesized meaning is correct, and if not, a system for generating additional guesses. This is the function of the next step, which is to generate a syntactic structure based on the initial analysis, and check its output against the original input sequence. The hypothesized meaning-form input to the syntax-formation process includes the actual inflected lexical items, the head-marked and categorized phrases, the initial syntactic framework, and the hypothesized conceptual structure. (Henceforth, we refer to this representation as the *initial meaning-form hypothesis*.) This sets many constraints on the possible initial syntactic structures selected by a grammar.

Within the current Minimalist Program (Chomsky 1995), the inflected lexical items provide the initial numeration as part of the input to a derivation. The conceptual structure adds information on likely functional relations. For example, patients of verbs and prepositions are likely to be accusative (in English), agents are likely to be nominative, verbs agree with their agent/subjects, and so on. The result is a numeration that meets the basic input requirements for a derivation, which can then proceed.

3. *Syntax generation and matching.* The derivation of a syntactic surface sequence proceeds in the normal manner of a grammar. The result yields as a fully specified syntactic description, a derivational analysis together with a complete surface phrase structure, word order, agreement markings, and so on. This is matched to the original input, and if it provides a match, the computation is terminated. If there is not a match, the computation starts again at various points. In later chapters, we discuss specific examples of initial misanalyses and strategies for recovery.

5.3 A Case Study: The Passive

Consider how this system works on simple declarative sentences, as in (14):

(14) Athens was rich.

The first logical stage is to segregate the phrases:

(15) $[\text{Athens}]_{\text{np}}$, $[\text{was}]_{\text{copula}}$, $[\text{rich}]_{\text{adj}}$

While the dominant NVN = agent, action, patient pattern does not apply here, an immediately subordinate canonical sequence and category template can apply to this sequence to postulate an initial meaning. That is, (16a) corresponds to (16b):

(16) a. NP, BE[inflected to agree with NP], ADJ
b. Adjective is predicated of NP

In this case,

(17) Rich:Athens (that is, *rich* is predicated of *Athens*)

This conceptual structure in turn constrains the possible grammatical structures that can express it, relying on conceptual to structural mapping regularities, in this case:

[adj]:np $\rightarrow$ NP is dominated by S

(18) ADJ is dominated by VP
insert BE as Verb
dominated by S

This regularity between conceptual structure and components of grammatical structure specifies a list of lexical items, their case and tense, and functional relations. All this is tantamount to an initial input of words and functional structures to the synthetic component. This initial structure in turn has as one of its most direct surface expressions, the exact input sentence, thus completing the parse analysis of the input.

Now consider how this sequence of processes applies to a more complex structure such as a transitive sentence:

(19) Sparta attacked Athens.

The first phase is isolation of the major phrases, based on lexical cues and surface morphology:

(20) $[\text{Sparta}]_{np}$, $[\text{attacked}]_{v}$, $[\text{Athens}]_{np}$

The next phase is to assign a canonical structure to the sequence, relying on surface order cues. In this case, the simple canonical order NVN can be taken as corresponding to agent-action-patient following the formula in (12), leading to the initial, and correct, hypothesis that the meaning of the sentence is:

Sparta = agent
attacked = action
Athens = patient

This along with the lexical items can then serve as input to the syntactic generator, using the following sorts of regularities:

Agent $\rightarrow$ the NP in construction with an agent-assigner
Action $\rightarrow$ verb that assigns agent and patient roles
Patient $\rightarrow$ verb-internal argument

These regularities between conceptual and functional organization specify a particular initial structure.

The generation of that structure and checking it against the original input constitute the final stage of applying a parse within the framework of analysis by synthesis. Thus, in both these cases, the sentence is initially correctly "understood" via surface regularities, and then an exact parse is applied using the initial conceptual analysis as a constraint on possible initial derivational structures.

This is all a straightforward implementation of the model. But consider now how the same sorts of processes apply to a passive construction such as:

(21) Athens was attacked by Sparta.

The first stage again is to isolate the phrases and their order and apparent morphological agreement:

(22) $[\text{Athens}]_{\text{np}}$ $[\text{BE}]_{\text{copula}}$ $[[\text{attacked}]_{\text{adj}}$ $[\text{by}]_{\text{prep}}$ $[\text{Sparta}]_{\text{np}}]_{\text{modifier}}$

The initial schema outlined for simple predications can apply to the initial part of this sentence to interpret the apparent adjective as a modification on the initial NP that agrees with the copula:

(23) [[attacked] [by Sparta]]:Athens

This analysis is conceptually correct, as far as it goes. That is, it is correct that *Athens is attacked*, and that *by Sparta* serves as a special modifier on the nature of the attack. However, it is part of the lexical meaning of a morphologically passive nonlexical adjective like *attacked* that it entails a passive concept. In other words, lexical information in *attacked* specifies that *Athens* is not the agent of the corresponding predicate but the "patient," as in:

(24) a. NP = agent
b. attacked by Sparta = predicate
c. Athens = patient

A default strategy is to fill in the one extra NP into the missing position for it. This default strategy yields a conceptual structure:

(25) a. by Sparta = agent
b. attacked = predicate
c. Athens = patient

Combining the conceptual information and the order information, and using the kind of conceptual–to–functional structure mappings described above, part of the initial input to the synthetic component of the system is:

(26) NP attacked Athens; by Sparta

This underlies a derivation that corresponds at the surface structure exactly to the original input passive sentence, which would thus complete the parse and be confirmed against the input during syntax checking.

