Language Processing and the Mental Representation of Syntactic Structure

Holly Parima Branigan

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Declaration

I declare that this thesis has been composed by myself and that the research reported here has been conducted by myself unless otherwise indicated.

Holly Branigan
Edinburgh, February 12, 1996

Abstract

This thesis investigates the mental representation of syntactic structure. It takes an interdisciplinary approach which exploits methods and insights from both experimental psychology and theoretical linguistics to explore the claim that syntactic representation can be the subject of empirical psychological study. The thesis makes use of corpus analysis and two experimental methods, agreement error elicitation and syntactic priming, to examine syntactic structure in both language production and language comprehension.

I argue that assumptions about syntactic representation are fundamental to all models of language processing. However, processing models have largely assumed the representations proposed by theoretical linguists, in the belief that syntactic representation is the province of theoretical linguistics. I propose that the mental representation of syntactic structure is a legitimate area of study for psycholinguists and that it can be investigated using experimental methods. The remainder of the thesis presents empirical evidence to support this claim.

I begin by discussing the use of corpora, arguing that spoken language corpora can provide evidence about language production. I present a corpus analysis of one particular structure – finite relative clauses – as a case study which highlights how such corpora can be used to generate and test hypotheses about syntactic structure in production.

I then examine two experimental methods, beginning with agreement error elicitation. I argue that agreement errors can be informative not only about processing but also about representation, and present the results of two written sentence-completion experiments. These demonstrate that predicate+argument units display a common pattern of behaviour which contrasts with that displayed by PPs and which suggests that predicate+argument units form a syntactic class in processing.

Next I consider syntactic priming effects, where processing a sentence with a particular syntactic structure affects processing of a subsequent sentence with the same or a related structure, because of that structure. I begin by considering priming effects in written language production. Using a sentence-completion task, I show that people tend to produce the same syntactic structure for consecutive sentences. This structure seems to be represented in terms of hierarchical relationships between abstract categories. I then present the results of a series of self-paced reading experiments which show that syntactic priming effects can also be found in comprehension: comprehension of a sentence with a local ambiguity can facilitate comprehension of a subsequent sentence involving the same ambiguity, where one possible resolution of the ambiguity causes considerable processing difficulty. The results suggest that priming is largely a competitive effect. Further evidence suggests that priming can occur between two sentences with the same constituent structure but different thematic structures, implying that the relevant representations specify constituent structure information but not thematic information.

Finally, I present the results of a bidirectional priming experiment which shows that comprehension of a particular structure can increase the likelihood of producing that structure. This implies that priming taps into something which is common to both production and comprehension. I suggest that the most plausible candidate for this is the knowledge of language which underlies all use of language.

The main conclusion of this thesis is that syntactic representation is amenable to psychological study. The evidence which is gathered in this way is in principle relevant not only to theories of language processing but also to any linguistic theory which claims to characterise knowledge of language.

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Contents

Chapter 1

Introduction

1.1 Introduction

Human beings have the ability to produce and comprehend an infinite number of novel sentences. To do this, it is not enough to be able to produce or understand individual words; people must also be able to combine these words into well-formed strings or sentences. For example, in order to produce a sentence which expresses the proposition SNEEZE (JOHN), the speaker needs to know that (1.1a), but not (1.1b), is a well-formed sentence in English.

(1.1) a. John sneezed.

b. *sneezed John.

Hence the ability to produce and comprehend a language requires knowledge of the well-formed structures of that language, in other words its syntactic structure. The existence of a common knowledge base which specifies syntactic structure and which underlies both production and comprehension is not controversial. It forms the object of study for some theoretical linguists and it forms an important part of any theory of language processing. How are the statements which encode syntactic structure and so constitute this knowledge mentally represented?

In principle, there are infinitely many possibilities. Let us consider just two possibilities for how the knowledge that *John sneezed* is a well-formed sentence is represented. Our knowledge of language might be specified in terms of the combinatorial possibilities of individual words or strings. For example, it might specify that the word *John* can appear preceding the word *sneezed*. Alternatively, it might recognise categories of linguistic entities which have related characteristics, for example a category of words which behave like *sneezed* or a category of words like *John*. In that case, the same part of the knowledge base which stated that (1.1) is a permissible combination in English would also be responsible for admitting (1.2):

(1.2) The boy yawned.

These two possibilities give us completely different pictures of syntactic representation: in one case, syntactic knowledge is tied to specific lexical items or specific strings; in the other, syntactic structure is represented in terms of categories which subsume individual words or strings, and a single statement in the knowledge base can account for a large number of lexically distinct sentences. They also have different implications for processing theories. For example, since the first possibility does not recognise categories, it would be difficult to reconcile it with a model of sentence comprehension where parsing decisions are based on syntactic category information.

Given infinitely many possibilities, how can we choose between them? That is, how is syntactic structure mentally represented and which methods could we use to investigate this? These are the issues with which this thesis is concerned. It rejects the suggestion that syntactic representation is the province of theoretical linguistics alone and that it can only be studied using the methods of theoretical linguistics. Instead, it contends that the mental representation of syntactic structure is an empirical issue which is best investigated from an interdisciplinary perspective. In particular, it proposes that the methods of experimental psychology can be brought to bear on representational issues.

The goals of this thesis are two-fold. On the one hand, it aims to validate the proposal that experimental psychological methods can in principle be used to investigate syntactic representation, by identifying some of the methods which can be put to use in this way. On the other, it aims to gain a better understanding of how syntactic structure is represented by examining the evidence which these methods provide. In what follows, then, I will be concerned with exploring both methodological issues and empirical evidence.

1.2 Organisation of the thesis

Chapters 2 and 3 present the background to this research. In Chapter 2, I begin by showing that the mental representation of syntactic structure is an important research issue for theories of language processing and at least some linguistic theories. I then suggest that most work in psycholinguistics has neglected representational issues in favour of an emphasis upon processing, under the assumption that linguistic theories provide the appropriate representational basis for theories of processing. However, linguistic theories are usually based on a single type of data – grammaticality judgements – which may not provide reliable data about syntactic representation. I argue that grammaticality judgements have no privileged status and that other sources of evidence can in principle be brought to bear upon the investigation of syntactic representation. The following chapter is concerned with theories of sentence processing. It discusses some of the theories of sentence production and comprehension which have been proposed, and the assumptions about syntactic representation which these theories make.

Having established the theoretical background to the research, the remainder of the thesis is concerned with empirical investigation of the issues. Chapter 4 considers one potential source of evidence about syntactic structure: corpora of spoken and written language. I survey some of the ways in which corpora are currently studied, and suggest that they potentially provide a rich source of evidence about language production which has yet to be fully exploited. To explore this possibility, I present the results of an analysis of one particular structure – finite relative clauses – in a corpus of spoken English. This case study shows how corpora can be used to test and to generate hypotheses about syntactic structure. It demonstrates that there is a convergence between the distribution of relative clauses which some theories of language production would predict and the distribution of relative clauses which is actually found in

the corpus. It also uncovers an unexpected pattern of data which raises possibilities for future research.

The following chapters explore two experimental methods and how they might be put to use in studying representation. Chapter 5 examines subject–verb agreement error elicitation. Most recent work using this method has concentrated upon its implications for processing issues; I argue that agreement errors are also informative about representation, because the incidence of errors seems to be influenced by the syntactic structure of the subject NP. The results of two written sentence-completion experiments are then presented. These suggest that predicate+argument units (corresponding to the linguistic notion of the clause) display a common pattern of behaviour which contrasts with the pattern induced by PPs. This suggests that in processing, predicate+argument units form a syntactic class.

Chapters 6, 7 and 8 are concerned with syntactic priming effects. Syntactic priming is the phenomenon whereby processing a particular syntactic structure affects subsequent processing of the same (or possibly a related) syntactic structure. It can occur between two sentences which have the same syntactic structure but otherwise have nothing in common (for example, lexical items or semantic content). I argue that these effects are informative about syntactic representation because they depend upon the processor recognising that two sentences are related at the level of syntactic structure, in other words assigning them related syntactic representations. In Chapter 6, I begin by showing that syntactic priming effects occur in written language production: in a written sentence-completion task, people are more likely to complete consecutive sentences with the same syntactic structure than with different structures, even when the sentences have no common lexical or semantic content. The results suggest that syntactic structure is represented in terms of local relationships between abstract categories. The prime and target do not have to have globally identical structures for priming to occur, but priming effects may not be found when the two sentences differ substantially in overall structure.

In Chapter 7, I then discuss how syntactic priming effects in comprehension could be informative about some issues on which the production priming results are silent. I present a series of self-paced reading experiments which show that comprehension of a locally ambiguous sentence can facilitate comprehension of a subsequent sentence with the same local ambiguity. The priming effects are only found with 'strong garden path' sentences, where one resolution of the ambiguity causes considerable processing difficulty. This suggests that priming is largely competitive: it affects the way in which the processor chooses which syntactic analysis to follow. The final self-paced reading experiment suggests that priming occurs between sentences which have the same constituent structure even if they have different thematic structures. These results suggest that thematic structure and constituent structure are represented separately: at the level which priming taps into, the processor is sensitive to one aspect of structure but not the other.

In Chapter 8, I consider the question of whether priming taps into processes which are specific to production or to comprehension, or whether it taps into something which is common to both. If the former possibility is correct, then it should not be possible to find bidirectional priming effects, where production of one structure facilitates comprehension of that structure, or comprehension of a structure predisposes its production. I present the results of an experiment which shows that it is possible to induce bidirectional priming effects from comprehension to production. From this I argue that priming must be tapping into something which is common to production and comprehension. I suggest that the most likely possibility is that priming taps into the knowledge base which underlies language use, and that priming occurs when a particular statement which specifies possible relationships between abstract categories is repeatedly accessed.

The final chapter draws the preceding chapters together, discusses the implications of this research for theories of language processing and for linguistic theories, and highlights some possibilities for future research. I conclude that the mental representation of syntactic structure is amenable to experimental study and that an interdisciplinary approach which exploits insights and methods from both experimental psychology and theoretical linguistics may prove fruitful for future research in this area.

Chapter 2

Syntactic structure in theoretical linguistics and psycholinguistics

2.1 Introduction

In the introduction, I outlined the area of study with which this thesis is concerned: how is syntactic structure mentally represented, and how can it be investigated? This chapter aims to site these questions in their wider context and discuss why they are important research issues, by showing that the nature of the mental representation of syntactic structure is directly relevant to at least some linguistic theories and to theories of language processing, but that the current methods used to investigate it are limited and may not provide reliable evidence. The first section discusses different approaches to theoretical linguistics and the ontological status of the entities which are identified in linguistic theories. I will argue that in at least some linguistic theories, these entities are intended to correspond to mental representations which encode knowledge of language. In the second section, I will turn to the field of psycholinguistics. I will suggest that syntactic representation has implications for processing theories in two ways: directly, because any complete model of language processing must specify the nature of the knowledge base which is drawn upon; but also indirectly, because the way in which syntactic structure is represented constrains the range of possible processing algorithms. In the third section, I will review current approaches to syntactic representation, arguing that the exclusive reliance upon grammaticality judgements is unwise and unnecessary, and that there is no principled reason why the methods of experimental psychology cannot be used to investigate the issue. Finally, I explore the implications for linguistic theories and theories of language processing of any evidence which is found using these methods.

2.2 Theoretical linguistics and syntactic representation

In recent years, syntactic structure has been probably the most dominant area of research effort in theoretical linguistics. Since the seminal work of Chomsky (1957), there has been considerable interest in the syntax of natural languages and how it can be characterised generatively. Theoretical linguists have attempted to define grammars for natural languages, i.e. precise descriptions of the relationships which may hold between linguistic entities. These grammars might contain statements like (2.1) below.

(2.1) NP $\rightarrow$ Det N

This statement, or phrase structure rule, can be expressed in English as 'a noun phrase can comprise a determiner followed by a noun.' Elsewhere in the grammar, a (possibly extensional) definition will be given for the notions determiner and noun. By definition, every grammar contains comparable statements of possible relationships holding between different linguistic entities, although these statements might not look like the phrase structure rule in (2.1) (for example, in Head-driven Phrase Structure Grammar (HPSG) (Pollard & Sag 1987; Pollard & Sag 1994), the same sort of information as the phrase structure rule in (2.1) is captured in terms of partially specified theoretical constructs called 'signs'). But what exactly is the ontological status of these linguistic entities, these rules and these grammars? More specifically, are they theories about mental representations? In the following sections, I will discuss two alternative approaches in theoretical linguistics which make very different assumptions in this respect.

2.2.1 Formalist approaches to linguistics

The first approach views language as something external to the minds of its speakers. This position, which I will term the formalist position, is based on an extensional concept of language as a set of sentences paired with meanings (see for example Lewis (1975)). In Chomsky's (1986b) terminology, formalist linguists are concerned with E-language (=externalised language). According to this concept of language, linguistics is a branch of the mathematical sciences. Some formalists (Katz 1981; Katz & Postal 1991) believe that the relationship between humans and natural languages is analogous to the relationship between humans and mathematical systems. That is, languages are platonic objects: they have an independent existence and are *discovered* by humans. In Katz's terms, a natural language is '...an abstract object, something not located in space–time or dependent for its existence on minds that know it,' (Katz 1981, p.22). On this view, it is possible for speakers to have an imperfect knowledge of their language. Other formalists (Soames 1984; George 1989) take a slightly different line. On their view, natural languages are defined with reference to human knowledge. A natural language consists of all the sentences which humans recognise as being part of that language. In that case, speakers cannot have imperfect knowledge of their language, because the language is defined as the object of their knowledge. Despite their differences concerning the status of a language, both groups make the fundamental assumption that linguistics is not concerned with the study of mental objects. Note that formalist linguists do not deny that humans mentally represent syntactic structure in some way; they simply believe that this is not part of their field of study.

