Understanding

THE JOYS OF READING Proust include the immaculate prose, the wonderful descriptions of characters that encapsulate almost everything there is about being human, and the very, very long sentences that sometimes seem to start on one page and finish several later. Among the contenders for longest "real" sentence is one 1287 words long, from William Faulkner's novel *Absalom, Absalom!*, according to the *Guinness Book of Records*, although Molly Bloom's soliloquy in James Joyce's *Ulysses* clocks in with one sentence 11,281 words long, and the following 12,931 words long, although I'm not sure I'd count these as real sentences. The point is that contrary to what I might have led you to believe I think so far, we deal with more than one word at a time. We speak mostly in sentences, and we hear and read sentences. But sentences aren't lonely creatures spoken in isolation; they're linked to what's come before and what's coming next. We tell stories, have conversations, read books about something.

The "something" language does isn't random, either. We speak or write with some purpose in mind. In our heads we have a representation of the world, and we use language to convey a part of that representation to other people. I speak to bring about some change in you: to get you to do something, or to inform you of something I don't think you

already know. When we speak or write, we have a representation we wish to convey, and your job as listener or reader is to decode that information, integrate it with our existing mental representation of the world, and decide how to act upon it. This process of bringing two mental representations together so they share more than they did before the linguistic interchange is called *alignment* (Pickering & Garrod, 2004). The alignment we achieve doesn't have to be perfect: it just has to be good enough. When I tell you "Felix is on the loose!", I don't have to convey my feelings about dogs, or my knowledge that Felix is good at catching Frisbees, just that Felix is a dog and he's got out of his kennel and something has to be done about it. Similarly as a listener you don't need to analyse every word I say for hidden nuances (although some seem to enjoy doing so) or align your representation of the world perfectly to mine before you do anything; you just have to extract my intention. You might not even need to analyse the sentence perfectly every time if you can get away without doing so. Language understanding, most of the time, has to be just good enough. The cost of this casualness is that we're not always right – sometimes people misunderstand what they're hearing or reading (Ferreira et al., 2002). So when people saw the sentence:

> While Anna dressed the baby played in the crib.

many participants afterwards believed both that the baby played in the crib (correctly) and that Anna had dressed the baby (incorrectly). So in the real world we might not analyse everything perfectly every time, yet clearly we do enough to get by (most of the time).

It's my experience that many students find the study of how we understand sentences to be the most difficult and least interesting part of psycholinguistics. And, I must now shamefully admit, I know what they mean. I think there are three difficulties with the work discussed in this chapter. First, there are many technical terms (e.g. "reduced relative", "relative clause"), and I find it difficult remembering what they all mean. Second, many of the materials used in the experiments in this area strike me as artificial and unnatural – not at all the sort of thing we use in real life. And third, related to this point, I wonder what the more general point of it all is. Obviously we can process reduced relatives (we'll come to what they are later), but why does it matter? Some researchers are very interested in them, but it strikes me as a very specialist topic – almost like train spotting (no offence intended), and not at all the sort of thing a wide-ranging scholar would spend too long on. So writing this chapter is a special quest for me: to minimise the number of technical terms and make them memorable; to discover if we are really troubled by these sorts of sentences in real life; and to discover if this work tells us anything more general about how the mind works.

We call the process of working out the syntactic structure of a sentence *parsing*. When we parse a sentence, we break it down into its constituents – nouns,

verbs, adjectives, and so on – and work out how they are related to each other. We can summarise the structure of a sentence such as "the old man jumped quickly into the boat" using a diagram (Figure 7.1).

We call the mechanism responsible for parsing the human sentence processing mechanism – or HSPM for short. The HSPM extracts the meaning of an utterance, and we then have to integrate that meaning into a representation that makes sense with what we already know.

What is grammatical ambiguity?

If language was completely unambiguous things would be much easier, and this chapter would be very short. We'd be able to hear or read a sentence, and

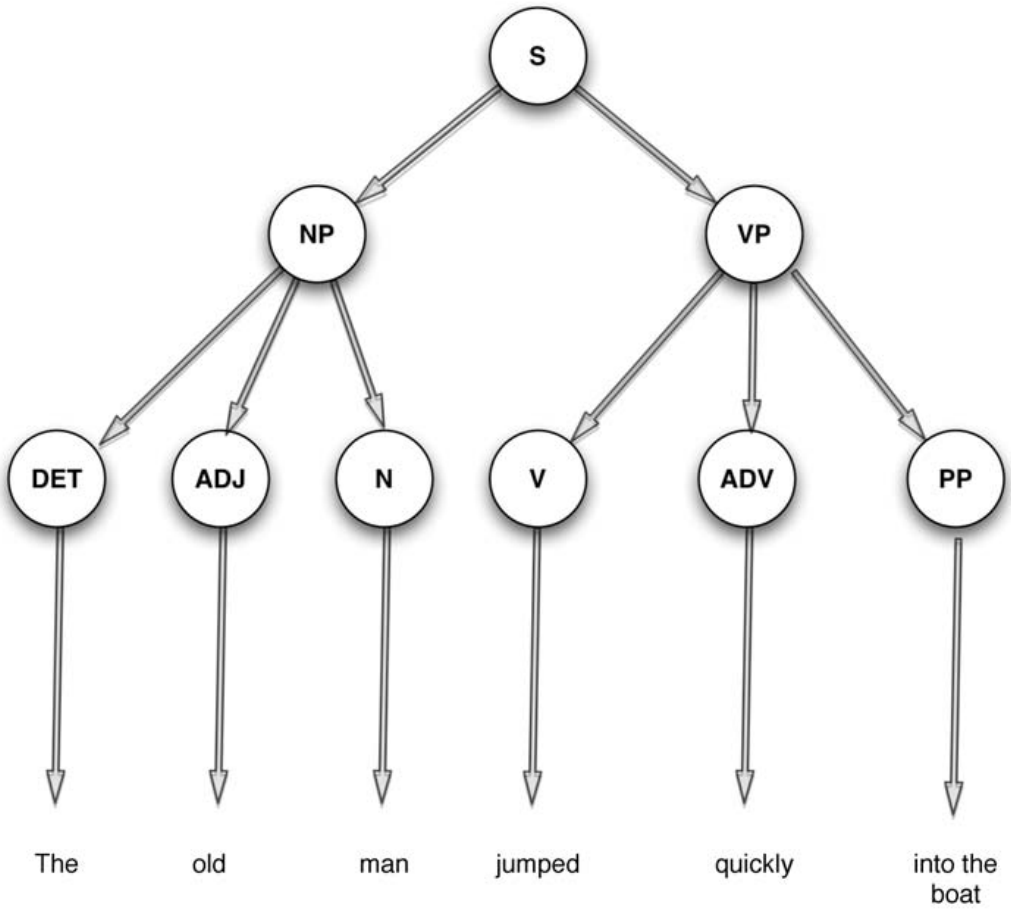

FIGURE 7.1 A parse tree for "The old man jumped quickly into the boat". Note: S = sentence; NP = noun phrase; VP = verb phrase; DET = determiner; ADJ = adjective; N = noun; V = verb; ADV = adverb; PP = prepositional phrase

immediately work out its grammatical structure correctly. We would never have to postpone a decision about what it means or backtrack and reanalyse what we've read.

But life isn't that simple. You're listening to someone speak on the radio: "The". OK so far, not much difficulty understanding what's happening. "The old". No problems yet. "The old man". Easy. "The old man the". What? Has someone made a mistake? "The old man the boats". Uh? Oh, I see. (Take a moment if you still don't.)

Here the sentence is to be understood with "man" as a verb ("man the boats!"), and therefore "old" as a noun, but virtually everyone, when they hear "the old man", at first identifies – *parses* – this structure with "man" as a noun and "old" as an adjective.

I've already talked about lexical ambiguity, and syntactic ambiguity is the other great source of ambiguity and difficulty in understanding language. Some sentences are permanently ambiguous in that we get to the end of them and we can't resolve the ambiguity (by which I mean settle on one unambiguous interpretation) without additional information.