This example is important in several ways. First, it shows that in certain cases, a preliminary incorrect parse can lead to a correct initial conceptual organization and hypothetical meaning, and thence a correct initial syntactic input derived from the conceptual organization. That is, the system first interprets a passive sentence as an active copula sentence with a complex adjectival predicate. Since the lexical meaning of the "adjective" is itself morphologically marked as passive, the correct conceptual interpretation is assigned. This in turn is the basis for reconstituting the correct deep structure and thence the correct surface parse.

A second feature of this analysis is that it depends critically on lexical morphology. For example, it is crucial that *attacked* is assigned a "passive" conceptual status with its argument assigned patient status. This is the basis for then assigning a deep structure with the argument noun phrase placed in the usual patient position. This is consistent with the fact that *attacked* is not an adjective within the permanent lexicon.

Contrast a true passive like *Athens was attacked by Sparta* with a superficially parallel structure such as (27):

(27) Athens was surprised by Sparta.

In this case, the immediate conceptual analysis accesses *surprised* correctly as a lexical adjective rather than a morphologically passive deverbal adjective. This is consistent with the differentiation of apparent "passive" constructions into those that are truly syntactic and those that are lexical in source. Some typical bases for differentiating lexical from syntactic passives are the distributional facts showing that lexical passive words can appear in adjectival locations:

(28) a. The surprised city
b. *The attacked city
c. Athens looked surprised.
d. *Athens looked attacked.

Accordingly, the conceptual structure of this sentence is:

(29) Surprised[by Sparta]: Athens

Since *surprised* is a lexical adjective, this is conceptually identical to *rich:Athens*. Hence, the initial structure it relates to is:

(30) Athens BE surprised [by Sparta]

This has the consequence that the same apparently passive surface sequence is assigned a deep structure passive analysis in one case, with noun phrase movement.

But in another case it is treated as an adjectival construction, for purposes of both initial conceptual analysis and syntactic structure. We return below to some empirical confirmation of this distinction.

The active or passive morphology of the verb then signals the actual argument structure. In the case of the passive, this occasions a reassignment of patient role to the surface subject. At this point, there is available for syntactic analysis the surface string, an initial segregation into major phrases, and a conceptual representation of those phrases and how they are related. The goal of the syntactic parser is to take these structures as input and construct a derivation of intermediate syntactic structures consistent with them.

The cases in which the correct conceptual interpretation is derived from an initially incorrect parse are particularly interesting. These appear to include all cases of NP-movement in English, in which a noun phrase is removed from the position that assigns it its theta role, but it has case assigned by its surface position. These cases include passive (31a), raising (31b), and perhaps tough-movement (31c):

(31) a. Athens was attacked t by Sparta.
b. Athens was likely t to attack Sparta.
c. Athens was tough to attack t.

In each of these cases, our hypothesis is that the initial conceptual interpretation is arrived at on the basis of an incorrect and incomplete organization into a complex predicate that modifies the subject noun. The incorrect organization in the case of passive establishes an adjective with modifier, in the case of raising a "double-verb" construction, and in the case of tough-movement a complex adjective, as below:

(32) a. Athens, was, [attacked-by-Sparta]$_{adj}$
b. Athens, was, [[likely-to-attack]$_{v}$, Sparta]$_{adj}$
c. Athens, was, [tough-to-attack]$_{adj}$

These cases of movement are distinct from apparent movement, in which the noun phrase is coindexed with another but receives its theta role and case from its deep structure position. *Wh*-movement is in this latter category: the acceptability of /whom/ versus /who/ reveals the case-marked patient role.

(33) a. Who are they; He hit whom; *Whom are they
b. Whom did Sparta attack t

Such cases show that, like other NP-movement, the *wh*-word [whom] acquires its patient role from its source position during the derivation. In addition, its inflected case is assigned by a nonfinal derivational position. Another reflection of this is that despite the fact that it is in superficial preverbal subject position [at least ordinally], the verb agreement is determined by the agent noun phrase.