Under these assumptions, the goal of linguistics is to provide systematic generalisations about the structural properties of sets of sentence–meaning pairs, with the ultimate aim of discovering what constitutes a possible natural language. Formalist linguists believe that such characterisations can be made purely on the basis of an extensional definition of language. For example, Gazdar, Klein, Pullum and Sag's (1985) work was based on the hypothesis – since shown to be false (see for example Shieber (1985)) – that all natural languages could be generated by a context-free phrase structure grammar. A grammar in a formalist approach is simply a characterisation of the possible sentences of a language. Formally, it is a function which enumerates the elements of the language. The rules of the grammar are analogous to, and have the same ontological status as, the axioms of a mathematical system. Membership of the language is an empirical question, but the characterisation of the language (i.e. the grammar) is not. Hence in a formalist approach to language, it makes no sense to talk of 'truth' or 'falsity' with respect to a grammar, except insofar as it correctly generates the strings of a language, as Quine (1972) noted: every grammar which correctly generates the sentences of the language is of equal validity. Any choice between two grammars which are extensionally equivalent can only be made on the basis of aesthetic grounds (such as which theory is the most parsimonious or makes the fewest stipulations). Formalist grammars therefore aim for observational adequacy (Chomsky 1965), i.e. they aim to generate the correct string sets (paired with the correct meanings) for a language.

In a formalist approach to language, the only admissible data is the sentences of the language. Hence the key issue is whether or not a given string is a member of the set of sentences which form the language. This is determined on the basis of the linguist's intuition, in practice via grammaticality judgements:[1] all and only sentences judged grammatical are members of the set. Katz (1981) likened the use of grammaticality judgements to a mathematician's use of intuition: 'a process of exercising grammatical intuition with respect to a particular sentence and thereby [constructing] a sufficiently revealing concept of its grammatical structure for the informant to judge whether the sentence has a certain grammatical property of relation,' (Katz 1981, p.214).

It is clear that psychological evidence concerning the mental representation/processing of language is irrelevant to the grammars which are postulated in formalist approaches. Since such grammars are purely derivative (in the sense that the real objects of inquiry are the sets of sentences that they characterise), evidence that people internally represent a particular sentence in one way and not in another can have no direct bearing upon the form of the grammar. As Katz expressed it, 'If, by some chance, one linguistic theory were to coincide to a greater extent than the others with a psychological theory, this would have no more significance for linguistics than the coincidence of Riemannian geometry with physical theory has for pure mathematics,' (Katz 1981, p.238). I suggest that the only way in which psychological evidence could have relevance for a formalist linguist's work would be if speakers' mental representation of a natural language corresponded to the most economical and most elegant grammar for it. We might expect that to be the case, under the assumption that the language faculty (including the mental representation of language structure, i.e. the internalised grammar) is subject to evolutionary pressures and has evolved to be approximately optimal. In that case, psychological evidence might be useful as a heuristic, but its value would arise solely from the coincidence of its properties (simplicity and elegance) with those valued by the linguist.

[1] 'Grammaticality judgements' is perhaps a misnomer because of the increasing emphasis upon interpretational issues, for example whether *John likes him* can be interpreted such that *John* and *him* have the same referent. In what follows I will ignore the issue of interpretation and concentrate on purely structural issues.

2.2.2 Conceptualist approaches to linguistics

The alternative to the formalist position is that language does not have an independent existence but must be understood in conjunction with the properties of the mind/brain. The conceptualist approach thus turns away from E-language, language considered as a set of sentences, and instead focuses upon what Chomsky (1986b) termed I-language (=internalised language), the knowledge which underlies speakers'/hearers' use of language. Under this assumption, linguistics is a branch of the biological sciences, more specifically psychology. In Chomsky's words, '...linguistics [is] that branch of psychology that focuses its attention on one specific cognitive domain and one faculty of mind, the language faculty,' (Chomsky 1980, p.4). The conceptualist approach is one which has gained wide acceptance.

For many conceptualist linguists, the object of inquiry in linguistics is a person's knowledge of language (his/her 'competence grammar'). The aim of linguistics is to characterise this knowledge. Hence whereas formalist linguists are concerned only with characterising the grammatical strings of a language (observational adequacy), the goal of a linguist in the conceptualist framework is to provide a grammar which also characterises the structure which the speaker assigned to these strings (descriptive adequacy) and ultimately – for those linguists working in the Chomskyan tradition – the features which enable a child to learn that language (explanatory adequacy). Since the goal of explanatory adequacy is not shared by all conceptualist linguists, I will ignore explanatory adequacy in what follows and concentrate upon grammars which aim to capture the knowledge of language of the adult speaker. (I will return to the question of language acquisition in the final section of this chapter). Under this assumption, the grammar which a conceptualist linguist writes is a theory of the adult speaker's knowledge of language, and the statements of the grammar are '...statements about structures of the brain formulated at a certain level of abstraction from mechanisms,' (Chomsky 1986b, p.23).

Hence conceptualist linguists aim to construct a grammar which is psychologically real, in the sense that '...the grammar corresponds to the speaker's internal description of that domain,' (Bresnan & Kaplan 1982, p.xxiii), in other words the adult's mental representation of syntactic structure.[2] In that case, the statements of the grammar are empirical hypotheses which are either true or false. That is, they may or may not correspond to the structure of the speaker's internalised representation of linguistic knowledge. For example, the use of the symbols N and V in a conceptualist linguist's grammar encodes the empirical hypothesis that the speaker's knowledge of language includes a distinction between a class of linguistic entities that we call nouns and a class of linguistic entities that we call verbs. To take a slightly more complex example, to assign the sentence in (2.2a) a different structure from that in (2.2b) (see for example Stowell (1983)) in a conceptualist framework is to hypothesise that the two sentences have different mental representations at the level of syntactic structure.

(2.2) a. The teacher called the boy a liar.

b. The teacher gave the boy a book.

[2] Note that conceptualist linguists are not explicitly concerned with the representations which are implicated during language processing (though many subscribe to the strong competence hypothesis, to be described below); their sole interest lies in the way in which knowledge of language is represented, not in how that knowledge is put to use.

Hence for conceptualist linguists, any evidence concerning the nature of the mental representations which encode knowledge of language is in principle relevant to linguistic theory. In Chomsky's words, '...evidence concerning the character of the ... I-language could come from many different sources apart from judgements concerning the form and meaning of expressions: perceptual experiments, the study of acquisition and deficit or of partially invented languages such as creoles ... As in the case of any inquiry into some aspect of the physical world, there is no way of delimiting the kinds of evidence that might, in principle, prove relevant,' (Chomsky 1986b, p.37).

2.2.3 Summary

Formalist approaches to linguistics presuppose that the subject matter of linguistics is sets of sentence-meaning pairs, and that grammars provide a characterisation of those sentences. The only admissible evidence in this respect is grammaticality judgements, which determine whether or not a sentence forms part of the set. The validity of a grammar depends solely upon its success in specifying the set of grammatical sentences. Hence evidence concerning the mental representation of syntactic structure is irrelevant to formalist linguists and can have no bearing upon the grammars which they construct. Conceptualist approaches to language, on the other hand, believe that the subject matter of linguistics is humans' internalised knowledge of language, and that grammars characterise that knowledge. Hence conceptualist grammars are fundamentally characterisations of the mental representations which encode knowledge of language. The validity of a grammar is defined by the extent to which it is psychologically real, i.e. the extent to which it reflects people's internal description of the linguistic domain.

To sum up, the way in which syntactic structure is mentally represented is irrelevant to formalist linguistic theories. However, it is a central issue for conceptualist linguistic theories, and any psychological evidence which casts light on it is relevant to those theories. The remaining sections of this chapter discuss the implications of such evidence for conceptualist theories. In what follows, the term 'theoretical linguistics' is used as a convenient shorthand for 'conceptualist theoretical linguistics' and 'linguistic theories' as a shorthand for 'conceptualist linguistic theories'.

2.3 Processing theories and syntactic representation

From the discussion above, it is clear that the mental representation of syntactic structure is a fundamental issue for at least some linguistic theories. In this section, I will argue that it is also fundamental to psycholinguistic theories. Psycholinguistics is, like theoretical linguistics, concerned with the human language capacity. However, whereas theoretical linguistics limits itself to studying knowledge of language, psycholinguistics aims to provide a complete computational model of the human language capacity and hence encompasses both knowledge and processing of language.

Such a computational psychological model can be characterised at four levels of description, following a slightly amended version of the framework proposed by Marr (1982). Marr (1982) identified three of these levels. Level 1 characterises the function which is computed and its abstract properties, and states why it is appropriate for the task; Level 2 describes the algorithm which computes the function defined at Level 1 and the nature of the input/output representations; and Level 3 describes the hardware in which the algorithm is realised. Peacocke (1986, 1989) proposed that there is another relevant level of description which is not captured in Marr's framework. He suggested that this level lies between levels 1 and 2 (hence his term Level 1.5). According to Peacocke, Level 1.5 specifies the information which is drawn upon by an algorithm. For example, an algorithm which maps from words to sequences of phonemes must make reference to information which specifies the possible relationships between different words and different sequences of phonemes. In principle, the algorithm could draw upon a range of bodies of information: it could draw upon a set listing the sequence of phonemes corresponding to each word; or upon information about the pronunciation of syllables; or upon information about the pronunciation of a subset of the class of words, with words outside this subset being pronounced by analogy.

If we carry this general framework over to the study of language, then psycholinguistics is concerned with Levels 1, 1.5 and 2: describing the functions which are involved in language production and comprehension (e.g. a function which maps from unstructured strings of words to a hierarchical syntactic structure during comprehension); characterising the information which is drawn upon (the competence grammar); and identifying the algorithms which compute those functions (e.g. a left-corner parser) and their input/output representations. From this, it is clear that the way in which syntactic structure is mentally represented is an important research issue in psycholinguistics: any model of production or comprehension must specify the nature of the knowledge base (the representations which encode knowledge of syntactic structure) and the input/output representations (the representations which are constructed during processing).

However, the mental representation of syntactic structure also has implications for the nature of the *processes* involved in comprehension and production, because the form of the grammar upon which processing draws imposes constraints upon the possible processing algorithms. Of course, more than one processing algorithm will always be compatible with any given grammar, but the distinctions which are made in the grammar can narrow down the range of possible algorithms. For an algorithm to be characterised in terms of a certain aspect of structure, that aspect must be represented in the grammar in some way: the algorithm cannot be based upon distinctions which the grammar does not make. For example, if a grammar does not encode information about verb transitivity in its characterisation of the well-formed sentences of the language, then there is no way in which the parser can make decisions based upon verb transitivity. I leave it open here whether the grammar upon which processing draws is the competence grammar or a grammar derived from it in some way; I return to this point in section 2.5.1.

Assumptions about the representational basis of the language faculty are evident in any model of language processing. These range from basic assumptions, e.g. that the processor recognises a distinction between nouns and verbs, to more controversial assumptions, e.g. that empty categories are involved in processing. It is important to note that even theories which differ greatly in their overall architecture may make some (or even all) of the same representational assumptions. Let us consider thematic information as an example of this. In the parsing

model proposed by Frazier (1990) (see also Rayner, Carlson & Frazier (1983)), the processor initially makes decisions based upon phrase structure and then subsequently uses thematic information associated with the head of a phrase to decide whether or not that analysis is appropriate. The crucial points to be made here are that such a model of processing presupposes that the grammar which is drawn upon during processing encodes thematic information; and that this information is represented distinctly from phrase structure information. (Note that it also assumes the existence of phrase structure). The same assumption was made in two models which differ from Frazier's in taking a content-based rather than form-based approach to parsing (see Crocker (forthcoming) for a discussion of this distinction). Pritchett (1988) and Crocker (forthcoming) proposed a Theta-Attachment strategy and an A-Attachment strategy respectively, both of which suggest that constituents are preferentially attached in positions which potentially receive a theta-role. The model of parsing proposed by MacDonald, Pearlmutter & Seidenberg (1994) differs radically from all three of the theories described above, since it assumes that multiple analyses are proposed and subsequently chosen between on the basis of probabilistic constraints. Nevertheless, it too assumes that the grammar encodes thematic information: thematic information can affect the analysis which the processor chooses through the varying strength of the links between a verb and its alternative thematic frames. Note that these models could all be identical at Level 1.5, if they make – as they appear to do – identical assumptions about the information which is drawn upon during processing. However, they all differ at Level 2, since the processing algorithms which they propose are distinct.

In addition to these high level assumptions about the dimensions of syntactic structure which are represented, some processing theories also depend upon assumptions about the representations of specific constructions. For example, Frazier (1979) suggested that (2.3b) below is harder to parse than (2.3a) because the parser preferentially attaches a PP to the VP in this context, in keeping with the principle of Minimal Attachment, given in (2.4). In the case of (2.3b), this analysis is wrong and so the parser must reanalyse. Experimental studies by Rayner, Carlson & Frazier (1983) and Ferreira & Clifton (1986) have provided evidence for this preference.

(2.3) a. I saw the girl with the binoculars.
$_{S}[\ _{NP}[\ I\ ]\ _{VP}[\ _{V}[\ saw\ ]\ _{NP}[\ the\ girl\ ]\ _{PP}[\ with\ the\ binoculars\ ]\ ]\ ]$

b. I saw the girl with flu.
$_{S}[\ _{NP}[\ I\ ]\ _{VP}[\ _{V}[\ saw\ ]\ _{NP}[\ _{NP}[\ the\ girl\ ]\ _{PP}[\ with\ flu\ ]\ ]\ ]\ ]$

(2.4) Minimal Attachment: *Attach incoming material into the phrase marker currently being constructed using the fewest nodes consistent with the well-formedness rules of the language.*

However, this crucially depends upon the structure in (2.3b) involving fewer nodes than that in (2.3a), in other words upon assumptions about the way in which the two sentences are represented (as Abney (1989) pointed out, it is not clear that such an analysis would be accepted by many linguists). Under alternative assumptions about the syntactic structure of the relevant sentence, this model of processing might predict that both sentences would be equally hard to process or even that (2.3a) would be harder to process that (2.3b). Clearly, for this type of processing theory, the representation of syntactic structure is of fundamental importance.