I saw the Pennines flying to Dundee.

Structurally, this sentence is ambiguous. You probably instantly and without any thought settled on the structure corresponding to "When I was flying to Dundee, I saw the Pennines", but it could mean "There I am standing there and all of a sudden I looked up and saw the Pennines flying overhead on their way to Dundee"; well, there are fantasy or science fiction scenarios where it wouldn't be totally impossible. I suppose we could also think of the Pennine family, and we see them peering through their plane window en route to Dundee. Or for something less dramatic:

Visiting relatives can be boring.

Either going to visit them can be boring, or it can be boring when they come to visit us. Both interpretations are nearly always true in my experience.

With these sorts of sentence, we get to the end and that's it. There's no more help, and we just have to work out which is likely to be the correct structure on the basis of the context.

But the worst is yet to come: in addition to permanent ambiguity, we, or our HSPM, have to worry about temporary ambiguity, where we can assign more than one syntactic interpretation to what we've got so far. Later material in the sentence then disambiguates the structure so we are left with just one reading. Now virtually every sentence is ambiguous at some point; if you just hear the first word, "The –", there is an extremely large number of possible continuations and structures that could follow. We could have "the dog" or "the brown dog", "the brown dog

chased", "the brown dog was chased", and so on. Let's put aside this trivial sort of temporary ambiguity and stick to parsing where commitment matters.

I saw the man with the binoculars

Let's stop there; that's all you've heard, and what you've heard so far is ambiguous – it's ambiguous between a structure that means "I saw a man, and it was the man who had some binoculars" and one that means "With my binoculars, I saw the man". At some point – and the really big question here is when – we have to choose between these two structures. At some point the temporary ambiguity might be resolved by additional material:

I saw the man with the binoculars that I had just picked up.
I saw the man with the binoculars use them to swat a fly.

In some cases the material might have been preceded by helpful context. In some cases the intended interpretation might remain unclear at the end of the sentence. We have to do the best we can.

At least these sorts of ambiguous sentences don't seem to derail us most of the time. Our HSPM moves along without our noticing; we assign syntactic structures, and usually aren't aware of any ambiguity or conflict. Now try to read the following sentence – and this isn't easy – one word at a time, quickly, without looking ahead. Ready?

The horse raced past the barn fell.

Most people who haven't seen this sentence before get to the end and say "what?" That "fell" doesn't seem to fit there. Your head jerks. Is this even grammatical? You probably had the experience of going back and reanalysing the sentence. What appears to have happened here is that we analyse the structure of the sentence (work out who or what is doing what to what) initially as "There is a horse and it raced past the barn", which is fine until we come to the word "fell". We then have to reanalyse the sentence to come up with a structure that can accommodate "fell". Hence we decide the sentence must mean "There was a horse that was raced past the barn and it fell". Got it? Some people need some time to see the correct structure (that is, one that works without leaving any words over!).

These sorts of temporarily ambiguous sentences, where we have a very strong initial interpretation that turns out to be wrong, are called *garden-path sentences*; we've been led up the garden path. They contain what's called a reduced relative clause. A relative clause is one that modifies a noun. Here the "horse" is the noun, and "raced past the barn" is the relative clause. Often relative clauses are

introduced by grammatical words called relativisers, "that" and "which"; if one had been present in this example it would have read:

The horse that was raced past the barn fell.

And there wouldn't have been a problem because the relativiser would have prevented the structure from being ambiguous. When we omit the relativiser the relative clause becomes a reduced relative, and it's these reduced relatives that cause us trouble. Not all sentences that lead us up the garden path are reduced relatives: "the old man the boats" isn't, but it garden-paths most people.

A note on garden-path sentences: many people find them odd, and some find them ungrammatical. "People never really speak like that!" they say, or "Surely there should be a comma there!", and I have some sympathy with these views. However, we do sometimes speak like that, perhaps more than we think. Just as I broke off from writing this section, I looked, in the gloomy depression- and recession-framed time of writing the first draft, at the financial part of the *Daily Telegraph* only to be met with "Treasury reveals biggest growth forecast cut since records began". I was all right until I got to the word "cut". If we're going to understand how we understand language, we need to understand how we cope with the type of ambiguity found in garden-path sentences; garden-path sentences are a tool to help us study the human sentence parsing mechanism.

With this dash around ambiguity we can identify a number of interrelated issues of potential interest to the psycholinguist. How do we resolve ambiguity? What sorts of information do we use? When we come across ambiguity, do we keep both possible analyses open and only make a choice when we have enough information to make a conclusive decision? Or do we make a best bet as soon as we encounter the ambiguity and, if it turns out to be wrong, go back and reanalyse? And on what basis then do we make the best bet?

How do we deal with temporary ambiguity?

Perhaps the garden-path examples have already given us the answer: after all, when we come across garden-path sentences we have the very strong impression that we are forced to *reanalyse* the sentence. We hear "The horse raced past the barn" and analyse it simply as noun phrase (the horse), a verb (raced), and prepositional phrase (past the barn). We construct the syntactic structure and use that to extract the meaning. But then along comes "fell", nothing fits any more, and so we stop, go back, and reanalyse it correctly this time as a reduced relative.

There are two main theories of how we parse incoming structures. According to the *garden-path model*, we pick the most likely structure on syntactic grounds and carry on with it unless we're forced by subsequent conflicting information to

I saw the Pennines flying to Dundee

reanalyse. According to the *constraint-based model*, we use multiple sources of information to assign a structure. I'll look at these two approaches in more detail, bearing in mind that the key differences emerge when the HSPM comes across syntactically ambiguous material such as a garden-path sentence.

In the garden-path model, we create just one syntactic structure, which means the HSPM has to make a choice – I'll come back to how it chooses among alternatives in a moment. If the choice is correct, we move on. If the first parse turns out to be incompatible with later syntactic, semantic, or pragmatic information, then we have to go back and reanalyse. The garden-path model therefore is a two-stage model, with an initial stage that uses just syntactic information, and a second stage that makes use of any semantic or pragmatic information (Frazier, 1987; Rayner et al., 1983).

In constraint-based models, the parser uses multiple sources of information, called *constraints*, to activate alternative syntactic structures in parallel. Constraints are anything that could influence parsing – syntactic preferences, semantic knowledge about what can do what to what, pragmatic information about the topic of conversation, even the relative frequency of different syntactic structures (Boland et al., 1990; Taraban & McClelland, 1988).

The two main differences between the two models then are, first, whether parsing takes place in one or two stages and, second, whether any kind of information other than syntactic knowledge can affect the initial parse.

The question of how we resolve syntactic ambiguity might seem very narrow, perhaps even tedious, but in fact it addresses one of the most fundamental issues about the design of the mind. Are we made out of little boxes, each doing their own thing, never interfering with each other, forming a strictly regimented regime? This is the East Coast view, and if you read any of Steven Pinker's books, you will get the impression that this is the way things have to be. Or does anything go? Is our mind a laid-back free-for-all society of co-operating individuals always interfering in each others' business? This is the West Coast view, the connectionist one.

How do we decide where to attach phrases?

In the garden-path model, what syntactic information does the parser use to assign the initial structure? It has two biases, *minimal attachment* and *late closure*. These will take a bit of explaining.

According to the principle of minimal attachment, new material should be attached to the syntactic representation we have so far to create the simplest legal structure possible. Of course "simple" needs a formal definition, and more strictly minimal attachment stipulates that incoming material should be attached to the partial syntactic structure using the fewest nodes possible. A *node* is a point in the syntactic structure, and at this point we really do need a diagram and a little knowledge of how we analyse syntactic structures.

According to the principle of late closure, if possible new material should be incorporated into the clause or phrase structure being processed. We also assume the current clause is the main clause of the sentence. If there's any conflict between these two principles, minimal attachment takes precedence. Let's have some fun with parse tree diagrams (Figures 7.2A, 7.2B, and 7.2C).