The implications of these facts is that the initial assignment of conceptual structure to such sentences with movement must first treat the *wh*-word as moved back into its source position. This movement allows the comprehension system to meet the requirement that the input have the appearance of a well-formed sentence. Until the *wh*-word is related to its source position, it does not have an assigned case relation. That is, the first stage of comprehending sentences such as (34a) is to assign the *wh*-word to its source position as in (34b) and the surface subject *Sparta* to its preverbal position so each can receive case.

(34) a. Who_1 is Sparta attacking t_1
b. Sparta_1 is attacking who_1

The conceptual analysis of this sentence then proceeds as for a regular transitive active sentence. We discuss some implications of the difference between NP- and *wh*-movement below and in the next chapter.

These considerations require a revision of the order of decoding events during comprehension. The first stage includes carrying out the minimal "syntactic" operations that yield a superficially well-formed sentence. In English (and we expect universally) what this comes down to is moving *wh*-marked main-argument phrases back into their source positions before applying the canonical template strategies to provide an initial meaning/form analysis.

5.4 Pseudosyntax, Real Syntax, and the Grain Problem

This sketch outlines the framework and stages of the model. There are several additional general points that put the model into perspective.

5.4.1 Cycles, Online Comprehension, and Dummy Variables

The first point concerns computations and comprehension during sentences. We have presented the model as a "whole-sentence" cyclic process. Through a strictly literal interpretation of what we have said so far, one could conclude that comprehension does not "really" occur until the end of each sentence. We have presented the model that way to simplify the discussion; but in fact, the essential idea that initial meanings are hypothesized before their full syntactic analyses can apply at many levels and subsequences simultaneously. To return to example (1), as the initial NP is assigned and regenerated to analyze it syntactically as *(the horse)np*, it can also trigger the NVN template in (12) to yield a complex construction as in (35):

(35) (the horse)np
N = agent (V (N (N)))

The initial lexical cycle has correctly assigned the phrase, while it also is assigned the initial component of the larger template. With slow speech, or in a context of many simple sentences with *the horse* as agent and subject, this could also trigger a syntactic cycle. This would be based on treating the V and N as dummy elements, yielding a derivation that glosses as (36):

(36) The horse V_i-es (some NP_i (some NP_j))

Thus, it is appropriate to think of the comprehension process as potentially a simultaneous cascade of analysis-by-synthesis cycles. If such overlapping cycles are rampant, indeed it could be difficult to empirically disentangle the analysis-by-synthesis model from certain "syntax-first" models: difficult, but not impossible in principle. First, it remains the case that meaning is initially assigned at each level. Thus, in principle we should be able to show that meaning precedes structural assignment in each case, even if it is not clear how to show that with current methods. But, most important, the model is constrained to work in real time, not abstract computational space. In empirical fact, auditory input may come too fast for complete synthetic cycles to occur at intermediate points.

5.4.2 Pseudosyntax and the Grain Problem

Our model suggests that the initial comprehension of a sentence depends on lexical and surface cues that have built up inductively with experience and time. We learn to associate particular lexical items with particular categories, and sequential frames with particular conceptual relations, based on the frequency of those pairings in our experience. This is a classic associationistic claim, and if we do not elaborate it, it is subject to the classic rejoinder, namely, that there is no obvious solution to the problem of independently defining the units that are to be associated. This critical weakness of associationism was first pointed out by Chomsky in his review of Skinner's S-R treatment of language and all behavior (see section 2.2.1), and has been reborn in modern psycholinguistics as the "grain problem" (see section 4.3). In a simple declarative sentence

(37) The jockey rode a horse and . . .

how do we know that the relevant associations to reinforce are between *jockey* and *rode*, and *rode* and *horse*, and not between *The* and *rode* or *rode* and *a* or between *horse* and *and*? How do we know where to delimit a higher-level structure for reinforcement? For example, it is relevant at the level of word-association pairs that jockeys ride, and that horses get ridden; but how do we define the structure that reinforces the concept that *jockeys ride horses* in particular? It cannot be merely an accumulation of the separate NV and VN associations, because there are many counterexamples:

(38) The jockey rode his bicycle.

(39) The horse rode the train to Kentucky.

(40) The cowboy rode the horse.

Thus, there must also be a superordinate level, roughly corresponding to the proposition, available for a reinforcing relation to the lexical sequence. To form the appropriate associations, there must be a skeletal analysis that delimits the relevant units.

The classic proposal is that syntax provides the required skeletal information about sentences. Indeed in the introduction to this book, we noted that sentence-level grammar makes a critical contribution to any associationistic treatment of language behavior. Sentence-level grammar defines the objects over which associations can be learned. Most structurally minded linguists would agree that this is what makes grammar acquisition a prerequisite to the accumulation of inductive language habits. That is all well and good. But while it is logically sufficient to make the claim against mere associationistic treatments of language, it is more productive to show how the grammar might provide the needed skeletal information, and the units among which the associations are formed. Somehow we must envisage a theory that maintains the grammar and associative components distinct enough from each other, so that they each can inform the other during comprehension. The impasse that we otherwise face is that associationistic enterprises will be tempted to exclude any role for grammatical structures, and grammatical theories will be distorted by attempts to build frequency information into the grammars themselves. We have seen some of each in the current theories reviewed in chapter 4.