2.3.1 Summary

To summarise, the nature of the mental representation of syntactic structure is critical to psycholinguistic theories. A complete computational model of the human language capacity must include a characterisation of the knowledge base which underlies linguistic behaviour and specify the form of the input/output representations. Hence the mental representation of syntactic structure is of interest in and of itself. In addition, however, it is impossible to construct a processing model without making assumptions about how syntactic structure is represented, since the form of this representation imposes constraints upon the possible processing algorithms. Thus the nature of syntactic representation is critical even for research which is primarily concerned with processing issues.

2.4 Evidence about the mental representation of syntactic structure

The above discussion has established that the mental representation of syntactic structure is a central research issue for both theoretical linguistics and psycholinguistics. At least some linguistic theories are proposed as theories about the state of mind of a speaker. They aim (among other things) to characterise the knowledge of language which allows the speaker to produce and comprehend the grammatical sentences of his/her language. Thus such linguistic theories aim to provide a descriptively adequate characterisation of the adult speaker's competence grammar: a description which corresponds to the speaker's own internal description, i.e. mental representation, of the syntactic structure of the language. Psycholinguistic theories aim to model the human language capacity. As such, they must specify the knowledge base which underlies linguistic behaviour, the input/output representations at each stage of processing, and the processes themselves. The first two aspects are directly concerned with syntactic representation; the third is affected by it, since the range of possible processing algorithms depends upon the information which is represented in the grammar upon which processing draws (either the competence grammar or a covering grammar – this will be discussed below).

Given the fundamental importance of this issue, we might expect it to be a focus of research for both fields. In fact, most work investigating syntactic representation has been carried out by theoretical linguists. Psycholinguists have tended to assume that the study of syntactic structure is the province of theoretical linguistics. As a result, they have tended to concentrate upon modelling the processes involved in comprehension and production, assuming that the theories proposed by theoretical linguists provide an appropriate characterisation of syntactic structure. Their processing models are therefore based upon assumptions about the nature of syntactic representation derived – often directly – from linguistic theories (e.g. Frazier (1990), Pritchett (1992) and Crocker (forthcoming) all assume that the overall architecture of Government-Binding theory (Chomsky 1981, 1982, 1986a) provides the appropriate characterisation of knowledge of language). To this extent, processing theories are reliant upon the

validity of the linguistic theories on which they are based and hence – indirectly – upon the validity of the evidence on which linguists base their theories. In theory, any psychological evidence which casts some light upon the mental representation of syntactic structure is relevant to the investigation of the competence grammar, as for example Chomsky has repeatedly acknowledged (see Chomsky 1980, 1981, 1986b). In practice, however, conceptualist linguists – like formalist linguists – have relied almost exclusively on grammaticality judgements in constructing their theories.

2.4.1 Grammaticality judgements as evidence about mental representation

Grammaticality judgements are a convenient source of data, since all that is required is a native speaker, in practice often the linguist him/herself. They can provide evidence about whether or not a particular sentence is a member of the E-language defined by the I-language; they are also assumed to give direct evidence concerning the structure of the I-language (see for example Chomsky (1986b)). It is thought that the use of grammaticality judgements in conjunction with the linguist's intuitions can go a long way in uncovering the underlying structure of a language.

However, there is reason to believe that the data provided by grammaticality judgements should be treated with some caution, as such judgements are not necessarily reliable, particularly where the sentence is of borderline grammaticality. Unfortunately, it is often the borderline cases which provide the ultimate test of a particular syntactic theory. Levelt (1974) discussed a number of factors which might influence an informant's judgement, including the context in which a sentence is presented (e.g. in a theoretical linguistic report versus in isolation); comparison with other sentences (a borderline sentence is more likely to be judged grammatical if it preceded by strongly ungrammatical sentences)[3]; the use of unnatural and misleading examples (e.g. unnecessarily complex examples); conceptual factors (informants are more likely to accept a sentence as grammatical if they can imagine a context in which it might be said); and the linguist's own theoretical biases (a linguist is more likely to accept a sentence as grammatical if it fits his/her theoretical viewpoint). Levelt also reported an experiment which tested the reliability of grammaticality judgements. He presented a group of linguists with a set of example sentences taken from published papers and asked them to judge them as grammatical or ungrammatical. He found that the judgements of his subjects varied greatly from those of the authors of the examples. Sentences which the original authors judged *ungrammatical* were twice as likely to be judged grammatical by Levelt's subjects as sentences which the original authors judged as grammatical. Levelt concluded from this that '...it is an illusion to think that an objective absolute judgement of grammaticality is possible,' (Levelt 1974, p.17). More recently, Karin Stromsfold reported the results of some experiments investigating grammaticality judgements in a posting to the electronic newsgroup 'the Linguist List' (Article 6.1045, 3rd August 1995). She found that when subjects had to

[3] Bard, Robertson & Sorace (1994) developed a grammaticality judgement elicitation technique which avoids this problem by forcing subjects to make judgements with reference to preceding sentences. This shows that the practical difficulties associated with eliciting grammatical judgements are not insurmountable, but does not alter the fundamental point that such judgements as currently elicited may be unreliable.

make repeated judgements, their judgements became unreliable, they took longer to make them and they reported being uncertain of their own intuitions.

The effects of the unreliability and subjectivity of grammaticality judgements have clear consequences for theoretical linguistic research, where debates concerning the merits of alternative analyses often hinge upon disagreements concerning the evidence, i.e. whether a crucial example is grammatical or ungrammatical. Indeed, in the most extreme cases (and perhaps the ones which best exemplify the problems with relying on grammaticality judgements), a researcher disagrees with his/her own judgement as expressed in a previous paper. For example, Chomsky (1982) argued that (2.5) below was grammatical, contra the argument in Chomsky (1981) that it was ungrammatical. Hence the same sentence was used as evidence both for and against a particular proposal.

(2.5) Who did you give a picture of to?

Overall, the evidence suggests that grammaticality judgements are not a reliable source of evidence.

2.4.2 Alternative sources of evidence and their implications

Given these problems, the reliance of linguists upon grammaticality judgements seems unwise. Surely it would be preferable to investigate syntactic representation using alternative methods which might not be subject to the same drawbacks. As we have seen, the representation of syntactic knowledge is as much the concern of psycholinguistics as it is of theoretical linguistics; it would seem common sense to bring the methods of psychology to bear upon it.

However, there has been surprisingly little work regarding the use of alternative methods, such as controlled experiments. The main reason for this seems to be pessimism concerning the extent to which experimental methods can tap into syntactic representation. Because experiments involve subjects comprehending or producing language, there has been concern that any effects which are found might be explained in terms of the processing algorithm, not the representations. Furthermore, even if it could be shown that the evidence was evidence about the syntactic representations constructed during processing, such evidence might not be informative about knowledge of language, given that the relationship between underlying knowledge of language and the operations and representations which are constructed during processing is unclear.

This pessimism seems unfounded. A grammaticality judgement is itself in Chomsky's words 'the result of an experiment, one that is poorly designed but rich in the evidence it provides,' (Chomsky 1986b, p.38). Grammaticality judgements involve complex processing, including parsing the sentence, and hence are open to exactly the same criticisms as any other experiment. In particular, although they may well provide evidence about whether the sentence is a grammatical string (and hence whether it forms part of the E-language), it is not clear that they provide insights how language is mentally represented. Hence calling upon evidence from psychological experiments is in effect an extension (and improvement) of current theoretical practices, not a revision of them.

Clearly, there is no principled reason why experimental psychological methods cannot be used to investigate how people represent syntactic structure; on the other hand, there are

many advantages to doing so. Such methods might provide more accurate data than grammaticality judgements, given the problems noted above with obtaining reliable and objective metalinguistic judgements. They might also be able to shed some light on issues about which grammaticality judgements are silent or distinguish between alternative hypotheses where grammaticality judgements do not. Finally, if nothing else, evidence from other sources could be used to confirm the distinctions proposed on the basis of grammaticality judgements. If grammaticality judgements really do provide evidence about the mental representation of syntactic structure, then we should be able to find converging evidence from other sources.

2.5 The implications of the evidence

If there is no principled difficulty with using experimental psychological methods, the only remaining difficulties are practical, identifying which methods are informative about representation and what sort of inferences can be drawn from the evidence which they provide. In the remainder of this thesis, I will be concerned with exploring alternative sources of evidence, such as the use of corpora and experimental methods; in this section, I will concentrate on the implications of any evidence which is found using these methods.

2.5.1 The relationship between the competence grammar and processing

In the discussion above, two aspects of syntactic structure were identified: the representations which form part of the linguistic knowledge base, or competence grammar, and which encode the speaker's knowledge of language; and the representations which are constructed during processing. In principle, it might be possible to tap into either aspect of representation. For example, one method might tap into the representations of the competence grammar whilst another might tap into the processing representations. The implications of each type of evidence depend upon the relationship between the competence grammar and processing.

The simplest and strongest assumption is that the rules or principles of the competence grammar are directly invoked during processing, in other words that there is an isomorphism between the structures of the grammar and the processes involved in production/comprehension. The assumption that a transparent mapping exists between the statements of the competence grammar and the representations and operations of the parsing/production systems has been termed the strong competence hypothesis (see Chomsky (1965) and Bresnan & Kaplan (1982); see also Berwick and Weinberg's discussion of 'type transparency' (Berwick & Weinberg 1984)). However, it is not necessarily the case that the comprehension and production systems make direct use of the statements of the competence grammar. Instead, their operations and representations might be based on a grammar derived in some way from the competence grammar, perhaps for reasons of improved performance, as Berwick & Weinberg (1984) discuss. This proposal can be termed the weak competence hypothesis. For example, parsing might be based on a compiled-out version of the competence grammar.

If the strong competence hypothesis is assumed, then evidence about the representations implicated during processing is, ipso facto, evidence about the representations of the competence grammar, and vice versa. For example, if it could be shown that during comprehension the processor makes use of a rule corresponding to VP $\rightarrow$ TV NP (where TV = transitive verb), then under the strong competence hypothesis we could conclude that the underlying competence grammar also has a rule corresponding to VP $\rightarrow$ TV NP. However, under the weak competence hypothesis we could not draw this inference. Since the covering grammar is derived from the competence grammar, any distinctions which are made by the processor must also be made in the competence grammar, but the covering grammar may not make all of the distinctions which the competence grammar does and it may not represent them in the same way. That is, I am assuming that the covering grammar is derived via some sort of transformation (in the non-Chomskyan sense) from the competence grammar and hence can only make distinctions which the competence grammar also makes; it involves no other information beyond that contained in the competence grammar.

In this case, from evidence that the covering grammar uses a rule corresponding to VP $\rightarrow$ TV NP we could infer that the competence grammar recognises a distinction between transitive verbs and intransitive verbs, but we cannot be sure that it contains a rule of this type. For example, if the covering grammar is a compiled-out version of the competence grammar, the competence grammar might contain a single abstract rule XP $\rightarrow$ X YP in place of VP $\rightarrow$ TV NP. Equally, from evidence about the form of the competence grammar, we might be able to rule out certain potential processing representations (information which is not present in the competence grammar cannot be present in the processing representations) but we could not draw any conclusions about the form of the processing representations. In this case, evidence that the competence grammar contains a rule of the form VP $\rightarrow$ TV NP would not allow us to conclude that the processor makes use of transitivity information during comprehension or production.

In the remainder of this thesis, I am going to assume the strong competence hypothesis. As Bresnan & Kaplan (1982) noted, it is both the simplest and strongest hypothesis which can be adopted. To accept the alternative is to hypothesise a separate processing grammar (or perhaps even separate processing grammars for production and comprehension), in addition to the knowledge base which underlies both. On methodological grounds alone, this should be rejected in the absence of any compelling evidence to the contrary. (It should be noted that even if the weak competence hypothesis ultimately turned out to be correct, the research presented here would still be of value, since – for example – any evidence about syntactic distinctions which are made during processing would be informative about the representations which are involved in processing, if no longer about the representations of the competence grammar).

Assuming, then, that evidence about the representations involved in processing also constitutes evidence about the representations of the competence grammar and vice versa, what would be the implications of such evidence for linguistics and psycholinguistics?

2.5.2 Implications for linguistic theories

Psychological evidence about syntactic representation is clearly irrelevant to formalist theories of linguistics, except insofar as the mental representation of syntactic structure might be

optimally simple and elegant. However, any syntactic theory which claims to characterise the adult speaker's knowledge of syntactic structure, i.e. which claims descriptive adequacy, must take such evidence into account. It has the same empirical status as the grammaticality judgements on which such theories are usually based. Hence any distinctions for which there is processing evidence (for example from experiments or from corpora) must be made in the linguistic theory. For example, if there is evidence that speakers make a distinction between arguments and adjuncts, the linguistic theory must also encode this distinction.

The statements of the grammar which are motivated by processing evidence should be distinguished from two other types of statement which the theoretical linguist might want to include in his/her overall theory. The first type consists of distinctions which are relevant to the child during language acquisition but which play no part in the adult speaker's linguistic behaviour. As an example, consider information about head position within a phrase. If it is correct that there is a set of parameters common to all human languages (see Chomsky (1980)), one plausible candidate for parametric variation is head position: head-initial or head-final. In that case, the child's competence grammar might contain a general rule XP $\rightarrow$ X YP (for convenience, I am ignoring the issue of intermediate bar levels here). However, the same information might be represented implicitly in the adult speaker, in terms of a set of category-specific rules, e.g. VP $\rightarrow$ V NP, NP $\rightarrow$ N DP, PP $\rightarrow$ P NP. In that case, the adult's internal description of the language would not correspond to the child's internal description: they would have different rule sets, which whilst weakly equivalent (i.e. having the same extensions), would not be represented in the same way. At this point, a tension arises. A linguist who is interested in explanatory adequacy might want to represent the rule XP $\rightarrow$ X YP in his/her grammar. However, this would not be a correct characterisation of the adult's competence grammar. The adult speaker would draw upon explicit knowledge that a VP may comprise a verb and an NP; he/she would not draw upon information that a phrase (which may be instantiated as a verb phrase) may comprise a zero-level category (which may be instantiated as a verb) and a phrase (which may be instantiated as an NP).