They're called parse trees because they're supposed to look like upside-down trees, although with branches coming off. They're very useful for showing the structure of a sentence. Here we have the start of a sentence; you hear "The burglars stole –". "The burglars" must be a noun phrase, and "stole" a verb, announcing the start of a noun phrase. So far, so unambiguous. But now suppose you hear "all the statues in the –". How are we to attach this? Let's wait until we hear the

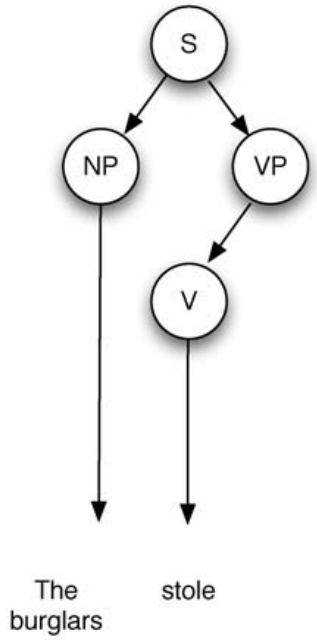

FIGURE 7.2A Parse tree: "The burglars stole"

final word before drawing diagrams, and the final word is either "house" or "night". These two words necessitate different syntactic structures, as can be seen by their associated parse trees.

"In the house" has to be combined directly with "all the statues", so the

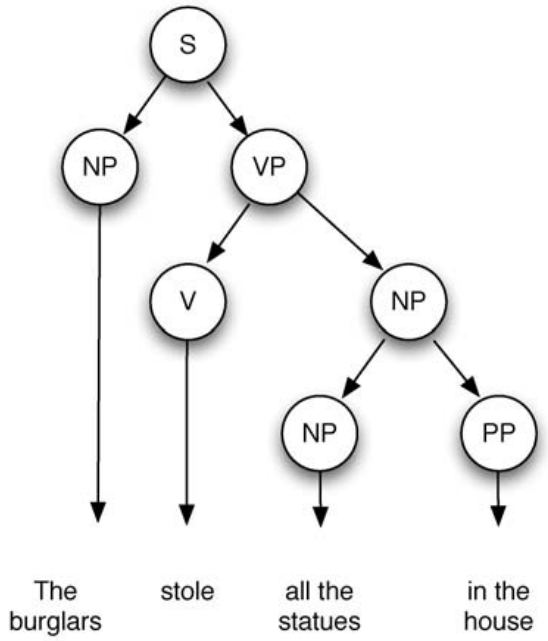

FIGURE 7.2B Parse tree: "The burglars stole all the statues in the house"

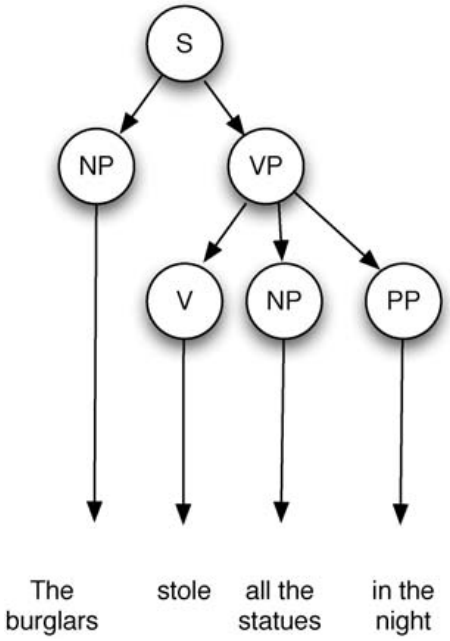

FIGURE 7.2C Parse tree: "The burglars stole all the statues in the night"

whole makes "all the statues in the house" a noun phrase. "In the night" has to be combined with the verb, so it is attached as a prepositional phrase to the verb phrase.

Which is the simpler structure – which is the minimal attachment structure? Simply count up the nodes, the circles. The first structure, the noun phrase structure, has seven nodes; the verb phrase structure has six. So according to minimal attachment the second, verb phrase structure is the preferred simpler structure – an important prediction to which I'll return.

A favoured technique for studying parsing looks at people's eye movement while reading text. There are a number of devices available now that enable us to see where people are looking and for how long; one favoured mechanism involves bouncing an infrared beam off the eyeball and monitoring the reflections. Studies of eye movements show that sentences that only make sense when these two principles are violated always seem to cause difficulty.

The first example below is very straightforward, but the second is not.

The criminal confessed that his sins harmed many people.
The criminal confessed his sins harmed many people.

You might find the second sentence to be slightly more difficult to understand. That's because when we deal with the first part of the sentence ("the criminal confessed his sins"), minimal attachment says that we should construct the simplest possible structure, which is for "sins" to be the direct object of "confessed", so

"sins" should be the end of the clause; after that it should be a new sentence, or a conjunction such as "and" or "because". The final part of the sentence, "harmed many people" – what we can call the *disambiguating* material, because it resolves any temporary ambiguity – is in conflict with this simple structure, and to resolve this conflict we have to go back and reanalyse (putting the second parsing stage into action, according to the garden-path model). Rayner and Frazier (1987) monitored people's eye movements, and found that this sort of structure did cause temporary difficulty: people looked for a relatively long time in the disambiguating region and looked longer at the second sentence overall than the first. The first sentence above doesn't cause this problem because the word "that" prevents any ambiguity, so people spend a relatively short time looking at the "harmed many people" section.

Other studies show that sentences that violate late closure also cause difficulty. In the second sentence below, the processor tries to attach "a mile and a half" to "jog", because it's treating this material as part of the main clause. But then we get "seems a short distance", which throws a spanner in the works. Frazier and Rayner (1982), again looking at people's eye movements, found that people found the second sentence harder than the first, where the word "this" again prevents any ambiguity.

> Since Alice always jogs a mile and a half this seems a short distance to her.
> Since Alice always jogs a mile and a half seems a short distance to her.

We have data then that are consistent with minimal attachment and late closure, but can semantic knowledge prevent us from being led up the garden path? The results of an experiment by Ferreira and Clifton (1986) suggest not. Consider these two sentences.

> The defendant examined by the lawyer turned out to be unreliable.
> The evidence examined by the lawyer turned out to be unreliable.

The sentence fragment "The noun examined –" is ambiguous; it's consistent with either a nice, simple direct object structure (as in "the defendant examined the evidence") or the more complex reduced relative structure (as in "the defendant examined by the lawyer"). Hold on a moment, I hear you say, surely it depends on what the noun is? I grant you that animate nouns, such as defendants, can be ambiguous in this sort of structure, because they can be both subjects and objects, but what about inanimate nouns, such as "evidence"? As soon as we hear "the evidence examined" we know to expect something like a reduced relative, because evidence can't go round examining things – it's got to be examined *by* something. So while the first of these of two sentences might be difficult, the second should not, because our semantic knowledge of what things can do should prevent the ambiguity. Or at least it should if parsing can make early use of semantic information. But

Ferreira and Clifton found that these two sentences were equally difficult – people were getting garden-pathed by "the evidence examined –" just as much as they were by "the defendant examined –". This result suggests that we make the very first parsing decisions on syntactic grounds alone; the semantic information is quickly used to hasten our way out of the garden path, but it can't prevent us being led up it in the first place.

The analysis of the electrical activity of the brain ("brain waves") supports this two-stage idea. We can attach electrodes to a person's scalp and measure the electrical activity across the brain in response to events – called *event-related potentials* (ERPs). There are two particularly pronounced spikes of interest to our understanding of how we process verbal material. We observe one event called the N400 (so called because it's of negative amplitude and observed 400 milliseconds after the event) after we observe a semantic anomaly – so when you read:

> When Alice pressed the switch nothing happened, so she realised she had to change the bulb in the ostrich.