The analysis-by-synthesis model segregates the two kinds of information, placing associative templates in the "analysis" component, and syntactic structures in the "synthesis" component. The relation between the two components offers two points of information and constraint that reduce the intractability of the grain problem. First, pseudosyntax provides the synthetic grammar with a lexical and grouping analysis, along with an initial-meaning hypothesis that can map onto functional-category relations. Second, the syntax meets the analytic component by giving a full syntactic analysis and checking the literal form of the sentence. Both points of contact set constraints on the units available for associative processes.

- Most obviously, the grammatical syntactic analysis provides a repertoire of units over which associations might be selected. That is a specific formulation of the linguist's traditional answer to the grain problem: The grammar provides the units, while experience forms associative relations between them.
- Along with an initial-meaning hypothesis, the pseudosyntax must provide just those structures required to trigger a potential syntactic derivation. Thus, the relevant units for associative learning out of those the syntax makes available, are just those that are critical at the input stage of a grammatical derivation. In the minimalist framework, this set includes the inflected lexical items, grouped sequences, and functional-category information that plays a role in relating the groups in terms of predicates and argument positions.

Thus, the analysis-by-synthesis framework and minimalist syntax together offer a particular architecture that can resolve the grain problem. The units over which associations can be confirmed are drawn from those that the syntax provides, and the particular subset are just those units and kinds of information the grammar needs to start a derivation.

5.4.3 Formation of Canonical Templates

The processes that create templates in the pseudosyntax automatically give greatest associative strength to those aspects of analysis that occur most frequently. This has the consequence that broad-ranging canonical sentence patterns will be most strongly confirmed. Almost every instance of English clauses and most sentences have the superficial form, "NV((N)N)"; most of those correspond to "agent action ((patient) recipient))". Thus, while there are many variations in finer sentence details, almost every experience with an English clause or sentence confirms the association expressed in the canonical "NVN = agent action patient" template. It is likely that this will in fact be the most strongly confirmed abstract pattern available to the pseudosyntax.

In the following chapters, we will expand on the explanatory role of the NVN template. It is truly astounding how much of the existing experimental literature it describes. In light of the possibility of shorter (and longer) analysis-by-synthesis cycles, it is important that the analysis-by-synthesis model actually predicts that the canonical sentence-level template will be the most pervasive. Consider the different kinds of information primed in the pseudosyntax:

1. Initial segmentation and phrase-category assignment
2. Assignment of subcategorization information
3. Assignment of thematic relations between phrases

Each of these components has both a categorical and an associative component. That is, phrase segmentation can be locally influenced based on frequent patterns (see the discussion of Juliano and Bever in chapter 4), and it can be determined by function word classification. Verbs carry with them subcategorization information about the arguments they take, but this information itself can be graded with different subcategorization patterns having different strength, unique to each verb (see the discussion of Tanenhaus et al. in chapter 4). Finally, the thematic relations assigned to the segmented phrases as required by the verb frames can be influenced by the statistical properties of the verbs and the noun phrases as potential fillers of those arguments.

All this information can be locally coded. It has been argued by some (see sections 4.3.4 and 4.3.5) that it is entirely lexically based and best modeled within a framework that sets up spreading activation strengths only between pairs of lexical items. We agree that this is one of the important grains of truth to be found in the associative approach to comprehension. But we see that the analysis-by-synthesis model predicts a special status for sequences of words that comprise a potential complete proposition. This follows from the fact that in the model, the synthetic component usually applies to assign a complete syntactic structure to complete clauses. If the language has a favored "canonical" form, a natural outgrowth of the application of the synthetic component will be special importance attached to an apparent "perceptual strategy." In the case of English, this is (41):

(41) N V (N (N)) = Agent Action (Patient (Recipient))

In the subsequent three chapters, we will focus mostly on the extraordinary range of supporting evidence and explanatory power of this schema.

5.4.4 Pseudosyntax Is Associative and Real Syntax Is Categorical

The analysis-by-synthesis model segregates the role of associative information in the pseudosyntax, and of categorical information in the synthetic component, the grammar. This offers a specific architecture that resolves the question of how to integrate associative and categorical information while preserving each separately. Pseudosyntax is couched in terms of associative frequencies between surface forms and associated structures and meanings, as articulated by the grammar. This may seem circular, since it is not possible to form associations within a sentence without already knowing its grammatical structure, yet the model proposes that the first comprehension step in forming the structure is based on associations. For the moment, we will assume that the two kinds of knowledge have accumulated by the time the language learner is proficient at language understanding. As recognized by many of the more modest connectionists (e.g., Seidenberg 1997), this recasts the problem as one of acquisition. We answer it in chapter 9, where we briefly address the learning problem.