Hence it might turn out that it is not possible to achieve both explanatory and descriptive adequacy in a single grammar, and that linguists will have to choose between one or the other in formulating their theories. This problem is not of course restricted to experimental evidence; research based on grammaticality judgements by children and adults might lead to exactly the same conclusion. The point which I am making here is that the evidence which we are seeking will be evidence about the adult's knowledge of language and hence relevant to any theory of the adult's competence grammar, but it might not be relevant to linguists who are interested in Universal Grammar and explanatory adequacy.

The second type of statement which linguists might want to include in a grammar consists of rules which capture regularities in the language but which play no part in processing. That is, the distribution of a structure or of particular morphemes may be elegantly described using a rule, but this rule does not form part of the competence grammar. Rules of this type may reflect historical relationships between words and structures. Diachronically, the rule might have formed part of the adult speaker's competence grammar, but synchronically it has no psychological reality. This possibility has recently been discussed with respect to morphology by Marslen-Wilson, Tyler, Waksler & Older (1994). They investigated lexical priming effects between words with various degrees of morphological complexity. Priming occurred between a free stem and a morphologically complex word derived from it, such as *happy* and *happiness*, and between morphologically complex words which shared a semantically transparent stem, such as *observation* and *observant*. Marslen-Wilson *et al* suggested that priming occurred because processing the prime and target words involved accessing a common stem morpheme, e.g. *observ-*. Thus these derived forms are mentally represented in terms of a stem+affix. However, they only found priming effects between pairs where there was a clear semantic relationship. With words where the semantic relationship was opaque, e.g. *apart/apartment*, no priming effect was found. Marslen-Wilson *et al* argued from this that *apart* and *apartment* do not have a common stem and hence that words such as *apartment* are mentally represented as monomorphemic, not as composed of *apart-* and *-ment*. This is not in keeping with linguistic and etymological analyses, according to which the target word is morphologically decomposable: the derived form has a recognisable affix; when the affix is removed, the resulting stem is the same as the paired free stem (the prime); and the pair of words have the same etymon.

Marslen-Wilson *et al* argued that not all linguistically-motivated distinctions are mentally represented and that a distinction should be drawn between morphemes which are implicated in processing and those which can be justified on historical or linguistic grounds but which play no part in processing: '[The former] should be understood ... as a cognitive, or psycholinguistic, concept of the morpheme, developmentally definable for each listener in terms of its synchronic semantic interpretability. This cognitive morpheme does not include all entities definable as morphemes on linguistic and diachronic grounds, so that linguistically polymorphemic forms, like *apartment* or *submit*, can behave like unanalysed simple forms, with no internal structure, as far as their mental representation is concerned,' (Marslen-Wilson, Tyler, Waksler & Older 1994, p.31).

Carrying this over to the level of syntactic structure, it may be that there are generalisations, or rules, which can be made on the basis of distributional data but which do not correspond to internalised distinctions. For example, there might be a rule which captures a diachronic distinction between two structures but which does not form part of the adult competence grammar. A rule of this type is not psychologically real, in the sense that it does not form part of the speaker's knowledge of language. It cannot therefore be drawn upon in his/her use of language. Under these circumstances, we might say that the data is rule-describable, since there is a rule which describes the pattern of data, but not rule-governed, because the rule plays no part (via processing) in causing that pattern of data. Descriptive rules of this type have a different status from the rules which are implicated in processing: the latter have a causal role in linguistic behaviour, because the speaker draws upon this rule in his/her use of language and this results in a particular pattern of behaviour. The linguist may wish to include descriptive rules in the grammar, since they capture generalisations about the data, but it should be recognised that the ensuing grammar will not represent the speaker's internalised grammar.

2.5.3 Implications for processing theories

The implications for processing theories of any evidence which we find are straightforward, assuming that the strong competence hypothesis is correct. As I have already argued, the form of the competence grammar imposes constraints on the possible processing algorithms. If it were to be shown that the competence grammar does not encode a distinction between arguments and adjuncts, for example, that would preclude any processing theory in which the argument/adjunct distinction played a causal role. Note that it would not preclude a *description* of the processor's behaviour in terms of arguments/adjuncts. It might be that for other reasons the processor treats linguistic objects which linguistic theories define as arguments differently from linguistic objects which correspond to adjuncts, and in that case it would be reasonable to describe the processor's behaviour in those terms. Crucially, however, the argument/adjunct distinction could not be used to *explain* the processor's behaviour, only to describe the results of that behaviour. This is essentially the same distinction as that made above between rule-described behaviour and rule-governed behaviour.

Essentially, the representational assumptions made by processing theories would have to be compatible with the representations for which we find evidence. This is not to say that all of the distinctions will be relevant to both production and compehension. It might be the case that some distinctions are only drawn upon during production, for example. In that case, finding evidence of a particular distinction during production would constitute evidence that the distinction is made in the competence grammar but would not necessarily mean that it is implicated during comprehension.

2.6 Summary

In this chapter, I have shown how questions about the mental representation of syntactic structure are central to theories of language processing and to at least some linguistic theories. I have argued that at present, syntactic representation is overwhelmingly investigated using grammaticality judgements but that these are an unreliable source of data. Instead, I have suggested that syntactic representation could in principle be investigated using some of the methods of experimental psychology. In essence, I am proposing an interdisciplinary approach to syntactic structure: the representation of syntax is a topic of interest to both linguists and psychologists and as a result we would expect that insights from one field should be able to inform the other.

Research of this type would be of value in several ways: the data which is gathered might be more reliable than that from grammaticality judgements; it might cast light on areas which grammaticality judgements fail to illuminate; it might be informative about syntactic processing; and it might also serve as confirmation for some of the syntactic representations which have been proposed on the basis of grammaticality judgements. Any evidence which is found would be directly relevant to linguistic theories which aim to characterise the adult's competence grammar; it would also constrain the range of possible processing algorithms for language production and comprehension.

Chapter 3

Syntactic structure in theories of sentence processing

3.1 Introduction

In the previous chapter, I showed that evidence about syntactic representation is in principle relevant to both processing theories and some linguistic theories. This chapter is concerned with theories of language processing. It aims to provide some necessary background for the remainder of this thesis. It presents the processing architecture which I am going to assume, and discusses some current processing theories and the assumptions about syntactic representation which underlie them.

The chapter is divided into two main sections, one devoted to production and one to comprehension. I will begin each section by briefly discussing the sources of evidence which are used in formulating processing theories. Next I will present an overview of the processing architecture which I am assuming, identifying the different components and the type of processing with which each component is concerned. I will then focus on the components which are concerned with syntactic structure in more detail. For each component, I will examine the relevant empirical evidence, some of the processing theories which have been put forward on the basis of this evidence, and the representational assumptions which those theories make. I should make it clear at this point that I will address slightly different issues in each section. This is because research into the two components has concentrated on different areas: research into production on identifying the levels of processing, and research into comprehension on processes themselves and the way in which they are governed.

3.2 Theories of language production

In studying language production, we are concerned with identifying how a message in the speaker's mind is translated into a syntactically and phonetically well-structured linear array which has an appropriate prosodic contour. (I leave aside here issues relating to articulation). In order to investigate these issues, we must rely on behavioural evidence, since the processes

of language production are not generally open to conscious introspection.

Most research into language production has concentrated on analysing corpora of speech errors and other imperfect speech, in order to identify which processes have malfunctioned, and from this to deduce how these processes would normally function. There are several varieties of imperfect linguistic behaviour: speech errors (Dell & Reich 1981; Fromkin 1971; Fromkin 1973; Garrett 1975); hesitations (Butterworth 1980; Goldman-Eisler 1968; Beattie & Butterworth 1979); self-repairs, where a speaker corrects an error which he or she has made (Schegloff, Jefferson & Sacks 1977); and language pathology, such as anomia (Kay & Ellis 1987). However, the utility of corpora of imperfect speech is limited, since the quantity of data which they provide is small (based on a taped corpus, Garnham, Shillcock, Brown, Mill & Cutler (1982) found estimated error rates of only 1.5 sound errors and 2.5 word errors per 10,000 words). Furthermore, the researcher cannot manipulate factors which are hypothesised to be important but instead can only examine the structures which speakers happen to have produced. In addition, there is always the danger that some feature of abnormal behaviour which motivates a particular proposal for normal behaviour may just be aberrant.

As a result, recent work has tended to concentrate upon experimental studies, which allow the experimenter to examine normal speech, to manipulate factors of interest and to collect larger quantities of data. Experimental techniques for eliciting data include asking subjects to talk about a particular topic (Holmes 1988); asking subjects to describe a stimulus, which may be as varied as a film (Bates & Devescovi 1989) or a picture (Bock 1986b); or asking subjects to complete a sentence (Bock & Cutting 1992). Of course, the study of imperfect speech and the use of an experimental technique are not mutually exclusive: a number of researchers have studied imperfect speech in an experimental context. For example, Baars & MacKay (1975) devised experiments to elicit slips of the tongue from speakers, Holmes (1988) provided an experimental study of hesitations in speech, and Levelt (1983) monitored self-repairs during a production experiment.

3.2.1 The architecture of the production system

Overview

The production of a sentence requires the satisfaction of several constraints: the sentence must have a well-formed syntactic structure; it must contain appropriate lexical items; it must have a suitable prosodic contour and phonological structure; and in addition, each of these aspects must be congruent with the intended message. Thus language production involves at least semantic, syntactic, lexical and prosodic/phonological aspects. The particular aspect of interest here is that of syntactic structure, but I will begin by giving a very brief overview of the production system as a whole, before focusing upon the parts of the system which are concerned with syntactic processing.

There is wide agreement that the production system is organised according to the overall architecture presented schematically in Figure 1 (after Bock & Levelt (1994)). As the diagram shows, the production system comprises four levels of processing: the message level, which is concerned with semantic processing; the functional and positional levels, which are concerned with what Bock and Levelt term grammatical encoding; and the phonological level, which is concerned with phonological processing. To make the discussion more concrete, I will discuss how these four levels are involved in generating a target utterance, *An apple rolled*.

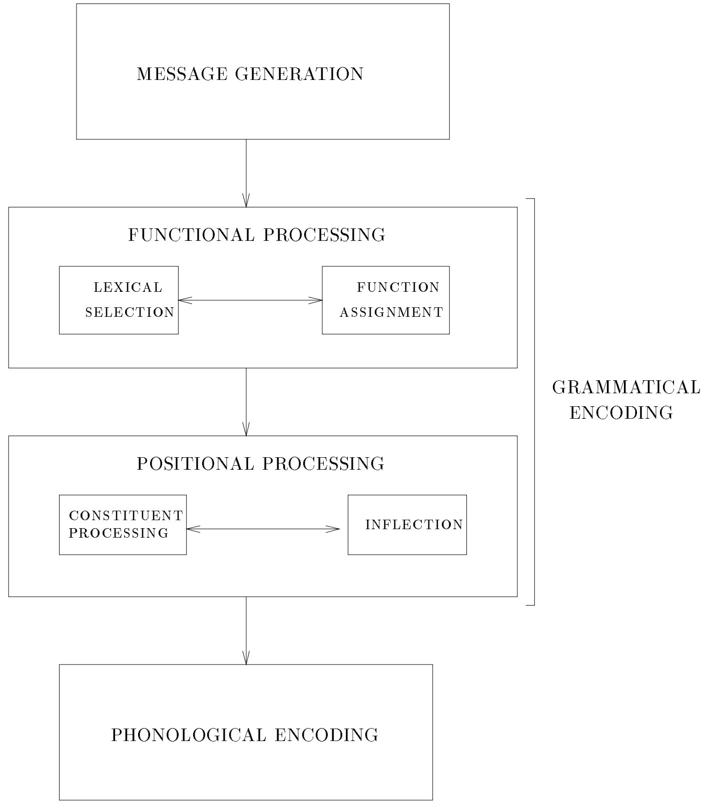


Figure 1

Message generation

The initial stage in language production involves construction of the message to be conveyed. It has been suggested that the domain of message generation is something like conversational goals/discourse topics and that it involves units corresponding to several clauses (Levelt 1989). There is some evidence to support this. Henderson, Goldman-Eisler & Skarbek (1966) showed that speech occurs in fluent and dysfluent supraclausal phases; they suggested that dysfluent phases occur when the speaker is carrying out 'macro-planning,' i.e. elaborating goals and retrieving information for subsequent discourse. In keeping with this, Butterworth

(1975) and Beattie (1980) found that sentences within fluent phases typically have stronger semantic/discoursal connections. Levelt (1989) suggested that the output of this level is a pre-verbal message which typically consists of a propositional structure but may also encode sub-propositional elements, such as structures denoting individuals and modifiers. In this case, the output might be the proposition $\text{ROLL}_{pst}(\text{APPLE})$.

Functional Processing

Functional processing is the first step following message generation. It comprises two processes, lexical selection and function assignment. Lexical selection involves the activation of items in the mental lexicon by the coincidence of their meaning with semantic features in the message; this results in retrieval of their lemmas. Lemmas are relatively abstract forms which are specified for syntactic privileges and semantic features (and possibly rhythmic features such as stress and syllable count); however, there is substantial evidence that they do not include a specification of phonological form. For example, tip-of-the-tongue phenomena reveal that speakers can know the meaning, syntactic privileges and often the rhythmic features of a word but be unable to retrieve its phonological form (Brown & McNeill 1966). Corroborative evidence also comes from speech errors and language pathology (see for example Fromkin (1971) and Kay & Ellis (1987)).

Function assignment involves linking the syntactic relations/grammatical functions (e.g. subject, direct object) which are specified by the verb lemmas to the noun lemmas which are retrieved during lexical selection. (I will use the term 'grammatical function' in the remainder of this chapter). For example, given the message $\text{ROLL}_{pst}(\text{APPLE})$, lexical selection might result in the retrieval of the lemmas for *roll* and *apple*; during function assignment, the nominative function specified by *roll* will be associated with the lemma *apple*. The output of functional processing is a functional structure in which lemmas and grammatical functions are linked together. This functional structure does not specify ordering relations between the individual elements.