Your brain will show a nice big N400 when you get to "ostrich". Another event, the P600, is of positive amplitude and observed 600 milliseconds after a syntactic anomaly. So when you read:

> Alice persuaded to dig it.

your brain will show a glorious P600. Several studies have used these ERPs to map the time course of sentence processing (e.g. Ainsworth-Darnell et al., 1988; Friederici, 2002; Osterhout & Nicol, 1999). For example, Osterhout and Nicol presented participants with sentences containing words that were appropriate, semantically anomalous, syntactically anomalous, or both semantically and syntactically anomalous:

> The new species of orchid will grow in tropical regions.
> The new species of orchid will sing in tropical regions.
> The new species of orchid will growing in tropical regions.
> The new species of orchid will singing in tropical regions.

The doubly anomalous sentences elicited both an N400 and a P600, with the size of effect being the same as single anomalous sentences. Different parts of the brain seem to respond to syntactic and semantic anomaly, with each being unaffected by the other. Osterhout and Nicol concluded that semantic and syntactic processes are independent.

Other researchers have met these results with more scepticism. It is one thing to say that different parts of the brain store different types of knowledge and

deal with different types of processing, and another to say that these processes don't have any influence on each other (Pickering, 1999). While the first claim is relatively uncontroversial, the second is much more so.

How much like a parse tree does this look?

How do multiple constraints operate?

According to constraint-based models, multiple sources of information converge to bias how the HSPM parses sentences. Semantic information can be used from an early stage, and can override pure syntactic biases. Consider the two sentences:

> The thieves stole all the paintings in the museum while the guard slept.
> The thieves stole all the paintings in the night while the guard slept.

Taraban and McClelland (1988) used a task known as self-paced reading to measure how difficult people found these sentences to understand. In this task people press a key for each new word, and so you can measure how long it takes them to read the whole sentence. The more difficult the sentence is to understand, the reasoning goes, the longer people will take to read it. The first sentence above, with "all the paintings in the museum" forming a noun phrase, is the more complicated syntactic structure according to minimal attachment.

An eye-tracking device (photograph Ben Tatler)

Nevertheless, people took longer to read the grammatically simpler second sentence than the more complex first sentence. Taraban and McClelland argued that the meanings of all the words of the first sentence (thieves, paintings, museum) conspire to create a bias for the more complex, non-minimal interpretation. What matters, they argue, aren't syntactic biases, but semantic biases: what cause the parser problems aren't violations of abstract syntactic principles, but violations of semantic expectations. In this type of approach the verb is king: each verb comes with a set of possible roles (called thematic information) about what can do what to what. If you ask a hundred people to complete the sentence "the thieves stole the paintings in the –", they're more likely to complete it with the place the paintings were stolen from (e.g. museum, gallery) than some general setting (in the night, in the day) (Figure 7.3). Taraban and McClelland went on to argue that the earlier studies that showed effects of minimal attachment had in fact done so because the materials had confounded syntactic and semantic biases. When you balance them out, such as here, only semantics matters.

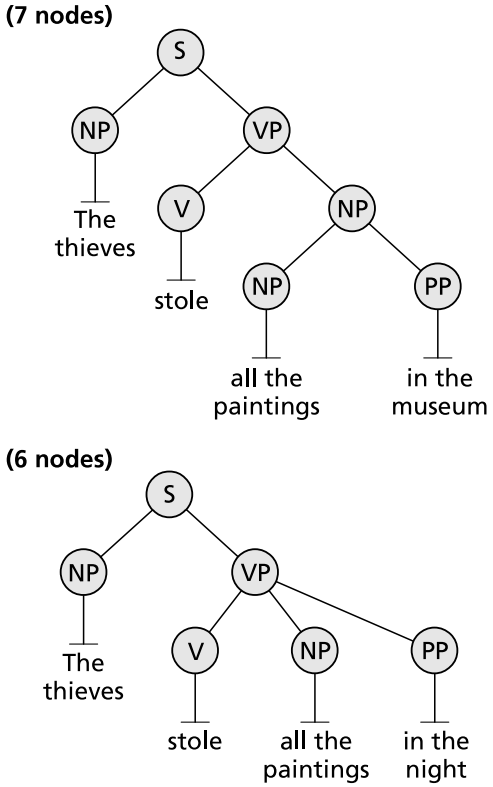

FIGURE 7.3 Noun phrase and verb phrase attachment structures in Taraban and McClelland (1988)

Providing an appropriate semantic context can eliminate the garden-path effect. When we have two similar sentences:

The teachers taught by the Berlitz method passed the test.
The children taught by the Berlitz method passed the test.

The first causes us more difficulty than the second, as measured by the number of people who think it's ungrammatical. We expect children to be taught and teachers to teach, and so the syntactic structure of the second sentence doesn't cause us any difficulty at all (Crain & Steedman, 1985). For the first sentence we have to construct a model where for some reason teachers are being taught something, and it's making sense of this information that's costly. We find the same thing with other materials using different tasks:

The archaeologist examined –
The fossil examined –

Fossils are inanimate and can only be examined, they can't examine. Measures of eye movements show that if semantic constraints are strong enough, people are not

garden-pathed by reduced relative constructions such as the following sentence (Trueswell et al., 1994).

The fossil examined by the archaeologist was important.

On the semantic account, there's no such thing as neutral context. Even if no semantic context is provided by the material, we have knowledge and expectations about how the world works, as with teachers teaching in this example. The more assumptions we have to make, the harder the sentence is to understand. This idea is powerful, and casts light on why our old friend, the original garden-path sentence "the horse raced past the barn fell", is difficult.

The horse raced past the barn quickly.
The horse raced past the barn fell.

People find the first sentence much easier to understand than the second. In the first, we only need to think about one horse. The second only really makes sense if there are a number of horses being raced and it was the one that was raced past the barn that fell – otherwise why would the speaker bother mentioning the bit about the barn? So we have to construct a model with more than one horse, which is more effortful than in the first, quick, case.

How specific is the sort of information that can influence parsing? Recent experiments with eye movements suggest we make use of all possible sources of information to help construct the most likely syntactic structure. In the real world, we aren't always limited to hearing or reading a few sentences. What's in front of our eyes is sometimes a rich source of information. Suppose you read:

Put the apple on the towel in the box.

This sentence by itself is ambiguous. It could mean either "there's an apple on a towel, and you should put that in the box" or "there's an apple somewhere else and you should put that on a towel which is in the box". Garden-path theory says that we should always interpret the sentence initially in the second way, with the towel being the destination, because that's the grammatically simpler structure. How we understand this sentence depends on what's in front of our eyes (Tanenhaus et al., 1995). In the one-referent condition of the Tanenhaus et al. experiment, there was an apple on a towel, and another towel in the box. In the two-referent condition, there was one apple on a towel and another on a napkin. In the one-referent condition, participants spent considerable time looking at the incorrect destination, the irrelevant towel, whereas in the two-referent condition they rarely did so. "On the towel" was interpreted as the destination only in the one-referent condition; in the two-referent condition it was interpreted as a modifier of "apple".

Visual information is used to help us decide how to analyse ambiguous material. Furthermore, a similar experiment by Sedivy et al. (1999) showed that people make use of this sort of information very quickly.

Put the apple on the towel – seems easy enough

There is now then a great deal of evidence that people make use of multiple sources of information while constructing a syntactic representation of incoming language. Remember though that an earlier study by Ferreira and Clifton (1986) found that semantic factors can't prevent us from being garden-pathed (with defendants and evidence being examined). How can we explain this apparent contradiction? Trueswell et al. (1994) argued that experiments that failed to find semantic effects on parsing preference did so because the semantic constraints weren't strong enough. Semantic contraints can prevent us being garden-pathed, but only if they're strong enough. It is also interesting to note that the more realistic information there is available (as in the visual world experiment above), the more likely we are to find evidence of interaction.

We have two sources of variation that make a comparison of studies in this area very difficult: we have the strength of the semantic constraint provided by the materials (and this can be difficult to measure independently) and we have different researchers using different experimental techniques (eye movements, ERP, grammaticality judgement, self-paced reading) – and even within a technique such as eye-movement analysis there are different measures to be compared (total reading

time, the number of times you look back, the time you spend first looking at something before you move on). So if you don't like somebody else's results, there are plenty of ways out. The debate is far from settled, and this is another area in which the jury is still out (even if many researchers don't think it is). But I can't sit on the wall for ever, and I admit I find the evidence for the constraint-based approach more compelling and powerful.