Theorists of many different stripes are willing to postulate that both the syntactic category and meaning of individual words and perhaps major phrase patterns may be recognized by overlearned templates. The watershed between associative and structural theories involves higher-order associations between words and phrases and associations to compositional meanings. In our view, pseudosyntax relies on such associations to form initial meaning-form hypotheses. This has an important implication for understanding what pseudosyntax does and does not do. Pseudosyntax does activate particular structures and meanings using associative relations between cues, structures, and concepts. It does *not* provide a "preliminary syntactic analysis." Another way of clarifying this is to distinguish the mental operations available to pseudosyntax from those available to the grammar. The *lingua mentis* of pseudosyntax is "spreading activation" (that is, it is associative); the *lingua mentis* of the grammar is "symbolic manipulation" (that is, it is categorical). Thus, in theory, what looks like the same information about a sentence actually can be represented in two ways mathematically. For example the notion that *horse* is a noun and that *the horse* is a phrase is expressed associatively as follows ("/" indicates grouping boundary):

horse—(strength H) $\rightarrow$ noun
the—(strength D) $\rightarrow$ determiner
the noun—(strength DP) $\rightarrow$ /the noun/

The corresponding information is expressed syntactically as:

$[\text{horse}]_{\text{n}}$
$[\text{the}]_{\text{det}}$
$[[\text{the}]_{\text{det}}\ [\text{horse}]_{\text{n}}]_{\text{DP}}$

Similarly, subcategorization information about a verb with different options like *want* can be represented, for example, as

want—(strength O) $\rightarrow$ want [noun](patient)
want—(strength C) $\rightarrow$ want [compS](patient)

while syntactically it is represented as:

$((\text{want})_{\text{v}}\ \text{NP})_{\text{VP}}$
$((\text{want})_{\text{v}}\ \text{CompS})_{\text{VP}}$

Finally, sequential information bearing on conceptual relations can be represented as:

$/\text{det noun}/_1$ verb $/\text{det noun}/_2 \rightarrow$ noun_1—(strength Nvn) = agent of verb
noun_2—(strength nvN) = patient of verb

while syntactically it would be:

$(((\text{det})(\text{N}))_{\text{NP}}\ ((\text{verb})(\text{det}(\text{N}))_{\text{VP}})_{\text{S}})$

This distinction is important at all levels of analysis. If it is not understood and respected, the reader (especially the syntax-first theorist) will be inclined to interpret pseudosyntax as a distillation of just those syntactic structures needed for comprehension. It is a short distance from there to arguing that pseudosyntax invalidates the need for a full syntax, and hence the role of the synthetic component. We have noted that pseudosyntax differs critically from real syntax in that it can actually prime an initial structure that would correspond to the *wrong* syntactic analysis. We strengthen the independence of pseudosyntax and real syntax by noting that they use entirely distinct kinds of computational relations.

In our discussions, we generally explicate the processes involved in pseudosyntax serially, and sometimes use terms that sound categorical. This is purely a descriptive convenience that is sometimes necessary for clarity. There is no principled reason why all types activation processes in pseudosyntax could not be effective simultaneously, with cross-connections between them.

5.4.5 Relation of Pseudosyntax to Prior Models

The initial stage of pseudosyntax corresponds historically to the "perceptual-strategies" model (Bever 1970a; Fodor and Garrett 1967; Fodor, Bever, and Garrett 1974; see chapter 2). Most salient is the fact that the strategies have as input surface sequences, and have grammatical organization as their output. In addition, the strategies were allegedly learned inductively and could apply simultaneously. However, there are numerous critical differences between the perceptual-strategies approach and our current understanding of pseudosyntax. First, perceptual strategies were themselves couched in a full set of syntactic categories. Second, the perceptual-strategies model had as a goal, mapping surface structure onto a complete and accurate deep structure that would feed into a conceptual representation (following the *Aspects* model of syntax; see section 3.4.1). Always having to get the analysis ultimately correct, or to mimic human failures to do so, created an unbearable burden on the set of strategies. This is an important reason that the strategies approach lost currency; working out the details of a zillion strategies and substrategies seemed daunting and never-ending. While the details remain numerous, the current model is consistent with connectionist spreading-activation implementations, which at least provide a calculus with considerable power. In addition, the current model offers a theoretical motivation for the unique strength of certain sentence-level canonical forms. Finally, the current model depends critically on the synthetic component, both to fill in derivational syntactic details and to provide a separate check on the entire proposed meaning.