Positional processing

The order of elements in the utterance is fixed at the next level of processing, positional processing. In the model which I am assuming here, this comprises two processes, constituent processing and inflection processing (it is a matter of some debate whether there is a distinct process of inflection, as will become clear in the discussion below). During constituent processing, the functional structure is mapped onto a constituent structure which specifies word order and syntactic dependencies between the different elements. For example, the functional structure which links the subject relation of *roll* with *an apple* may be mapped onto a constituent structure in which *an apple* and *roll* form a finite clause, and *an apple* precedes *roll*. Inflectional processing is the stage at which information concerning such dimensions as number, tense and aspect are bound to other words; for example, the third person simple past tense inflection *-ed* would be associated with *roll* at this point. The output of this level of processing is a structure which is syntactically well-formed and lexically specified, but has no phonological content.

Phonological encoding

Phonological content is computed at the next level, phonological encoding. At this level of processing, the constituent structure which forms the output of positional processing is mapped onto an overall phonological structure, which specifies the prosodic contour and rhythm of the sentence. It has been suggested that this overall phonological structure is computed directly from the syntactic structure of the sentence (Selkirk (1986); see Ferreira (1991) for supporting experimental evidence). After the overall structure has been computed, the phonological form of each word in the utterance is retrieved and associated with the appropriate position (Ferreira 1993). For example, a phonological structure for the sentence *an apple rolled* will be computed on the basis of the syntactic structure $_{S}[\ _{NP}[\text{An apple}]_{VP}[\text{rolled}]]$, followed by the retrieval and insertion into the structure of the word forms /an/, /apl/ and /rold/. The output is a structure which is syntactically, lexically and phonologically specified and can be passed to the processes responsible for articulation.

Information flow

Having identified the different components of the system, we must discuss the information flow between them and in particular whether information from one component can directly affect processing in another. Although some researchers have put forward interactive models of production, where for example phonological factors can affect processing at the functional or positional level (see for example Dell (1986) and Stemberger (1985)), there is restricted evidence for this. Bock (1987a) found that in picture descriptions, phonologically primed words tended to be assigned the object role in transitive events and to appear later in conjunctive phrases. This is consistent with a model where function assignment and constituent structure processing are sensitive to and guided by the phonological accessibility of word forms; word forms which are phonologically accessible are assigned higher functions (hence appear earlier in the sentence) and constituent structure positions earlier in the sentence.[1] However, as Levelt (1989) pointed out, there is an alternative explanation. It could be that the processor initially chooses a syntactic frame in ignorance of the phonological accessibility of the relevant word forms. Subsequent difficulty in retrieving a word form at the phonological level could cause the processor to revise the syntactic frame and choose an alternative frame, one which would allow the word causing difficulty to appear later. That is, activity at one level may cause difficulties which result in subsequent revision at a higher level but crucially cannot *guide* initial processing at the higher level. Furthermore, other experiments have found no effect of phonological factors on functional processing or constituent structure processing. For example, Bock (1986a) found that phonological priming had no effect upon word order in picture descriptions, and a sentence recall experiment found no effect of phonological factors – prosody and word length – on either functional role assignment or conjunct ordering within sentences (McDonald, Bock & Kelly 1993).

Overall, the evidence may be more consistent with a production system which is modular, in the sense of Fodor (1983).[2] Each component is informationally encapsulated, in that processing within a component cannot be directly affected by information from outside that component. For example, conceptual factors may affect function assignment, we will see below, but cannot affect constituent structure processing. Note that strong modularity does not mean that processing of the entire structure at one level must be complete before processing at the next level may begin. Indeed, such a situation seems highly unlikely, since it would cause serious disfluency, with long pauses intervening between bursts of speech. Experience tells us that speech is not produced like this but instead in a more-or-less fluent stream. Furthermore, most people have had the experience of initiating articulation of a sentence without any idea of how it will end, which must mean that the initiation of articulation can precede the completion of grammatical encoding for a sentence.

It is reasonable to assume that the production system aims to maintain maximal fluency. In that case, production must proceed incrementally, so that as processing of some part of an utterance is completed, the result may be passed onto the next level, whether or not the rest of that utterance is still being processed. Lindsley (1975) provided some experimental evidence to support this, showing that articulation of the subject may begin before the rest of the sentence is fully encoded.

A second question concerns whether processing takes place serially or in parallel. For incremental processing to occur, clearly there must be simultaneous processing at different levels (for example, simultaneous phonological processing of the subject NP and grammatical encoding of the direct object NP). However, the existence of lexical and syntactic 'blend' errors provides evidence that alternative structures are processed in parallel. In these errors, the utterance actually produced seems to be a blend of two alternative formulations of the same message at a lexical (3.1) or syntactic level (3.2):

(3.1) That's torrible !
(Intended: That's horrible/That's terrible) (Garrett 1980)

(3.2) Would you turn on the light on ?
(Intended: Would you turn on the light/Would you turn the light on) (Fay 1980)

Stemberger (1985) suggested that lexical blends result when two words are proposed and inserted into a single structural slot. Syntactic blends involve constructions which are in some (undefined way) related, such as particle placement alternations, as in (3.2) above. Bock (1987b) noted that they could be characterised as the result of blending two phrase structure rules. It is difficult to explain the occurrence of either type of blend unless we assume that in at least some cases, more than one structure is active and moreover being pursued by the processor, even to the point of utterance. Overall, the errors suggest that sentence proudction is a competitive process. More than one lemma or structure may be activated to encode a particular message. These alternatives then compete with each other for further processing. Normally, alternative structures are quickly suppressed in favour of the most highly activated competitor, but in certain circumstances two closely-matched competitors may both undergo elaboration, resulting in a blend.

[1] Phonological priming has an inhibitory effect, making the primed words phonologically less accessible, which is why they were assigned *lower* functions and *later* positions in the sentence.

[2] Although note that Fodor himself denied that the language system is entirely modular, since it interfaces with the general cognitive system.

Summary

The above discussion has given a brief overview of the components which make up the language production system. In the following sections, I wish to examine in more detail the components which are concerned with syntactic processing: function assignment and constituent processing.

3.2.2 Function assignment

I will begin by reviewing the evidence which supports the existence of a stage of syntactic processing which is concerned with unordered grammatical functions and which is dissociable from constituent structure. I will then discuss the factors which affect this process and the representational assumptions relating to it.

Evidence for function assignment

It may not immediately be clear why grammatical functions should be distinguished from constituent structure, since there is to a great extent an isomorphism between function and configurational position in English; for example, the subject almost always appears immediately preceding the verb. This is not true of all languages, however. In German, for example, it is possible for the subject and object NPs to appear in both pre- and post-verbal position, as (3.3) shows, with the grammatical function of each NP being indicated by the case marking on the determiner.

(3.3) a. Das Mädchen sah den Mann
$The_{nom/acc}$ $girl_{nom}$ *saw* the_{acc} man_{acc}
'The girl saw the man'

b. Den Mann sah das Mädchen
The_{acc} man_{acc} *saw* $the_{nom/acc}$ $girl_{nom}$
'The girl saw the man'

Hence functional structure must be dissociated from constituent structure.

The main evidence for a process of function assignment comes from speech errors. The first type of error involves pronominal substitutions. In English, pronouns – unlike other types of NP – are marked for case, associated with particular grammatical functions. Pronouns associated with the subject function are assigned nominative case, whilst those fulfilling other functions are assigned oblique case. In an error such as *You must be too tight for them* (intended: *They must be too tight for you*) (Stemberger 1982), each pronoun is marked with the correct case for the position in which it appears (for example, nominative case in subject position) and not that of its intended position. This suggests that it is not simply a case of words being associated with the wrong position in the syntactic structure, but rather of words being associated with the wrong grammatical function. The second piece of evidence concerns subject–verb agreement in sentences where the NP intended to appear in subject position exchanges places with another NP. In these cases, Stemberger (1982) noted, the verb usually agrees with the NP actually in subject position and not the intended subject, as in *Most cities*

are true of that (intended: *That's true of most cities*), which implies that the subject NP was already assigned the nominative function when subject–verb agreement was computed.

Bock, Loebell & Morey (1992) found experimental evidence for functional processing. Their experiment (described in more detail in Chapter 6) required subjects to produce a sentence and then describe a conceptually unrelated picture. In previous work (Bock 1986b; Bock 1989; Bock & Loebell 1990), it was found that the constituent structure of the first sentence could affect the constituent structure of the picture description. In the 1992 experiment, Bock *et al* manipulated two factors. One was conceptual, relating to the animacy of entities in the prime and picture, while the other was – as before – constituent structure. They found distinct effects of each factor. The conceptual factor affected the assignment of animate/inanimate entities to different functions (e.g. an inanimate subject appeared more often following another inanimate subject than following an animate subject), but this was distinct from the effect of the constituent structure manipulation. They interpreted this as evidence that they were tapping into two processes, one involving the assignment of grammatical functions and one involving the creation of constituent structure.

Factors affecting function assignment

We now turn to the processes which underlie function assignment and the factors which determine which lemma is associated with which grammatical function. This assignment must of course be compatible with the pre-verbal message, but within this constraint there is a large degree of flexibility.

A number of factors have been hypothesised to play a role in function assignment, including thematic roles, perceptual prominence and linguistic prominence. Thematic roles could control function assignment in terms of the Thematic Hierarchy proposed by Jackendoff (1972). The Thematic Hierarchy places Agent in the highest position; if function assignment followed this, then the entity with the Agent role would be assigned the subject function, and so on, simultaneously descending the Thematic Hierarchy and the NP Accessibility Hierarchy (Keenan & Comrie 1977) (thus the next function to be assigned would be the function associated with the direct object, and so on). However, although there is a close correspondence between agency and subjecthood, the correspondence is not complete. For example, two entities standing in essentially the same semantic (thematic) relationship may fulfill different grammatical functions: in (3.4), *Rachel* is the Experiencer and *the picture* is the Percept in each case:

(3.4) a. The picture pleases Rachel

b. Rachel likes the picture

Alternatively, the apparent connection between agenthood and subjecthood could be an instance of a link between perceptual/attentional focus and subjecthood: agents tend to be perceptually prominent because they move. Experimental studies do not offer strong confirmation of this hypothesis. Studies by, among others, Osgood (1971) and Bates & Devescovi (1989) showed only weak effects of perceptual prominence on word order, for example in descriptions of actions, once features such as animacy had been taken into account. For example, Osgood found that it was difficult to induce passive constructions by purely perceptual means.

In addition to perceptual prominence, an entity can also be linguistically prominent. Clefting, pseudo-clefting and interrogatives (3.5) can all serve to make one entity prominent (e.g. for contrastive purposes):

(3.5) a. It was the bike that was stolen.
b. What Anna was riding was the bike.
c. What was happening to the bike ?

Similarly, entities which have already been introduced into the discourse may be prominent. A link has frequently been drawn between the nominative function and 'given' information (Halliday 1970). Experimental evidence has demonstrated that information already present in the discourse tends to be associated with the subject function over new information (Bates & Devescovi 1989; Perfetti & Goldman 1975; Bock 1977; Bock & Irwin 1980; Engelkamp & Zimmer 1983). For example, Bock (1977) found in a recall test that subjects tended to promote given information to subject position (in other words, assign it the nominative function) and relegate new information to a lower function, although the original stimulus had the opposite order.

Bock (1987b)

These effects suggest that function assignment may be driven by a number of factors. However, there does seem to be a link between the factors. In each case, the subject function seems to be connected to saliency or accessibility. For example, agency, animacy and discourse focus all have the effect of making one entity more salient and hence, plausibly, more accessible. This idea was developed by Bock (1987b), who suggested that function assignment is based on accessibility, with functions being assigned from least to most oblique (following the Keenan-Comrie Accessibility Hierarchy), governed by the accessibility of the appropriate lemmas.[3] Accessibility could be affected by a number of factors, including those outlined above. One attractive feature of this proposal is that it is a means of capturing the partiality of the connections outlined above between thematic roles, perceptual focus etc., and grammatical functions. No single factor would determine the assignment; instead it would be the result of the interaction of several factors. For example, although Agents would typically be more accessible and hence appear as the subject, in certain circumstances their accessibility could be surpassed by that of the Patient if the Patient was animate and in discourse focus.

There is supporting evidence for this proposal. Bock & Warren (1985) found that the concreteness of entities (which seems to be linked to predicability and hence to accessibility - more predicable entities have a richer set of links in the conceptual network and may hence be accessed in more ways) had an effect upon grammatical role assignment. Bock and Warren presented subjects with sentences which they were subsequently asked to recall. The sentences included active/passive constructions and conjunctive structures. Each sentence included nouns which contrasted in concreteness, such as *doctor* and *shock*. They found that subjects had a tendency to promote the more concrete entity to a higher grammatical function during recall, resulting in its appearance earlier in the sentence. However, there was

[3]Note that the Noun Phrase Accessibility Hierarchy (Keenan & Comrie 1977) refers to the possibility of relativisation upon an NP fulfilling a particular grammatical function; it does not refer to 'accessibility' as intended here.

no comparable effect with the conjunctive expressions, where both entities fulfilled the same grammatical role: there was no tendency for more concrete conjuncts to precede less concrete ones. Bock and Warren argued from this that conceptual factors must be affecting function assignment and not simply word order. McDonald, Bock & Kelly (1993) used a similar technique but systematically varied the effect of animacy. Animacy is also linked to predicability, and hence animate entities should be more accessible than inanimate entities. McDonald *et al* found that animacy had an effect upon functional assignment in simple transitive sentences but no comparable effect upon word order in conjunctive expressions.

Bock (1986a) showed that *relative* accessibility could also be artificially manipulated. She used an experimental method where subjects heard and repeated a priming word and then described a subsequently presented picture. The prime was semantically related to one of the entities which appeared in the picture. Bock found that there was an overall tendency for primed entities to appear as the subject in the picture description, irrespective of their animacy or thematic role. This can be interpreted as priming affecting the relative accessibility of one entity and hence increasing its likelihood of being assigned the nominative function.