When we hear or read then, we construct a syntactic representation which we adjust with each incoming word. We do this quickly and mostly effortlessly. The HSPM makes use of every source of information, particularly semantic and pragmatic knowledge, and especially our knowledge of how different verbs behave. If a structure is ambiguous, representations of both structures are kept open, although one is usually more activated than the other. As with the TRACE model of word identification, competition is used to resolve ambiguity (MacDonald et al., 1994). The most activated structure beats the others into submission, which has two implications. The first is that if the less activated structure is very much less activated, but turns out to be the correct one, the HSPM will be momentarily taken aback – which presumably is when we have the strong overt sensation of having been led down the garden path (Tabor & Hutchins, 2004). The second implication is that if competition is high, such as when there are two highly activated competing structures, processing will be difficult, which makes sense and is what we observe.

Where does this leave us with the big issue of modularity? It leaves us near Hollywood on the West Coast. If the multiple-constraints approach is indeed correct, language processing is a free-for-all – or, in Spivey's (2007) terms, it's a *hungry* process, actively seeking possible interpretations, gobbling up as much information as it can as quickly as possible, and looking ahead to see what's left on the linguistic plate.

What do we remember of what we understand?

Think back to the introduction you've just read, and ask yourself what you remember of it. Do you remember every word? Almost certainly not. Do you remember the syntax, the grammatical structure of every sentence? Again, almost certainly not. You might remember the odd word (particularly novel ones like *alignment*), or the odd sentence verbatim, but what you remember – hopefully – is the gist, the general idea.

Several early psycholinguistic experiments confirmed this impression. Sachs (1967) gave participants stories containing sentences such as the following:

He sent a letter about it to Galileo, the great Italian scientist.

She later tested their ability to distinguish this original from three variants of it:

He sent Galileo, the great Italian scientist, a letter about it.
A letter about it was sent to Galileo, the great Italian scientist.
Galileo, the great Italian scientist, sent him a letter about it.

She tested their memory after 0, 80, and 160 intervening syllables – equivalent to about 0, 25, or 50 seconds. She found that unless people were tested immediately they couldn't tell the original from the first two variants, which each change the syntax of the original. In contrast, they were able to distinguish the original from the final version, which changes the meaning of the original, even after some time had elapsed. This result confirms our intuition: people usually dump the details of the wording and syntax as soon as they've extracted the meaning, but retain the meaning for some time.

We don't always dump word order information. Sometimes what we hear is important, or in some way particularly memorable, or just funny. Students remember material from lectures well for a couple of days but in the absence of additional exposure have forgotten most of it after five days (Kintsch & Bates, 1977). A depressing result from this study for educators is that students were no better at remembering the most important points of the lecture than the peripheral material. What students remembered best of all were the announcements and jokes. There's a lesson here.

This conclusion is consistent with the work on eye-witness testimony I discussed earlier.

The conclusion is that processing sentences is just a tool to extract the gist of the meaning. We're not concerned with the details of the words, or the specifics of the syntax, once we've extracted what we think is the intended meaning. It's that intended meaning that's important, and it's that that we try to fit in with our model of the world.

How do we make use of context?

It's not surprising to me that our memory for word order is usually so poor. After all, the goal of language understanding isn't to construct a syntactic representation, but to use that in the short term to extract the meaning of the sentence – to work out how the meanings of words are related, and to connect that meaning with what we already know, and to decide what to do next. It's the bigger picture that matters. How do we paint this bigger picture, and what does the picture look like?

Try reading an advanced text in an area of which you have little or no prior knowledge. It's hard going, isn't it, to say the least? Close the book; how much of it do you remember? Probably very little indeed. The point may be obvious, but we need some context, some background knowledge before we can make sense of what we hear or read. Part of the skill of writing a good textbook is being able to pitch it

at a level that provides sufficient context for the novice in the area, without making it boring; part of the skill of being a good student in an area is discovering the gaps in your knowledge and finding that context.

Several classic psycholinguistic experiments show the importance of prior knowledge – and knowing that you know the context. One of the earliest experiments made just this point. Here's a little story:

> The procedure is actually quite simple. First you arrange things into two different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities, that is the next step; otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do fewer things at once than too many. In the short run this might not seem important, but complications can easily arise. A mistake can be expensive as well. At first the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then one can never tell. After the procedure is completed, one arranges the material into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more, and the whole cycle will then have to be repeated. However, that is part of life.

Can you make any sense of it? How much can you remember of it? When presented like this, people recall an average of only 2.8 out of a maximum of 18 ideas in the story (Bransford & Johnson, 1973). Now suppose I'd told you in advance that this story is about washing clothes; your comprehension of and memory for the story would have been much better. In fact people told this context before being given the story to read remembered 5.8 ideas. Interestingly, being given the context *after* hearing the story didn't seem to help much; people recalled only 2.7 ideas, about the same as if they'd had no context.

The context doesn't have to be very much; having a title sometimes is all we need, as was demonstrated in a similar sort of study by Dooling and Lachman (1971), who gave their participants the following story:

> With hocked gems financing him, our hero bravely defied all scornful laughter that tried to prevent his scheme. "Your eyes deceive," he had said. "An egg, not a table, correctly typifies this unexplored planet." Now three sturdy sisters sought proof. Forging along, sometimes through vast calmness, yet more often over turbulent peaks and valleys, days became weeks as doubters spread fearful rumours about the edge. At last, from nowhere, welcome winged creatures appeared signifying monumental success.

You'll probably find this story equally difficult to make any sense of, but with the

title "Christopher Columbus's discovery of America", everything falls into place: the three sisters are the ships, the turbulent peaks and valleys the ocean, the edge the supposed edge of the flat earth, welcome winged creatures birds showing land is near. Again, though, the context only helped if presented before the story.

You might say that these are pretty odd stories, designed to be obscure. Context still has striking effects when comprehending more mundane material, as is shown with this story from an experiment by Anderson and Pichert (1978).

> Two boys play hooky from school. They go to the home of one of the boys because his mother is never there on a Thursday. The family is well off. They have a fine old home which is set back from the road and which has attractive grounds. But since it is an old house it has some defects: for example, it has a leaky roof, and a damp and musty cellar. Because the family is wealthy, they have a lot of valuable possessions – such as ten-speed bike, a colour television, and a rare coin collection.

Participants were told in advance that the story was about a house to be considered either from the perspective of a burglar, or from that of a potential house buyer. The perspective supplied influenced what people remembered of the story; so, for example, those reading it from the estate agent perspective would be more likely to recall the leaking roof, and those from the burglar perspective the list of valuable possessions. However, the participants were then given the other perspective – so that if they'd previously been given the burglar perspective they would now be given the estate agent perspective. This shift in perspective aided recall, so that people recalled ideas from the story that they could not previously. This positive effect of shifting perspective might seem to contradict the findings above that you need to know the context before hearing the story, but this difference can be explained in terms of the difficulty and bizarreness of the stories: these very odd stories are too difficult to be rescued by context afterwards. But most of the time, context before and after is a very good thing, and changing your perspective will help you remember more.

How do we go beyond the words?

I have a friend who is a master of not saying what he means, so that you can work out what he really means with quite a bit of knowledge and effort. He is the master of obliqueness: if he means "no", he will say "yes", but in a very roundabout way such that if you know him you can eventually work out that he really means "no". But it takes a lot of work. His words differ from his intentions.

We go beyond the literal meaning of what we read or hear in many ways: we make *inferences* that sometimes go far beyond the meaning of the sentences we

come across. Sometimes these are warranted, sometimes not. Sometimes the inferences are made so easily they appear to happen automatically; sometimes we have to really struggle to work out what was intended.