Thus, it is important that the operation of pseudosyntax is consistent with contemporary proposals about nongrammatical activated structures. These include Tanenhaus and Carlson's (1989) notion of lexical thematic grids, as well as proposals by Frazier (1978), Marcus (1980), Steedman (1996), and Kaplan and Bresnan (1982). Each of these authors is arguing (for different reasons) that the linguistic input must be initially organized in part by principles outside the actual grammar. Most important for the current intellectual milieu is that as an inductive associative activation mechanism, the pseudosyntax is appropriately modeled within connectionist frameworks.

5.4.6 Relation of the Model to Minimalist Syntax

The analysis-by-synthesis model sets the syntactic parsing problem in a somewhat different light than currently fashionable. However, the model is entirely consistent with the minimalist syntactic model. The Minimalist Program in syntax integrates with this model in interesting ways (see section 3.4). In the Minimalist Program, a derivation starts with a numeration of the actual lexical items in their surface morphological form, marked for case where relevant. Thus, an important component of the initial part of a syntactic derivation is already available from the first-pass analysis of a sentence. In addition, the semantic analysis of the verb can specify aspects of the derivation that are not immediately apparent from the actual words. For example, a verb's action type (e.g., "telicity") can require a particular kind of movement (chapter 3): *attack* is an activity verb, with a specific action and point in time. Accordingly, it must be delimited by a patient or in some other way, in verb phrase–internal position. A natural way to achieve this in the syntactic passive case is to postulate a copy of the surface subject that can then be attached in patient position, as one of the initial subtrees of a derivation.

This formulation allows for a rather compelling model. The initial analysis based on pseudosyntax provides the lexical groupings and an initial conceptual interpretation. The lexical items comprise part of the numeration input to a derivation. The semantic interpretation in turn sets further constraints on the particular trees, including the specification of missing elements that ultimately correspond to traces. Clearly, we need to work out and test a variety of examples to explore the limits on this formulation. But it appears to be a quite promising reunification of psychological modeling with linguistic theory. This is significant, because such unification has been lacking generally, since the formulation of the *Aspects* model in the mid-1960s. Later syntactic architectures, especially government and binding, provided a hodgepodge of theoretical systems of constrains, each of which might correspond to psychological operations (as, e.g., in the minimal attachment model; see chapter 4). But it was not clear how to set up an architecture of the behavioral application of these different sets of constraints, other than the free form provided by the grammar itself. In the present case, we can now develop specific hypotheses about the actual sequential operations involved in building subtrees, checking features, and so on. Of course, in the limiting case, we may have to accede to the notion that the relation between formal syntax and actual instantiated derivations is "abstract," in which the behavioral operations are not directly mapped from the syntactic operations. But at least we can now attempt a coherent search for what the mapping might be.

Hope springs eternal: perhaps a new "derivational theory" of the psychological operations involved in assigning syntactic derivations is at hand.

5.4.7 Pseudosyntax in Other Kinds of Languages

The model may seem to depend on peculiarities of English. For example, English inflection and agreement systems are sparse, leaving much of the information dependent on explicit function words and word order. Languages with freer word order generally have correspondingly rich inflections and agreement systems. In those languages, the associative component of the pseudosyntax can converge on the inflections as reliable cues (Bever 1970a; Bates and MacWhinney 1987; see section 4.3.4). Indeed, inflections often seem to be more reliable cues to grammatical relations than order constraints are.

Verb-final languages may also seem to present a special problem for the model, especially the phrase-segmentation component. Many verb-final languages have inflection and function words at the end rather than the beginning of words and phrases. However, so long as the inflections are consistent and the function words consistently located, phrase segmentation proceeds as easily as in English.

5.5 Some Basic Facts Consistent with the Model

The next chapters review a range of largely experimental facts in support of the analysis-by-synthesis model we have just sketched. But first we turn to some more traditional kinds of linguistic facts and one enduring behavioral fact. We consider the implications of the stages of the comprehension model for the acceptability of different kinds of sentences.

5.5.1 Linguistic Phenomena

In this section we examine various linguistic phenomena in terms of stages of the Late Assignment of Syntax Theory (LAST). We consider the processing of sentences without function words, reduced relative clauses, *wh*- and NP-trace, and ungrammatical sentences that initially appear acceptable.

No Function-word Cues The most elementary process of comprehension involves the isolation of function words and the segregation and categorization of phrases based on that. This process predicts that sentences devoid of explicit function words should not only be odd, but that they are often unacceptable to the point where they might be thought of as ungrammatical. Thus, (37a) is grammatical but very odd and almost incomprehensible because of the lack of function words:

(42) a. Sheep sheep butt back butt.
b. Some sheep that other sheep butt back do butt.

Reduced Relative Clauses We have invoked canonical sentence-level strategies as crucial in providing an initial organization and meaning for sentences. The most significant of these is the so-called NVN strategy, which assigns agent-predicate-patient to such sequences. A significant problem arises if a sentence has sequences that superficially conform to a simple declarative NVN structure, as in (43):

(43) The horse raced past the barn fell.