Overall, Bock's model suggests that verb lemmas are specified for arguments which are in turn specified for thematic role and grammatical function (e.g. subject). Those lemmas which correspond to entities are tagged with thematic roles according to the message specification and then linked to appropriate argument slots, such that the least oblique function is assigned first. The eventual structure which is returned depends upon two factors: the accessibility of the entity lemmas and the relative strength of the verb forms. The more accessible an entity (whether through inherent or derived saliency), the faster it will be accessed and hence the more likely it is to appear in a higher function, such as the subject function. This may be in tension with the strength of the verbal lemma: actives, for example, have greater base activation than passives and hence are more likely to fill their argument slots first. A competition may result between assigning a particularly accessible element to the subject role of a passive sentence (function assignment takes priority) versus assigning it to the object role of an active sentence (verb form strength takes priority). Bock (1987b) suggested that verb form strength usually takes priority.

The span of functional processing

There seems to be a general consensus that these processes operate over approximately clausal units. There are two sources of experimental evidence for this. Recent work by Bock & Cutting (1992) investigated the incidence of 'attraction' errors, where the verb agrees with a noun embedded in a complex subject NP rather than with the head noun, such as *The story about the small babies were all lies* (see also (Bock & Miller 1991; Bock & Eberhard 1993; Fayol, Largy & Lemaire 1994; Vigliocco, Butterworth & Semenza 1995)). Bock and Cutting presented complex NPs with either clausal or PP modifiers (*The story that they stole the babies* versus *The story about the small babies*) to subjects and asked to complete them as full sentences. They found that there were significantly more errors following PP modifiers than following clausal modifiers. Bock and Cutting proposed an explanation based upon the assumption that the units of functional processing are clauses. In the clausal modifier condition, the error-eliciting local noun *babies* is in a separate clause from the main verb;

since it forms part of a separate planning unit, it cannot affect the agreement features on the main verb. In the PP modifier condition, however, the local noun is in the same clause as the main verb and so in the same planning unit; as a result, it can interfere with the process of subject–verb agreement. Bock and Cutting suggested that this implicates clauses as an basic unit in functional processing. (I will return to this experiment and its implications in considerably more detail in Chapter 5).

Further evidence comes from a series of experiments by Ford and Holmes (Ford & Holmes 1978; Ford 1982; Holmes 1988). Ford & Holmes (1978) found that subjects' response latencies to random auditory signals during extemporaneous speech increased at the boundaries of both 'surface' and 'deep' clauses, which essentially correspond to finite and non-finite clauses. Ford (1982) found similar results in a study of pauses, though her results were more equivocal. Holmes (1988), also studying pauses in speech, confirmed that finite and non-finite clause boundaries induce qualitatively comparable patterns of pausing. In a further experiment, she asked subjects to read aloud a number of sentences taken from descriptions elicited in the first experiment. Holmes reasoned that since both content and form were provided for them, any pauses should reflect phonological and prosodic planning, perhaps to aid listeners' comprehension. She found that non-finite clauses do not tend to elicit pauses during reading aloud. This suggests that the pauses found before these clauses in extemporaneous speech result from the speaker's syntactic/semantic planning and not from phonological/prosodic planning. Overall these results suggest that clauses, both finite and non-finite, play an important role in speech production.

Evidence from speech error data implies possible limitations on the number of clauses which can be processed simultaneously. In his corpus, Garrett (1980) found that only 20% of word-exchange errors occurred across clause boundaries. On this basis, he proposed that a maximum of two clauses can be planned at a time.

Summary

To summarise, there is both experimental and speech error evidence for a level of processing at which grammatical functions are assigned to lemmas prior to constituent structure elaboration. The models discussed here assume that verb lemmas are associated with argument frames which are specified for grammatical functions and thematic roles. In addition, the models assume that functional processing makes reference to a syntactic category of clauses.

3.2.3 Constituent structure processing

The previous section discussed how a functional structure is generated; in this section, I will discuss how this functional structure is then mapped onto a constituent structure. It should be noted that while the picture of the production system which I have presented so far is one which is generally accepted, there is a certain degree of disagreement about the elaboration of constituent structure.

Evidence for constituent structure processing

Speech error evidence concerning sound substitutions suggests that there is a level of processing at which ordering information is encoded and which acts over smaller units than functional processing. Unlike the word substitutions discussed in the previous section, which seem to offer evidence about function assignment, sound substitutions such as *He bings sadly* (intended: *He sings badly*) overwhelmingly involve words which are adjacent within the same phrase; in Garrett's (1980) corpus, 87% of sound exchanges involved words within the same phrase. Experimental evidence suggests that this level of processing is concerned with constituent structure.

Studies of the phonological properties of speech show a close correlation between a phrase structure analysis of sentences and pausing and changes in word/vowel length and fundamental frequency. Grosjean, Grosjean & Lane (1979) found a strong correlation between pause duration in normal speech and the complexity of phrase structure (as measured by an index of branching complexity). Cooper & Sorenson (1981) showed that words are pronounced with a greater fall in pitch preceding major syntactic boundaries. In sentence recall tasks, Johnson (1965, 1966) found that subjects were better at recalling words within the same phrase than words which formed parts of different phrases.

Most convincingly, Bock and her colleagues' studies of syntactic priming effects suggest that processing at this level is concerned with constituent structure (Bock 1986b; Bock 1989; Bock & Loebell 1990; Bock, Loebell & Morey 1992). Bock (1986b) showed that the constituent structure of subjects' picture descriptions was influenced by the constituent structure of a previous, unrelated sentence. Bock found that subjects were more likely to produce a passive description (e.g. *The boy is being stung by the bee*)after repeating a passive priming sentence (*The referee was punched by one of the fans*) than after repeating an active priming sentence (*One of the fans punched the referee*). Bock argued that this was caused by the priming of the processes responsible for creating syntactic structure in language production. In subsequent experiments, Bock & Loebell (1990) examined whether the form-repetition effect could be based upon the repetition of metrical structure or event-type instead of syntactic structure. They found that similarities along these dimensions were not responsible for the priming effect. Priming occurred as long as the constituent structure was held constant over prime and target, even if the type of event varied (locative sentences such as *The 747 was landing by the control tower* primed passive sentences, for example); however, when they compared primes with the same prosodic structure but different syntactic structures (*John brought a book to Stella* versus *John brought a book to study*), only the primes with the same constituent structure as the target produced a priming effect. This implies that the processes responsible for the output are essentially syntactic in nature. I will return to this in more detail in Chapter 6.

Theories of constituent structure generation

The evidence suggests that the output of this level of processing is a constituent structure representation. We can now ask the question of how the functional structures which are the output of functional processing are mapped into these constituent structure representations. Below, I will present some of the theories which have been proposed.

Garrett (1980,1982)
Garrett (1980, 1982) proposed a model of language production with the same overall architecture as that presented in Figure 1. It differs in one detail: as we shall see below, Garrett's model does not assume a separate set of processes for inflectional processing. Garrett was primarily concerned with identifying the various levels of representation and did not discuss the nature of the processes involved in language production or the relationship between linguistic theory and psycholinguistics. As a result, his model is wholly non-committal on the question of *how* constituent structure is elaborated; indeed, he referred to 'the (unknown) processes which select phrasal frames,' (Garrett 1982, p.61).

However, it is clear that in his model, constituent structure elaboration involves the selection and association of 'phrasal frames'. Garrett assumed that there are a finite number of frames and that individual lexical items are specified to be compatible with certain frames. For example, *run* and *sneeze* might both be associated with the same (intransitive verb) frame. Thus the frames must be at least partially defined in terms of abstract categories. However, it is not possible to identify other characteristics of these frames in any detail. It is not clear, for example, whether the term 'phrasal' in this case refers to the same type of entity as it does in theoretical linguistics, i.e. the maximal projection of a category. Nor it clear whether the frames should be equated with rules for generating structure or whether they are instead compiled-out fragments of structure which are simply slotted together. (Note that the latter would be incompatible with the Strong Competence Hypothesis which is assumed in this thesis; I will return to this in my discussion of Lapointe and Dell's model.)

The output of constituent structure processing consists of a hierarchically structured representation which contains pointers to open class words but not the words themselves. Closed class elements are afforded a different status: unlike open class words, they are directly encoded into the constituent structure, forming an intrinsic part of the phrasal frame and helping to define it. In Garrett's words, close class elements '...are identified with their phrasal configurations,' (Garrett 1982, p.61). Hence whereas an open class word like *run* is specified to be compatible with particular frames, a closed class element like *the* is actually specified as part of a frame.

Garrett made this proposal on the basis of speech error and pathological evidence which suggests that closed class and open class elements do not behave as a unified class. Firstly, closed class words do not tend to participate in speech errors. Even sound errors, which tend to disregard syntactic category information, usually respect the open–closed class distinction. More significantly, during word exchanges closed class elements usually remain in their original position while open class elements move around them, for example *She's already trunked two packs* (intended: *She's already packed two trunks*) (Garrett 1975), where the inflections appear in the positions appropriate for the intended utterance, rather than moving with their associated stems. This suggests that closed class elements have a strong connection to particular structural positions.

Evidence from language pathology supports the existence of a special route for closed class items. Agrammatic aphasics tend to display a particularly acute closed class impairment. This is unexpected, since closed class items are extremely high in frequency, and high frequency items are usually the best preserved in agrammatism. Bradley, Garrett & Zurif (1980) used

this evidence to argue for a specialised closed class retrieval system. They suggested that this system is normally involved in the construction of syntactic frames and that agrammatic aphasics' dysfluent speech results when the system is disrupted.

Garrett's model has been attacked on two fronts. The first casts doubt upon his speech error data, specifically the disparate behaviour of open and closed class words. It seeks to explain this in terms of differences in frequency, rather than a distinction based upon specialised access procedures. For example, Segui, Mehler, Frauenfelder & Morton (1982) found that closed and open class words behaved identically in a lexical decision task, once matched for frequency. Similarly, Dell, Segal & Bergman (1985) (cited in Bock (1989)) found an inverse correlation between frequency and susceptibility to speech errors for homophonous but non-homographic closed and open class words (such as *we* and *wee*), regardless of syntactic category.

The second line of attack focuses upon the model's empirical predictions. Bock (1989) used the syntactic priming technique which has already been described to test Garrett's model. Her experiment involved dative and prepositional object sentences:

(3.6) a. The girl was handing the man a paintbrush.
b. The girl was handing a paintbrush to the man.

Bock examined whether the proportion of prepositional object sentences such as (3.6a) would increase following both types of priming sentence in (3.7) below, which include different prepositions.

(3.7) a. The secretary was baking the cake for the boss.
b. The secretary was taking the cake to the boss.

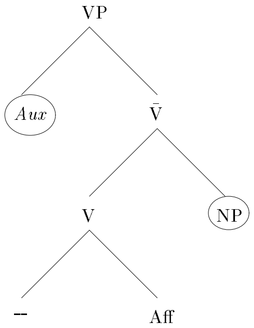
Prepositions are drawn from the closed class; if closed class elements are intrinsic to the syntactic frame, as Garrett claims, then the sentences in (3.7) below will involve different frames, one associated with the *for* sentence and another associated with the *to* sentence. We would therefore expect to find no priming effect when the priming sentence and the target sentence involve different prepositions, since they should involve different frames. If the syntactic frame is a more abstract representation, however, which specifies phrase structure but has no lexical content, then any priming effect will be unaffected by the different prepositions in prime and target, and both sentences in (3.7) above should be equally successful in priming a prepositional object sentence such as (3.6b). Bock found that the priming effect was equally strong whether the prime and target contained the same preposition or different prepositions. She concluded that the processes which build the phrasal structures in language production are not 'inextricably intertwined with the free-standing elements of the closed class vocabulary,' (Bock 1989, p.184).

To summarise, Garrett's model makes very few explicit assumptions about syntactic structure. It assumes the existence of 'phrasal frames', but it is not clear what information is contained within these structures, nor how they are constructed. One point which is clear, however, is that the structures are partially defined in terms of abstract categories and partially defined in terms of the specific closed class elements which they contain. Hence Garrett's model assumes representations which cannot be wholly defined in terms of abstract categories but must be at least partially lexically specified.

Lapointe and Dell (1989)

Lapointe and Dell's (1989) model was intended to address some of the empirical shortcomings of Garrett's model and also to cast some light upon the dynamic aspects which Garrett's model does not discuss, such as the nature of constituent structure representations and the processes responsible for generating them.

Lapointe and Dell proposed that syntactic structure is elaborated by assembling stored structural fragments. They distinguished two types of fragment. Full-phrase fragments are associated with major lexical categories; they encode structure corresponding to a maximal projection, extending down to the stem level. As in Garrett's model, inflections are built directly into the frame. These frames also contain tags of where other phrase fragments or function word fragments are to be attached. For example, the phrase fragment associated with a transitive verb will consist of a V node where the stem will be inserted, a direct encoding of that verb's inflection (marked here as 'Aff'), $\bar{\mathrm{V}}$ and VP nodes, plus markers of where the Aux and NP fragments will be attached, as in (3.8).



(3.8)

Function word fragments, the second type, are 'degenerate', in that they consist of just the category node (e.g. Det or Aux). They also differ from full phrasal fragments in that – like inflections – their lexical content is 'hard-wired' into the fragment, as in (3.9).

(3.9)

This approach captures the ambiguous status of function words. On the one hand, like inflections they are directly encoded into the fragment, predicting that they will not be affected by processes of word form retrieval. On the other hand, they are represented in their own fragments and are attached to the fragments containing inflections, suggesting – in opposition to Garrett's model – that function words and inflectional affixes are not processed identically during production.