Context can be a curse as well as a blessing, as shown dramatically by an experiment by Sulin and Dooling (1974), who presented this story to their participants:

> Gerald Martin strove to undermine the existing government to satisfy his political ambitions. Many of the people of his country supported his efforts. Current political problems made it relatively easy for Martin to take over. Certain groups remained loyal to the old government and caused Martin trouble. He confronted these groups directly and so silenced them. He became a ruthless, uncontrollable dictator. The ultimate effect of his rule was the downfall of his country.

Half the readers read the story as above, but the other half had "Adolf Hitler" substituted for "Gerald Martin". A little later they were given some sentences and asked if they had read them in the story; some of them really were in the story, but others weren't. Those who had been given the name "Adolf Hitler" were far more likely to think erroneously that they'd actually read "He hated the Jews particularly and so persecuted them" than those given the name "Gerald Martin". So context isn't always a good thing; here (and once again, remember the unreliability of eyewitness testimony, and how we can distort memory with leading questions) context can cause us to remember things we never heard. Our knowledge of the world can provoke errors.

There are three types of inference: logical, bridging, and elaborative. *Logical* inferences are the least interesting: if I tell you "Boris is a bachelor", you can easily infer that Boris doesn't have a wife. We make *bridging* inferences to keep our understanding of the text coherent, to ensure that everything links to everything else. We work, as comprehenders, on the basis that everything makes sense. So if I say,

> Boris had a haircut yesterday. He was happy about it,

who does "he" refer to? Boris, of course. You've made a bridging inference to relate new information to old. I'll deal with how we keep track of pronouns in the next section.

We make *elaborative inferences* when we go beyond the text and use our knowledge of the world to deduce something that isn't in the text. The Gerald Martin example shows how elaborative inferences can sometimes lead us astray. We make inferences to construct a more detailed model depicting what we hear; and given that our memory for what we actually read or hear is quite poor, it should

come as no surprise to hear that we are bad at distinguishing the results of elaborative inferences we make from what was actually in the text. This was famously shown in an experiment by Bransford et al. in 1972. They gave people a sentence such as:

> Three turtles rested on a floating log and a fish swam beneath them.

After a short delay people were given the following sentence:

> Three turtles rested on a floating log and a fish swam beneath it.

They were just as likely to agree that they'd heard the new sentence as the original because if the turtles are on a log then anything that swims beneath the turtles must also swim beneath the log. It's the model of what we hear that we remember, complete with all the inferences we make to construct the model, not the words we hear. If we change just two words in the above sentence, though:

> Three turtles were beside a floating log and a fish swam beneath them.

People no longer confuse this sentence with the "beneath it" one because the inference is no longer true.

Obviously the number of potential elaborative inferences that could be made is extremely large. The experimenters could have slipped any plausible information about Hitler into that version of the Gerald Martin story and still confused the participants. There's a considerable amount of evidence that we draw the bridging inferences we need to keep the text making sense automatically, but we only automatically draw elaborative inferences as and when we need to. According to the minimalist hypothesis, we keep the number of elaborative inferences to a minimum, and make them as simple as possible (McKoon & Ratcliff, 1992). The studies we've discussed so far that show that people make inferences have all been rather indirect, looking at people's memory for text, often in the light of confusing distractor items or misleading questions. The longer the delay between presentation and testing, the more errors people make. Now consider these two sentences:

> The housewife was learning to be a seamstress and needed practice, so she got out the skirt she was making and threaded the needle.

> The director and cameraman were ready to shoot close-ups when suddenly the actress fell from the fourteenth floor.

Participants are given a lexical decision task concurrently with these stories. In this task, if you remember, you have to press one button if you see a word, and another if you see a non-word, and we measure the reaction time to pressing the key. The

key target words for these stories are "sew" for the first and "dead" for the second. The word "sew" is strongly semantically associated with the words "seamstress", "threaded", and "needle" in the stories, and consequently its recognition is duly facilitated by the story. What about "dead"? It isn't strongly associated with any of the words in the story, and although it's a very reasonable, indeed likely, elaborative inference, it isn't necessary (and it might not even be true; she might survive, or have her fall broken by something in the way that happens so often in Hollywood). We don't find any facilitation of words like "dead" in these kinds of contexts. Further evidence comes from a study by Singer (1994), who presented participants with sentences like the following:

> The dentist pulled the tooth painlessly. The patient liked the method.
> The tooth was pulled painlessly. The dentist used a new method.
> The tooth was pulled painlessly. The patient liked the new method.

The participants were given a probe sentence to verify and the experimenter measured how long it took the participant to decide if the probe was true or not. The probe was "A dentist pulled a tooth". The first sentence more or less contains the probe, so people are fast to respond YES. In the second sentence people must make the bridging inference that the dentist pulled the tooth to make sense of the material and to maintain a coherent representation of the material. The bridging inference is that the dentist pulled the tooth, and we find that people are just as fast to respond "yes" to the probe with the second sentence as with the first. This result suggests that people make this sort of inference quickly and automatically. However, the third sentence requires an elaborative inference; the dentist isn't mentioned explicitly, so we have to put a bit of work into constructing a model that ties up the tooth, dentist, and patient. So bridging inferences are made automatically when we read text to maintain coherence, and elaborative inferences are made later when necessary.

What can we do with language?

Although I've noted that language serves many functions, from communicating to assisting thought, from play to maintaining social contact, often we speak because we want to have some effect on our listeners (or readers). Speakers have goals, and listeners try to work out what those goals are. Every utterance is a type of *speech act*, with some goal in mind, however trivial (Austin, 1976; Searle, 1969). Searle argued that speech acts fall into five broad categories.

1 *Representatives:* The speaker is asserting what they consider to be a fact (e.g. "Felix is a naughty dog").

2 *Directives:* The speaker is trying to get the listener to do something (e.g. if I ask you "Is Felix a good dog?", I'm trying to get you to give me some information).
3 *Expressives:* The speaker is revealing something about their psychological state (e.g. "I'm very disappointed in Felix").
4 *Declaratives:* The speaker brings about a new state of affairs (e.g. "You're fired!").
5 *Commissives:* The speaker commits themselves to some future action (e.g. "I promise I'll buy Felix a bone tomorrow").

I don't think we should see these as hard and fast categories, as some utterances might straddle two categories ("I'm very disappointed in Felix" conveys something about my psychological state and conveys a belief), but they provide a very useful framework for thinking about the sorts of things language can do. But often there's a mismatch between the literal meaning of what we say and the effects the utterance has, and the philosopher of language J.L. Austin (the initials standing for "John" and the splendid "Langshaw") recognised that each speech act can have three effects, which he called *forces*. If I make an apparently simple request such as:

Can you get me rat poison on the way home from work tonight?

the most obvious effect is that I interpret this utterance as a request that I should purchase some rat poison on my way home from work. Austin called this the *illocutionary force* – what the speaker is trying to get the listener to do. But notice that literally it's not what the utterance says at all; the literal meaning is a question about my ability to get rat poison on my way home from work. Austin called this literal meaning the *locutionary force*. It is possible to imagine scenarios in which the literal meaning of this sort of utterance is the intended one – that is, where the locutionary and illocutionary force match. For example, I might have just broken my leg, having previously offered to get some rat poison on the way home from work. Finally, our utterances can have all sorts of effects: I might annoy you because this is yet another unreasonable demand on your time I've made, or you might think I'm mean and heartless killing all those nice rats, or you might believe I'm going to poison you, or you might just go ahead and get the rat poison. All these effects, some intended, others not, are called the *perlocutionary force* of the utterance.

Utterances like this one, where there's a mismatch between the literal meaning and the intended meaning of the words, are very common. The mismatch, on reflection, is most apparent in this sort of *indirect request* where I'm trying to get you to do something. You might not have noticed it before, but "Can you pass the wine?" is an indirect request – my words don't strictly request you to pass the wine, but instead literally ask if you have the ability to do so. It's a good schoolboy jape to

reply "yes" to such requests, and leave it at that. Indirect requests are linked to politeness; the more polite we want to be, the more indirect we become.