This specific sentence and general construction have occupied a considerable portion of the psycholinguistic experimental litrature, which we review in detail in chapter 7. But, prima facie, sentences like (43) simply seem ungrammatical. It is often virtually impossible to convince nonlinguists that they are grammatical, even after exposure to a set of comparative sentences with similar structures that do not run afoul of the NVN strategy. The sentences in (44) are all easier than (43) because they weaken the NVN strategy in various ways. The final NV sequence may be implausible, as in (44a):

(44) a. The horse raced past the barn panted.
b. The horse raced near to the barn fell.
c. The horse ridden past the barn fell.
d. The horse that was raced past the barn fell.

There may be no apparent object, as in (44b). The morphology on the verb may be unambiguously a passive participle (see 44c). Or the initial verb may be signaled as subordinate, as in (44d).

***Wh*- vs. NP-Movement** We have argued that *wh*-trace and NP-trace are computed differently in comprehension (section 5.3). In particular, *wh*-trace is moved back into its source argument position before (or simultaneous with) the application of sentence-level strategies like the NVN strategy. This is necessary since *wh*-movement can yield noncanonical structures that are not otherwise instantiated in the grammar. Support for this distinction between NP-trace and *wh*-trace can be found in cases involving the interaction of the NVN comprehension strategy with subcategorization information.

Note that a sentence like (45a) has an intuitive very small garden path, in which the NVN strategy assigns the second noun status as a patient, while (45b) does not show this effect.

(45) a. ?Harry pushed the cat the bone.
b. Harry handed the cat the bone.

The reason is that *hand* requires two objects, while *push* does not. Simultaneous access to this information along with the NVN pattern facilitates premature closure with *push*, incorrectly assigning *cat* direct-object status, as in (46):

(46) a. Harry pushed the cat.
b. *Harry handed the cat.

This mistake is inhibited with *hand* since the proposition cannot end with one object, as in (46b). The effect goes away when the preposition explicitly marks the indirect object ((47a) and (47b)).

(47) a. Harry pushed the bone to the cat.
b. Harry handed the bone to the cat.

Now consider the facts when one of the objects is *wh*-piped to the front of the sentence:

(48) a. ?This is the cat that Harry pushed t the bone.
b. ?This is the bone that Harry pushed t the cat.

Both (48a) and (48b) seem relatively bad compared with (48c) and (48d).

(48) c. This is the cat that Harry handed t the bone.
d. This is the bone that Harry handed t the cat.

We can explain the relative unacceptability of (48a) and (48b) on the same basis as (46a). If *that* is moved to its source position first, the same principles will apply that contrast (45a) and (45b). The NVN pattern can apply but will be inhibited from closure in the case of *hand* because of the fact that it requires two objects to be a complete proposition. Notice that the difficulty of (48a) and (48b) is not due to the salience of *Harry pushed the bone/cat* at the end of the sentence. This is shown by the fact that (48a) becomes completely acceptable when the correct non-direct-object location of *cat* is marked, as in (48e).

(48) e. This is the cat Harry pushed the bone to [t].
This is the cat to whom Harry pushed the bone [t].

Now consider corresponding constructions with NP-trace in the passive:

Direct object topicalized, single object
(49) a. ?The bone was pushed the cat by Harry.

Indirect object topicalized, single object
(49) b. The cat was pushed the bone by Harry.

Direct object topicalized, double object
(49) c. ?The bone was handed the cat by Harry.

Indirect object topicalized, double object
(49) d. The cat was handed the bone by Harry.

Each of these examples is middling bad, with no particular difference between sentences with *push* and *hand*. These facts follow from the syntax-last model, in which passive sentences are first understood by the application of a complex predicate analysis strategy, as in (50):

(50) The bone was [pushed by Harry]$_{adj}$

Such a strategy applies equally well to *push* and *hand* and does not immediately reconstitute an NVN sequence. Hence, no difference is predicted between the two verbs.

Rather, in both of these cases, the versions with the indirect object topicalized ((49b) and (49d)) are noticeably easier than with the direct object topicalized ((49a) and (49c)). This is consistent with other cases, in which the [V + ed by NP]$_{adj}$ is treated as a separately moved constituent. For example, as an adjunct to a noun phrase, an adjective phrase is acceptable, as in (51a); with passive pseudoadjective phrases, this is acceptable when the noun is the indirect object ((51b) and (51c)), but not the direct object ((51d) and (51e)).

(51) a. Happy about the bone, the cat purred.
b. Pushed the bone, the cat purred.
c. Handed the bone, the cat purred.
d. *Pushed the cat, the bone disappeared quickly.
e. *Handed the cat, the bone disappeared quickly.

Apparently, when explicit in a small clause, the V + NP sequence must be Verb + Object as in *pushed the bone* in (51b), and (51c). (It is not clear at the moment whether this is a grammatical or perceptual constraint.) This is true even when semantic support for the indirect object interpretation is overwhelming, as in (51f):

(51) f. *Given the charity, the money was no longer tainted.