Both types of fragment are stored in an (unordered) set. Lapointe and Dell suggested that they are accessed through the mediation of semantic 'notion stores', sequences of semantic specifications such as tense, aspect, number and so on, which are typically associated with inflections and function words. Each notion sequence contains pointers to the phrase and function word fragments which express those notions. The syntactic processor scans the functional level representation and finds sequences of specifications which match one of the specifications stored in the semantic notions store, guided by a set of 'correspondence rules.' The rules define which fragments are accessed and simultaneously index them in such a way that the fragments can be appropriately associated together and the lexical stems inserted into the appropriate phrase fragments. This process makes an unordered set of fragments available to the processor. Lapointe and Dell claimed that the index which is assigned to each fragment during application of the correspondence rules is sufficient to ensure that the fragments eventually appear in the correct linear order and hierarchical structure and that the fragments are not combined into a larger structure, but instead are coindexed with positions expressed in the S and VP fragments.[4]

Lapointe and Dell's model makes some very specific assumptions about syntactic representation, both in terms of the type of information which is represented and the span of structure over which it is defined. Their model assumes the existence of syntactic categories such as N, V etc. The stored fragments encode both dominance and linear precedence information about relationships between these categories. Function word fragments encode local relationships, between lexemes and the category nodes which immediately dominate them. Full phrase fragments are maximal projections and encode more than strictly local relationships; for example, the fragment associated with a transitive verb contains specifications not only for V and $\bar{\mathrm{V}}$ nodes, but also for an Aux node. The model also assumes the existence of fragments with a specified lexical content: whereas a full phrasal fragment will be linked to a class of words – for example, the fragment in (3.8) above will be linked to all transitive verbs – function word fragments are associated with a single lexical item. Like Garrett, then, their model not only assumes a distinction between open- and closed-class words, but also that syntactic structure is not characterised in terms of abstract category information alone.

Yngve (1960)

Having examined psychologically-based theories of syntactic structure generation, I will now turn to two proposals from the fields of Artifical intelligence and Natural Language Processing. Theories from this background naturally tend to be more concerned with implementational issues rather than psychological adequacy, but the two theories discussed here both have implications for psycholinguistic models.

Yngve (1960) proposed a model based on a phrase structure grammar in which structure is elaborated top-down and from left to right. At each node, information is stored about right-

[4] Their statements in this regard appear contradictory: on page 134 they stated that 'there should be no need to *combine* fragments at all. The only thing that the control mechanism has to do is line up the returned fragments in the order determined by their indices,' [original emphasis]; on page 151, however, they argued that 'After being selected, a syntactic fragment is combined with other fragments by a set of well-defined composition rules.' Since they went to some length to describe a mechanism which obviates the need for a connected phrase structure representation, I am assuming here that the first statement most accurately conveys their position.

branch commitments. For example, generation of a sentence would begin with elaboration of the root (S) node, where a single right-branch commitment is made (for the VP), followed by elaboration of the subject NP, beginning with the determiner and then moving onto the noun. Yngve's model makes explicit predictions about the relative difficulty which branching imposes upon the production system. Since rightward commitments must be stored while other branches to the left are elaborated, the greater the depth of the left-hand side of the tree, the greater the memory load is hypothesised to be. Thus elaboration on the subject position in English should impose more of a memory load than elaboration on the direct object position, in a simple transitive sentence. A 'mean depth' can be calculated for any sentence by dividing the sum of the number of left-branches dominating each word in the sentence by the number of words in the sentence, giving some measure of the predicted complexity of the sentence. Yngve's hypothesis has been tested experimentally, with varying degrees of success; sentence recall tasks found no firm support (see Frazier (1985) for a review), but Forster (1967) showed that subjects found it easier to complete sentences which had their ends deleted than sentences which had their beginnings deleted, as Yngve's model would predict.

A non-experimental source of support for Yngve's theory comes from the fact that 'heavy' constituents typically appear later in sentences than lighter ones. This is particularly noticeable in cases of Heavy NP shift (3.10b) and extraposition from NP (3.11b).

(3.10) a. Amy handed the huge dark brown leather-bound book to Rebecca.

b. Amy handed to Rebecca the huge dark brown leather-bound book.

(3.11) a. Andy bought the vase which is very heavy Czechoslovakian lead crystal today.

b. Andy bought the vase today which is very heavy Czechoslovakian lead crystal.

Again, Yngve's theory predicts the appearance of syntactically complex constituents later rather than earlier in the sentence. On the other hand, as Frazier (1985) pointed out, this would be predicted by any theory where complex constituents appear at points of low processing complexity. Furthermore, as Bock (1987b) noted, for depth calculations to be made precisely speakers must know in advance how their sentences will end, yet as we have seen, there is evidence that utterances may be initiated before little more than the subject and the verb – or perhaps even just the subject – have been planned (Lindsley 1975).

In summary, Yngve's model is based directly on a phrase structure grammar. It makes interesting predictions about where we would expect to find a heavier processing load in production. However, there is evidence that one of the core assumptions on which its relevance to processing rests – that (at least a large part of) the sentence must be planned in advance – is not correct.

Kempen and Hoenkamp (1987)

An alternative approach was put forward by Kempen & Hoenkamp (1987). Instead of a central process which generates the structure associated with an entire clause, they suggested that individual phrases are generated in parallel by specialised procedures and then joined into a single structure. In their model they also rejected a distinction between knowledge of language and the way in which it is used. Instead, the model integrates assumptions about the form

of rules, and the structure and functioning of the syntactic processor. In particular, they proposed that the symbols referred to in rules should be viewed 'not as passive structural elements, but as *active procedures* or *modules*,' [original emphasis] (Kempen & Hoenkamp 1987, p.210).

In their model, structure building is triggered by the information contained in the lemmas. Each lemma contains specifications of its syntactic privileges. These specifications are active procedures: they consist of calls to procedures which will build the structure associated with the lemma. For example, a noun such as *dogs* will call the specialised procedure which constructs N nodes and the NP procedure which constructs NPs. As each lemma is retrieved, its procedures are initiated; if several lemmas are retrieved simultaneously, then these individual procedures may all run in parallel. Thus the procedures responsible for creating the subject NP, VP and object NP structures may carry out their work simultaneously. As each piece of structure is completed, it is returned to the procedure which called it and unified into the structure which that procedure has created. A set of 'appointment rules' encode dominance relations within the structure, whilst a set of word-order rules determine where the substructure is to be inserted if there is more than one possible slot. Thus an appointment rule may state that an AdjP called by an NP procedure will be the daughter of the $\bar{\mathrm{N}}$, whilst a word-order rule will specify that it must precede the N.

In this way, production can be incremental: articulation may begin as soon as the subject NP is unified into the S structure, whether or not the remaining processes have completed their work and returned their fragments of structure. This could also explain the preference noted above for syntactically complex constituents to appear late in the sentence. Such constituents must call many subprocedures and hence will take longer to encode, which means that they will become available later during production of a sentence than simpler constituents which require relatively fewer subprocedure calls.

The same principle might underlie the differences in articulation latency between sentences with complex subjects and complex objects found by Ferreira (1991). Ferreira found that articulation latencies were reliably longer preceding sentences which had a syntactically complex subject NP and a simple object NP than sentences which had a syntactically simple subject NP and a complex object NP. Although Ferreira explained her findings in terms of the complexity of phonological encoding, they are also consistent with an explanation based upon syntactic complexity: syntactically complex subjects take longer to grammatically encode than syntactically simple subjects and hence will take longer to become available for articulation. Syntactically complex object NPs will also take longer to grammatically encode than simple object NPs, but this can occur whilst articulation of the subject NP is taking place. Hence the syntactic complexity of the object NP does not affect the time taken to initiate articulation of a sentence.[5]

Whilst most structure is generated directly from lemmas, Kempen and Hoenkamp suggested that function words are generated separately, through a process which refines the set of procedures which a lemma calls, either by adding a new specification to the lemma itself (which results in the creation of inflections), or by adding an additional subprocedure to its

[5] Ferreira found that syntactically complex object NPs were more likely to cause pauses later in the sentence, following articulation of the subject NP, as we might expect from this account.

list of procedures to call (which may result in the retrieval of a function word such as a preposition). This must take place prior to the initiation of the procedure calls specified in the lemma, since it may affect the subprocedures which the lemma calls. Hence as in Garrett's model, functional elements do not play the same role in structure generation as open class elements.

In summary, Kempen and Hoenkamp's model allows flexible incremental production. It also makes explicit assumptions about both the format of grammatical rules and the structure and functioning of the syntactic processor. Notably, it eschews a competence/performance distinction: in their model, knowledge of language and process are intertwined, since the information which is contained in the lemmas consists of procedure calls, not declarative statements of syntactic privileges. However, their model is not entirely free from purely declarative knowledge. The procedure calls embodied in lemmas do not include any dominance specifications; for example, we have already seen that the NP procedure may call an AdjP procedure, which will return its resulting fragment of structure to the NP procedure. It must be specified somewhere that this AdjP will then be the daughter of $\bar{N}$; this information is not encoded in the lemma itself. Thus the Kempen–Hoenkamp model requires a set of (declarative) appointment rules to specify dominance relations within the final structure. Nor do lemmas contain ordering specifications. For this reason, their model similarly requires a set of word-order rules. But these declarative word ordering and immediate dominance rules contain a great deal of the same information as a declarative (competence) grammar. The only information which is omitted is how this information should be related to specific lexical items. Thus, although it blurs any sharp distinction between syntax and syntactic processor, Kempen and Hoenkamp's model does make reference to some declarative knowledge of syntax.

Summary

To sum up, we have seen that although there is behavioural evidence to support the existence of a stage at which constituent structure is processed during language production, little is known about how this structure is generated or the details of how it is represented. Existing theories assume that hierarchically structured abstract categories play some part in syntactic representation, but they differ with respect to the domains over which syntactic relationships are defined (for example, Lapointe and Dell's model employs fragments which specify entire phrasal projections) and the extent to which lexical content is specified as an intrinsic part of the structure. Most of the models also distinguish between the way in which structure associated with open-class words is processed and the way in which structure associated with closed class words and inflections is processed.

3.2.4 Summary

We have seen that the language production system can be decomposed into a number of distinct components whose identity is generally agreed. Their operation seems to be autonomous, although this is a more contentious point. The evidence suggests that syntactic processing takes place at two levels, one concerned with the assignment of grammatical functions to lemmas and one concerned with the elaboration of constituent structure. This implies that the

mental representation of syntactic structure includes both functional and constituent structure specifications. The way in which these specifications are represented (and indeed, put to use) has been the subject of little research, but there does seem to be agreement that constituent structure is represented at least partially in terms of hierarchically structured abstract categories which subsume individual lexical items.

3.3 Theories of Language Comprehension

In some ways, language comprehension is more amenable to experimental study than language production: while a major problem in investigating production lies in controlling the input to the production system, i.e. disentangling the effects of non-linguistic factors from linguistic factors upon sentence form, comprehension experiments allow the experimenter to control the input (for example the material which a reader must process) precisely. However, as a corollary it is much harder to investigate the eventual result of processing in comprehension than in production. In language production, the output lies in the public domain and hence is open to inspection; in comprehension, the input is in the public domain but the output – an interpretation – can only be inferred indirectly.

Experimental studies have therefore tended to focus upon the dynamics of performance rather than the form of the output, using reaction times as a measure of the difficulty encountered in processing. The techniques used to gather these reaction times vary considerably in their sensitivity, the degree to which they allow localisation of an effect, and their intrusiveness. They include self-paced reading, where subjects read a word, phrase or sentence at their own pace, pressing a button to request the next unit, and eye-tracking, where subjects' eye-movements during reading are recorded. Eye-tracking has the advantages of being less intrusive and more sensitive than self-paced reading, and may allow separation of initial analysis from subsequent reanalysis. However both methods are uninformative about the nature and time course of the underlying processes which are causing processing difficulty. They do not allow us to distinguish between qualitatively distinct types of difficulty which may coincidentally cause the same degree of eye movement disruption.

One new technique which may give more of an insight about types of processing difficulty is event related potentials (ERPs), positive and negative electrical charges which can be detected on the scalp during an encephalogram. Linguistic stimuli may induce systematic waveform deflections, time-locked to the onset of the stimulus. Two apparently distinct deflections have been isolated. One of these is a negative deflection which seems to be correlated with semantic anomaly, appearing as a negative wave approximately 400 ms after the onset of the anomalous word. The other is a late positive deflection which has been shown to appear approximately 500–800 ms after the onset of a syntactic anomaly. (See Garnsey (1993) for a review of these effects). While it is not possible to draw any conclusions about the procedural aspects of processing from the relative time course of these effects, nor about the site of syntactic/semantic processing from the position on the scalp where these effects are located, they do seem to distinguish two qualitatively distinct types of processing.

One final methodological point concerns the type of stimuli which are studied. Just as the study of language production has tended to concentrate upon evidence of imperfect processing

– in the form of speech errors – as a means of inferring how normal processing occurs, so research into comprehension has focused upon difficulties in processing. It is much easier to detect disruptions and then use these as a basis for a model of normal processing than it is to draw conclusions from a homogeneous behavioural pattern. As a result, work in comprehension has largely examined how people parse and interpret ambiguous sentences. Studying their preferences and strategies when faced with a choice of analyses can be informative about the principles which underlie sentence processing in general.

3.3.1 The architecture of the comprehension system

It is widely assumed that comprehension involves lexical, syntactic and semantic processing. In the following sections, I will give a very brief overview of the architecture of the comprehension system before concentrating on some of the models of syntactic processing which have been proposed, using as an example the sentence *The ship sank.*

Lexical access

The first stage in comprehension involves the identification of each lexical item in the input and the recovery of its associated syntactic and semantic features. The two major classes of model for lexical processing are search models and direct access models. Search models characteristically assume that lexical access involves constructing a representation of the input based on its perceptual features and then comparing this representation against representations stored in the lexicon (see for example Forster (1976)). In these models there is a central processor which oversees the initial construction process and the subsequent search. These models are hence two-stage, the initial stage comprising the construction of a representation and the second stage comprising a search through the bins.

An alternative to this view of lexical access suggests that input features are associated directly with representations in the lexicon. Alternatives which are compatible with the input are activated in parallel; a word which receives a criterion level of activation is recognised. The main differences between this approach and the search approach are that input features have a direct effect upon activation of representations; processing takes place in parallel, with multiple hypotheses active simultaneously; and processing is not governed by a central controller. Exemplars of this approach include Morton's logogen model (Morton 1969) and the connectionist model of Seidenberg & McClelland (1989).