Pass the wine!
Can you pass the wine?
Could you please reach over and hand me the wine?
Could you please think about passing the wine?
My glass is only half full.
The wine's lovely.
Look at the pattern the moonlight creates shining through my empty glass.

Some indirect requests are so common as to have become idioms – frozen sayings that have a well-known meaning of their own. "Can you –" requests are of this type, to the extent that it would be most unusual to have to interpret "Can you pass the wine?" literally as a request about your ability to pass the wine. There comes a point on this list, though, where indirectness is no longer idiomatic, and the listener has to do some real work to draw an elaborative inference about what the speaker's intention is.

We call this sort of conversational inference, where listeners have to compute the intended meaning from the literal meaning, a *conversational implicature*. The way in which we detect a mismatch, and the way in which we seek to resolve the indirectness, was suggested by the linguistic philosopher H.P. Grice (1975). Grice proposed that speakers in a conversation collaborate: adult conversation should be meaningful and purposeful. Only up to a point, surely, you might object, but even just discussing the weather has some conversational goal, and such conversations will still follow the rules. But what are the rules? Grice argued that we follow a *co-operative principle* when speaking, making our contributions such as is required when they are required. To do this, speakers follow four conversational maxims:

1 *Maxim of relevance*. Make your contribution relevant to the aims of the conversation.
2 *Maxim of quantity*. Make your contribution as informative as necessary, but no more so.
3 *Maxim of quality*. Make your contribution true – do not say anything you know to be false.
4 *Maxim of manner*. Be clear; avoid obscurity, ambiguity, and disorder in your speech.

Of these, relevance is probably the most important, and some have argued that the other three maxims are all implied by relevance alone (Sperber & Wilson, 1986, 1987). These maxims are most useful not when the speaker follows them, but when

they appear to have violated them. Given the importance of relevance, the following conversation seems very odd:

Bill: What do you think of my new hat?
Ben: What a lovely day it is!

Ben's utterance doesn't seem to follow from what Bill said at all. So odd does this seem that we strive to find some purpose in Ben's utterance – we try to make it relevant. How can we do this? We could make the inference that Ben really doesn't like Bill's new hat, and is trying to avoid the topic. Listeners assume that although on the face of things speakers might appear to be violating one or more of the maxims, deeper down they are not. We reconcile this discrepancy by making an inference – the *conversational implicature*. If you eavesdrop on a few conversations, and are looking for them, conversational implicatures are very common. We have to make one whenever there's a discrepancy between what someone says and the most straightforward reply the other speaker could give.

I don't mean to imply that we spend a great deal of conscious effort in conversation trying to work out what the other person meant, or intended. Sometimes we do; sometimes I've had the experience of realising a couple of hours later, when it's far too late to do anything about it, that the other person was intending something other than they'd said. But on many occasions we draw the inferences necessary to help us make sense of the conversation without even noticing that we're doing so.

How do we link new information with old?

Relevance means that what we say or hear is in some way linked to what has come before. Language wouldn't be of much use if every sentence was spoken in isolation, without any connection to the past. There are two different tasks for speakers and listeners. The speaker has to relate the new material that they wish to convey to the old so as to ease the work of the listener, and the listener has to integrate the new information with the old.

Here's a little story.

> Felix chased a cat. The cat found a small hole and he ran into it. The dog had to give up the chase. He sat outside the hole for a while looking disappointed. After five minutes he went off to chase some rabbits. It was sad to watch.

Not a terribly exciting story, perhaps, but an interesting one from a psycholinguistic point of view. Notice how with multi-sentence stories we get a picture of

events unfolding in time. Think about that first "he"; what does it refer to? I think most people won't hesitate to say "the cat". But now look at the second "he", and say what that refers to; this time it's Felix, the dog. In fact it's interesting that we know that Felix is a dog, because it isn't explicitly stated anywhere. Working out what refers to what in a story entails problems of establishing the *reference*. What we seem to be doing when we read a story such as this is that we construct some sort of model, and then we create entities in that model to represent the actors and objects in our story, and then we try to keep track of who's what. We call the thing first mentioned the *antecedent* (Felix) and subsequent different expressions referring to the antecedent (he, the dog) *anaphors*.

One way in which we keep track of reference is that we try to keep the number of entities in our mental model of the story to a minimum. Once we've introduced dear old Felix, we don't then postulate that "the dog" refers to something new. The word "the" is a cue; we wouldn't normally use "the" here to introduce a new dog; whereas "a dog" would imply something new in the story, "the dog" implies something has already been introduced.

Most troublesome are all those pronouns, "he" and "it". The first "he" refers to the cat, but the second "he", soon after, to Felix the dog. How do we decide what pronouns refer to? It turns out that we use a number of strategies based on cues from the sentence.

Sometimes it's very straightforward; there is only the referent, as below.

Felix was very happy; he caught the pesky rabbit.

We prefer to match the anaphors to antecedents in the same relative position, a strategy called *parallel function* (Sheldon, 1974).

Bill sold Ben his car because he no longer needed it.
Bill sold Ben his car because he needed it.

The first sentence is easy to understand because "he", the subject of the second clause, refers to Bill, the subject of the first clause. People find the second more difficult because the subject of the second clause does not refer to the subject of the first. And when we have a sentence such as:

Bill hated Ben so he kicked him.

The meaning and relative position of the antecedents and pronouns conspire to make reference assignment straightforward. *Gender* is another straightforward cue. Given:

Alice told Bill to get lost because he had annoyed her

it's trivial to work out to whom "he" and "her" refer. We access information about gender very quickly: eye-movement studies show that if people look at cartoons with male and female characters, they can use the gender of the pronoun to look at the correct picture within 200 milliseconds; if gender isn't a cue (as is the case if all the characters in the picture are male or female), people take much longer to work out to whom the pronoun is referring (Arnold et al., 2000).

The meaning of the sentence is another cue. In the following two examples you are likely to assign different antecedents to the pronouns because the meanings of the verbs imply things: it's the person who hates who is most likely to kick, and the person who is offended who is most likely to react.

Bill hated Ben, so he kicked him.
Bill offended Ben, so he sent him to Coventry.

Pronouns are processed more quickly the more recently the antecedent has been explicitly mentioned. Psycholinguists talk about items being in focus; we can think of these referents as being the most active in our representation of the text because of their recency and importance. We can only really use pronouns when an item is in focus. If we have the sentence:

Bill was driving to Birmingham.

it's perfectly acceptable to follow it with "He became tired", because he refers to Bill, who is in explicit focus; but to follow it with "It broke down" would sound distinctly odd, because the antecedent of "it" is presumably Bill's car, which isn't in explicit focus. The less in focus an antecedent is, the more difficult it is to retrieve it (Sanford & Garrod, 1981). If I suddenly spring on you:

He ran back to his kennel and drank some water

it's going to take you some time to work out that we're back to talking about dear old Felix again.

We clearly have several strategies for computing the antecedents of anaphors. How do we choose the best one? We seem to use them in parallel. Badecker and Straub (2002) discuss a parallel constraint model, similar to the interactive activation models of word recognition and the constraint-satisfaction models of parsing, where all possible cues contribute in parallel to the activation of possible antecedents in the mental model of the discourse. If all the cues converge, anaphoric resolution is fast and straightforward; if they conflict, resolution is slower, and might even come to need conscious, attentional processing.

The second, related way in which we have to mingle old and new information is based on the idea of focus. We can think of the focus of the text or discourse as

moving along as we come to new material and events happen. Here is my entry for the next Booker Prize:

> Felix slept until late most mornings. He'd get up, chase a few chipmunks, and drink some water. Then he'd wander around the cabbage patch and drink some more water. One day a cat came into the garden. Felix went wild. He chased the cat round and round until it went into a hole. He sat patiently outside. Eventually he worked out it was too small for him and then he gave up. He had some more water from his bucket and went back to sleep. When we got home the cabbage patch was ruined. The bucket was empty and the cat was still down the hole. It took some time before it ventured out.