Note that the corresponding full passive is acceptable, albeit more awkward than the alternative with the indirect object topicalized and the direct object as part of the apparent VP. We can explain the difference as a function of the fact that passives are perceptually analyzed initially as though actually a predicate construction. This initial analysis briefly gives the V + NP phrase-segmented status, which contributes to the difference in acceptability, based on the fact that when fully separate, the construction with the direct object is ungrammatical.

Really Odd Sentences That Make You Shake Your Ears We have argued that the initial comprehension of a sentence is based on the elicitation of sentence templates. If they lead to an incorrect sequence, the system tries again with subordinate templates. This leaves open the possibility that the system could run out of statistically supported templates and be left with an incomprehensible but arguably grammatical sequence. When the system runs out of templates, and the ones that seem to apply conflict with each other, sentences indeed become impossible to grasp.

Consider the following sentence, which is unacceptable, though it seems grammatical at first glace.

(52) The shopkeepers were unsatisfied by midnight.

Trace your intuitions as you consider this sentence. At first, it seems acceptable, but then you realize that it does not really have a stable meaning that you can rest on. There is no obvious grammatical reason this is unacceptable, as shown by the acceptability of several kinds of parallel constructions.

(53) a. The shopkeepers were still unsatisfied by midnight.
b. The shopkeepers were unhappy by midnight.
c. The shopkeepers were unsatisfied at midnight.
d. The shopkeepers were dissatisfied by midnight.
e. The shopkeepers were unsatisfied by the price.

It may be that the first sentence runs afoul of a conflict between a salient sentence template based on the apparent passive morphology, and the fact that *unsatisfied* is a lexical passive (i.e., an adjective that looks like a syntactic passive). The apparent local applicability of the NVN template requires that *unsatisfied* be derived from an agentive verb, which it cannot be. At the same time, the temporally delimiting quality of the final phrase *by midnight* requires that there have been a change of state. A change of state ordinarily is expressed as a verb if one is available. And *unsatisfy* apparently is available. But then, it is not really a verb. Thus, the initial templates in the pseudosyntax elicit competing initial representations of the sentence without a grammatical resolution.

Finally, there are intuitions that are neatly explained if people first apply sentence templates to a sequence, form an initial meaning, and then check its syntax. Consider (54a):

(54) a. *That's the first time that anyone sang to me like that before!
b. That's the first time that anyone sang to me like that.
c. No one sang to me like that before.

In fact, (54a) is an ungrammatical blend of two grammatical sentences. But what is important is the sequence of introspective events you go through when trying to understand it. First, it seems fine because it triggers well-oiled sentence templates with roughly the same meaning. Then it gradually starts to rattle as you realize that it does not quite compute into an actual sentence. The following sentence is even more marked because, while it triggers plausible sentence templates, they do not add up to a coherent initial meaning.

(55) a. More people have gone to Russia than I have.

This sequence works its way into the system at first, by triggering two templates:

(55) b. More people have gone to Russia than I . . . (could believe).
c. . . . people have gone to Russia [more] than I have . . .

But then, when synthesizing it into a surface sequence, nothing coherent emerges.

One might argue that these curios are insignificant ephemera at the boundaries of legitimate linguistic investigations. Similar objections have been raised against the use of visual illusions as tests of visual theories. But we find that the importance of illusions is critical in both the study of vision and language. Thus, the oddity of such examples and intuitions about the sequence of mental events they trigger are testament to the theory that predicts and explains them.

5.6 Conclusion: The Heightened Clarity of Grammatical Speech

The study of language comprehension has been the subject of hundreds of reported experiments since the 1950s. But the original report by Miller and Isard (1963) remains a puzzle: words that form a sentence simply sound clearer, and are more resistant to interference than the same words in a list or in an ungrammatical sentence. Fifty years of research on the detailed steps involved in sentence comprehension leave this profound fact unexplained (see chapter 2).

The analysis-by-synthesis model offers an explanation that has been largely unnoticed, but that we highlight here as a conclusion to this chapter. Consider the architecture of the system as shown in figure 5.2. When a sentence is understood, it involves a derivational synthesis of its surface form for comparison to the stored input. Thus, the process of assigning a syntactic structure creates *an extra representation of the surface form*. Many of the models we reviewed in chapter 4 presuppose that there is a store for the input, while comprehension processes are underway. But only the analysis-by-synthesis model requires that there be two simultaneous surface representations. It is the presence of two representations that explains the relative perceptual clarity: words in sentences sound clearer because they have two mental resonances, not one.

We take this as the first serious confirmation of the basic premise of the model—that comprehension involves comparison of stored and synthesized surface representations. The following chapters review other evidence in support of the model.