Notice how the focus of the story moves along, and how effortlessly we assign referents to pronouns. If we jumble the sentences up, the overall meaning of the story is preserved, but the flow of the focus is disrupted, and assigning antecedents to anaphors is now very difficult.

> He had some more water from his bucket and went back to sleep. It took some time before it ventured out. Eventually he worked out that it was too small for him and then he gave up. Felix went wild. He sat patiently outside. Felix slept until late most mornings. When we got home the cabbage patch was ruined. He'd get up, chase a few chipmunks, and drink some water. The bucket was empty and the cat was still down the hole. Then he'd wander around the cabbage patch and drink some more water. One day a cat came into the garden. He chased the cat round and round until it went into a hole.

Speakers and writers don't speak and write like this. Although it might seem obvious that we are most likely to present events in the order in which they happen, speakers go further than that: they try to make the listener's job as straightforward as possible. There's a contract between speaker and listener to present new information so that it can be readily assimilated into what is already known, a contract that's been called the *given–new contract* (Haviland & Clark, 1974). We find it harder to understand new material that violates the given–new contract, and find it easier to understand a new sentence where the link between the new material and the old is explicit rather than when it has to be inferred.

How do we construct a model of what we hear?

Here's a simple little story. Once again, I mean it really is simple, so don't get too excited.

> The lawn runs up to the flower bed. The rose bush is in front of the dahlias, with the fence behind. On the right of the rose bush, as you look towards the fence, are some violets. On the left of the rose bush are some daisies. Behind the violets is a big sunflower. Bill comes along and waters the sunflower. He accidentally steps back and treads on . . .

I did tell you it wasn't terribly exciting! But now ask yourself, what does Bill trample to death? The violets of course. How do you know?

Reflect on this for a moment. I formed some kind of picture, an image of the story. You might not have done exactly the same, but you probably constructed a model of some sort to represent what was depicted in the story. This sort of model goes by several different names: a *situational model*, a *mental model*, sometimes just a model. Let's go for brevity and stick with what I've been calling it so far, the mental model (e.g. Johnson-Laird, 1983).

The mental model, then, is our representation of what we're reading, or what we're talking about. It consists of all the activated word meanings involved tied together in some way to show the relation between them. The most active meanings will be present in our limited short-term memory. Exactly how the model is constructed, and how the meanings are tied together, is shown by Walter Kintsch's *construction–integration model* (Kintsch, 1988). The most important part of the model is a propositional network that ties together all the elements of the text. A *proposition* is the smallest unit of meaning that can be put into a propositional form – a verb operating on a noun. Propositions would be "Felix sleeps", "cat runs" "is in hole", "Felix chases", and so on. All these simple propositions can be connected together into a network that represents the complete meaning of the text. When you've read and understood material, all you're left with is a propositional network; most of the surface details have been dispensed with.

We construct the propositionally network incrementally. As new material comes in, we integrate it with the propositional network. We keep some propositions active in our working memory; these are the most recent, and what we consider to be the most important. Given its limited capacity, we can only keep a few propositions active in working memory at any time; it's these that we find easier to find the antecedents for when we come across an anaphor. As we construct the propositional network, we might come across some contradictions, but these are resolved by a process of spreading activation and competition as I've discussed before. New portions of the network are continually being integrated with the existing structure to expand the size of the propositional network. As it grows, we can search the network, and use it to deduce answers to questions such as "What did Bill trample on?"

The model can account for several key findings in the comprehension literature. The more complex the material, in terms of the number of propositions, the longer it takes to read, because the longer the model takes to construct. We

remember the most salient propositions better because they tend to be held in working memory for longer because they're the most useful propositions in constructing the network. We confuse inferences with the original material because we dump the source of the information as soon as we've constructed a stable network; all that matters is how propositions are connected, not how they became connected. The construction–integration model also predicts the ease with which we can read different sorts of material: text that makes it easy to construct a network, and that is constructed so that key propositions are likely to remain active in focus in working memory, should be the easiest to read. Material that keeps on bringing up different material that isn't in working memory, but that instead has to be inferred or brought from the network into working memory (by a process called a *reinstatement search*), is more difficult (Kintsch & Vipond, 1979). Individual differences in working memory span affect reading skill; clearly, the larger the span, the easier the person is going to find reading to be (Daneman & Carpenter, 1980). One lesson for writers here is that you can make your material easy to read by trying to minimise the number of times the reader has to dip into their propositional network by keeping important material in focus, by making referents as obvious as possible, and by constructing the flow of the text so that the focus assists the reader by keeping the most important propositions active.

Where does humour in language come from?

Brain damage can affect our ability to understand language in many different ways. I'm going to defer discussion of how it affects our ability to parse sentences until the next chapter. Brain damage can affect comprehension in a number of ways. I've already shown how understanding print can be disrupted by developmental and acquired dyslexia, and unsurprisingly there are types of brain damage that lead to difficulty in understanding spoken words. One of the most striking deficits in understanding language is known as *pure word deafness*. Patients with pure word deafness can read, write, and speak quite normally, but have great difficulty in understanding speech. They have extremely poor auditory comprehension and cannot repeat words back. On the other hand their hearing is normal, and they can identify musical instruments and other non-speech sounds (Saffran et al., 1976). The problem with pure word deafness patients must lie in constructing a pre-lexical code for speech.

A very rare variant is called *word meaning deafness*, in which the symptoms are similar to pure word deafness except the patient can also repeat words. The first case study was of a patient living in Edinburgh in the 1890s (Bramwell, 1897/1984); a more recent case was reported by Kohn and Friedman in 1986. Word meaning deafness shows that there must be a route that enables us to gain access to the sounds of words, and be able to repeat them back, but that bypasses meaning.

In the next chapter I'll talk about the consequences of damage to Wernicke's area of the brain, but patients with this sort of damage show difficulty in understanding speech and following conversations as well as pronounced difficulties in production. They also have difficulty in maintaining the coherence of discourse (Christiansen, 1995). And damage to the frontal lobes of the brain will lead to difficulty in controlling language, running conversations, and inhibiting appropriate material.

In this section though, I want to focus on the consequences of damage to the right hemisphere of the brain, which leads to an impairment to the ability to follow connected discourse without an impairment to recognising words or parsing sentences (Caplan, 1992). In particular, this sort of damage leads to a difficulty in understanding humour. Much as I wish I could write one, this section isn't an instruction manual on how to be funny. There are many different types and sources of humour: slapstick, puns, surreal, intellectual, incongruous, and the coarse and vulgar. It's unlikely that a single mechanism underlies all of these. But let's tell a joke.

> The quack was selling a potion which he claimed would make men live to a great age. He claimed he himself was hale and hearty and over 300 years old. "Is he really as old as that?" asked a listener of the youthful assistant. "I can't say", said the assistant, –

Now which of the following punchlines would be most likely to make them roll around the aisles?

1 "I've only worked with him a hundred years."
2 "I don't know how old he is."
3 "There are over three hundred days in a year."

The first, of course; the second is a coherent but non-humorous continuation, and the third just incoherent. Patients with right-hemisphere damage aren't very good at picking the funny continuation (Brownell et al., 1983); indeed, they often choose the incoherent ending. People with right-hemisphere damage find it particularly difficult to see implied meaning (something that is of course essential for understanding humour), make decisions about appropriateness, and integrate information (Myers & Mackisack, 1990). None of this is to say that patients with left-hemisphere damage might not have some difficulty in appreciating humour; after all, if you can't understand what's being said, you're unlikely to find it very funny, although you might be able to have a good laugh at the person saying it.

The right hemisphere isn't just important for understanding humour in language. It seems to play a more general role in helping us with the pragmatics of language – helping us understand how language is used and what we do with language. Damage to the right hemisphere interferes with our ability to use

non-verbal cues, to follow the rules of conversation, and to go beyond the words (see Kolb & Whishaw, 2003, for a review). People with right-hemisphere damage have difficulty in understanding metaphor and figurative language (time is a river, the raindrops exploded on the window) – I think the relation with humour is obvious.