Experimental evidence suggests that the processor initially accesses all meanings for ambiguous words, but chooses the appropriate meaning and discards the alternative meanings very rapidly (Swinney 1979; Rayner & Duffy 1986). There is some debate about whether all meanings are accessed in all circumstances, or whether this is only the case where the alternative meanings occur equally frequently. MacDonald, Pearlmutter & Seidenberg (1994) suggested that when one meaning is significantly more frequent than others, only that meaning may be accessed initially; however, Hagoort and Brown (1994b) found evidence in an ERP experiment which is consistent with all possible meanings being accessed initially.

Lexical processing of our example *The ship sank* will result in identification of the words *the, ship* and *sank* and retrieval of their lexical entries, including syntactic category information.

Syntactic Processing

The output of lexical processing is an unstructured string of words, which become available incrementally. During syntactic processing, the syntactic relations holding between these words must be computed, to produce a hierarchically structured output which can then be interpreted. For example, faced with an input of *the, ship* and *sank*, the processor must correctly associate *the* with *ship* and then identify the resulting constituent as the subject of *sank*. Experimental evidence suggests that grammatical errors can be detected and rectified extremely rapidly, apparently on a word-by-word basis (Marslen-Wilson 1975, Marslen-Wilson & Tyler 1987). This suggests strongly that parsing is incremental and that a decision about how to integrate each word into the syntactic structure must be made as soon as it is encountered. Syntactic processing has been the subject of extensive research and will be discussed in the remainder of this chapter; I will therefore postpone further discussion until the following section.

Semantic processing

The final step in comprehension involves recovering the semantic content of the message. This may require not only computation of the semantic relations holding between words and phrases in the sentence (sentence meaning), but also computation of relations which hold over the larger discourse context, for example reference resolution.

Following proposals made in linguistic theory (see for example Dowty, Wall & Peters (1981)), sentence meaning is generally considered to be compositional; in other words, the semantic content of a sentence can be determined on the basis of the semantic content of its constituent parts. There is little evidence concerning how this content is retrieved and put together; Johnson-Laird (1983) suggested that it results in a relatively superficial propositional representation. For our example sentence, this might be something like $\textsc{sink}_{pst}(\textsc{ship})$.

Johnson-Laird (1983) suggested that the propositional representation is then integrated into the speaker's 'mental model'. According to his theory, a mental model is a representation of the real or an imaginary world which can be updated on the basis of new information and which contains tokens representing a limited set of entities, severely restricting the set of possible referents for a referring expression such as an anaphor or a definite NP. In this case, the mental model might contain a token representing a ship with which the definite NP *the ship* would be identified.

Although it has been suggested that semantic processing is delayed until clause boundaries (Fodor, Bever & Garrett 1974), there is evidence that interpretation may be incremental. For example, Vonk (1984) found in an eye-tracking experiment that fixation duration on a pronoun depended upon whether it could be matched to its antecedent on the basis of gender, suggesting that readers begin constructing an interpretation immediately. Hence it appears that some semantic processing – for example, integrating individual clauses into a larger structure (Gernsbacher, Hargreaves & Beeman 1989) – may be delayed until clause boundaries but that some – such as anaphor resolution (Sanford & Garrod 1989) – is initiated immediately.

Summary

This section has been concerned with giving a brief overview of the architecture of the language comprehension system. In the following section, I will concentrate on syntactic processing in considerably more detail, examining some of the theories which have been put forward and the evidence on which they are based.

3.3.2 Syntactic processing

Most research in sentence parsing has been concerned with examining which sources of information (whether this information is syntactic or non-syntactic) are brought to bear in constructing a syntactic representation of the input and how this information is put to use. Research has tended to investigate how decisions are taken when the input is ambiguous, using this to infer how unambiguous input is parsed.

Form-based models

The first approach can be called 'form-based'. Models falling within this category hold that people have preferences governing how they parse ambiguous input which can be characterised in terms of the structure of the representation which is constructed.

Frazier (1979,1990)
The best-known exponent of this type of model is Frazier. In Frazier's model, the processor searches through the set of phrase structure rules stated in the grammar as each word is identified, to see which rules are compatible with the input. If only one rule is compatible, then that rule is applied to create the relevant structure. If more than one is compatible, however, then the processor will choose which analysis to follow – and hence which rule to apply – according to certain principles. Frazier's (1979) work drew upon the seven parsing strategies proposed by Kimball (1973) and showed how essentially the same effects could be achieved by postulating two overarching parsing principles, Minimal Attachment and Late Closure, which make reference to major category information.

(3.12) Minimal Attachment:
Attach incoming material into the phrase-marker being constructed using the fewest nodes consistent with the well-formedness rules of the language under analysis.

(3.13) Late Closure:
When possible, attach incoming material into the phrase or clause currently being parsed.

In case of a conflict between the two principles, Minimal Attachment takes precedence.

Frazier suggested that these are universal principles holding across languages, which guide the choice of analysis followed by the processor whenever it encounters ambiguous input. If the input turns out to be incompatible with this analysis, the reader will have been 'led up the garden path' into a misanalysis – hence the term 'garden paths' for sentences where the dispreferred reading ultimately turns out to be correct. Following such a misanalysis, the

reader will be forced to reanalyse. Frazier therefore hypothesised that garden path sentences will show increased reading times, compared to sentences which are compatible with the two principles above. This hypothesis has been tested experimentally using a range of techniques and a variety of sentence types.

Frazier (1979) used a rapid serial visual presentation (RSVP) method to examine how quickly subjects made grammaticality judgements for sentence pairs such as those in (3.14) and (3.15):

(3.14) a. Sally was relieved when she found out the answer to the physics problem.
b. Sally found out the answer to the physics problem was in the book.

(3.15) a. While Mary was knitting the sock the jumper fell off her lap.
b. While Mary was knitting the sock fell off her lap.

Both sentence pairs involve a local ambiguity. In (3.14), it is not clear whether *the answer to the physics problem* should be analysed as the direct object of *found out*, as in (3.14a), or whether it is in fact the subject of an embedded clause, as in (3.14b). Minimal Attachment predicts that there should be a preference to attach it as the object of the main verb since this only requires an additional NP node dominating *the answer ...*, whereas the embedded subject analysis would require two additional nodes, the NP and an S dominating it. This means that (3.14b) should be harder to parse than (3.14a), since (3.14b) will initially be misanalysed. (3.15) involves a similar local ambiguity: it is unclear when *the sock* is encountered whether it should be analysed as the object of *mending*, as in (3.15a) or the subject of the – as yet unencountered – main clause, as in (3.15b). Late Closure predicts that it will be attached into the current clause, i.e. as the object of the subordinate clause. Hence (3.15b) should be more difficult to parse than (3.15a).

Frazier found that subjects reacted more slowly to the (b) versions in both cases, supporting her hypothesis. Subsequent work using eye-tracking has replicated her results. Frazier & Rayner (1982), using the same types of sentence, found that first pass gaze durations were longer for the disambiguating word of the garden path versions than the non-garden path versions. Similarly, the disambiguating region of the garden path versions caused more regressive eye movements. This suggests that the garden path versions of the sentences are associated with a greater processing load, which Frazier and Rayner attribute to initial misanalysis and subsequent reanalysis procedures.

More recent versions of the model (Rayner, Carlson & Frazier 1983; Frazier 1990) incorporate an additional thematic processor, which allows semantic factors to influence processing *after* the initial syntactic structure assignment. The thematic processor evaluates possible thematic frames associated with a lexical head in parallel. Once all potential arguments have been received, it chooses the most plausible frame and compares it with the current constituent structure analysis. If the two are incompatible, the thematic processor can force the constituent structure module to initiate reanalysis procedures. The thematic component of the model was proposed in order to explain how reanalysis can be initiated in globally ambiguous sentences such as (3.16) below, where there is no point at which the preferred analysis is ruled out on syntactic grounds:

(3.16) a. The spy saw the cop with binoculars but the cop didn't see him.

b. The spy saw the cop with a revolver but the cop didn't see him.

Minimal Attachment predicts that in both cases, the PP will be attached into the verb phrase such that it will be identified as an instrumental phrase. This is the correct analysis for (3.16a) but not (3.16b), where it should be attached as a modifier of the noun *cop*. Note, however, that it is only world knowledge which tells us that a Minimal Attachment analysis is wrong (because a revolver cannot be used as an instrument of seeing); there is no syntactic motivation to reanalyse the sentence. Thus in a model such as this, without some means of bringing semantic information to bear – the role of the thematic processor – there is no way of ensuring that a reader will ever reanalyse the sentence and so ultimately recover the correct interpretation.

Rayner, Carlson & Frazier (1983) suggested that the thematic processor can also help the reader during reanalysis by allowing world knowledge to be brought to bear upon plausible reanalyses. They investigated this hypothesis using eye-tracking, examining sentences such as those in (3.16) above and also (3.17) below:

(3.17) a. The florist who was sent the flowers was very pleased with herself.

b. The performer sent the flowers and was very pleased with herself.

c. The florist sent the flowers was very pleased with herself.

d. The performer sent the flowers was very pleased with herself.

According the model, sentences (3.17a) and (3.17b) should pose no difficulties; however, both (3.17c) and (3.17d), involve reduced relative clauses, which are incompatible with Minimal Attachment and hence require reanalysis. Rayner, Carlson & Frazier (1983) therefore predicted that reading times should be longer for these two sentences than for the first two sentences. In addition, they predicted that (3.17c) should be more difficult to reanalyse than (3.17d), because real world knowledge suggests that florists are very plausible agents for sending flowers, whereas performers are more plausible recipients than agents. Hence in (3.17c), the thematic relations in the correct reduced relative clause reading are *less* plausible than those in the incorrect main clause reading. Thus both structural preference and thematic considerations favour the incorrect main clause reading in (3.17c). In (3.17d), however, the thematic relations in the reduced relative reading are ultimately *more* plausible than those in the main clause reading. Thematic considerations should therefore favour the reduced relative clause reading and hence aid recovery in the (d) version, although both the (c) and (d) versions should elicit comparable initial misanalysis.[6]

As predicted, they found that reading times for the disambiguating region (from the final word of the PP to the end of the sentence) in (3.16) were longer for the non-minimally-attached version than for the minimally attached version. They also found that the reduced relative sentences (3.17c) and (3.17d) caused longer total reading times and longer reading times in the disambiguating region than the unreduced relative and main clause sentences (3.17a) and

[6]Note that in this case, reanalysis is triggered by syntactic anomaly, unlike in (3.16) where it is triggered by the thematic processor itself.

(3.17b), and elicited more regressive eye movements. There was also a difference between the two types of reduced relative sentence: the version where the initial main clause analysis involved an implausible thematic assignment (3.17d) was recovered from quicker than the version where the main clause analysis was plausible (3.17c).

Frazier's model has a number of key characteristics. Architecturally, it is both serial and modular: only one analysis is ever pursued at a time, and that analysis is governed by purely structural factors; semantic and discourse factors cannot override or indeed affect this initial analysis, although they may subsequently reject it and/or facilitate its reanalysis. It assumes the strong competence hypothesis, in that rules stated in the grammar have direct processing correlates (e.g. a VP $\rightarrow$ V NP rule in the grammar is matched by a process which constructs a VP from a V NP sequence).[7]

The model also makes explicit assumptions about the form of the grammar on which the parsing mechanism draws and the type of representation which is constructed. These assumptions can be separated into two, those which bear upon the type of information encoded in the grammar, and those which specify the content of that information. Minimally, Frazier's approach requires a set of constituent structure rules, an articulated theory of thematic roles and a lexicon. Her more recent work (for example Frazier (1990)) also includes a Binding module which deals with coreference and a Reference module to deal with referentiality, but these are not intrinsic to her approach in the way that thematic structure and in particular constituent structure are. The driving force of the model is clearly the complexity of the constituent structure representation which is constructed and this guarantees a pre-eminence for constituent structure relations in the grammar. Frazier (1989) argued at length for a model in which the initial constituent-structure analysis of the input is governed by item-independent syntactic rules referring to major category information and against models in which lexeme-specific information such as subcategorisation information is accessed and made use of during initial analysis (see Mitchell (1987) for (somewhat controversial) evidence that subcategorisation information may be ignored initially). In contrast to the general constituent structure rules which govern initial syntactic analysis, thematic frames are lexically specific, tied to individual lexical heads.

The emphasis of Frazier's model on representational determinants of misanalyses also necessitates certain very specific assumptions about the internal structure of particular constructions. As we saw in the previous chapter, for example, Frazier *et al*'s explanation for the preference for the verbal modifier reading over the NP modifier reading in (3.16) above relies upon a syntactic analysis in which the verbal modifer reading has fewer nodes than the NP modifier reading – which is of course contingent upon the particular analysis that one adopts.

Content-based theories

An alternative approach would be to base preferences on grammatical content rather than the structure of the representation. According to such content-based theories, the task of the parser is to construct a representation in accordance with grammatical principles; garden-paths occur when the input turns out to be incompatible with the ensuing analysis. Hence

[7]More recent versions do not assume the strong competence hypothesis; for example, the model outlined in Frazier (1990) makes use of a precompiled set of grammatical principles.

preferences are defined over types of syntactic information rather than over representations. This type of approach fits naturally with one particular linguistic theory, Government-Binding theory, where the concept of a single grammar subsuming all types of syntactic information has been replaced by a move towards knowledge of language as a set of individual modules imposing well-formedness constraints on syntactic structures.

Pritchett (1992)

Pritchett (1992) developed a theory of this type which is based on the assumption that 'the core of syntactic parsing consists of the local application of global principles,' (Pritchett 1992, p.68). Unlike Frazier and her colleagues, Pritchett restricted his attention to those misanalyses which give rise to conscious difficulty.[8] Pritchett's model is based on two principles, the first of which accounts for initial parsing preference, whilst the second accounts for the relative difficulty of reanalysis should that initial analysis turn out to be wrong:

(3.18) Generalised Theta Attachment:
Every principle of syntax attempts to be maximally satisfied at every point during processing.

(3.19) On-Line Locality Constraint:
The target position (if any) assumed by a constituent must be governed or dominated by its source position (if any), otherwise attachment is impossible for the Human Sentence Processor.

According to Pritchett, the parser will adopt whichever analysis allows it to satisfy the maximum number of grammatical constraints. He explicitly adopted a GB architecture for the grammar, comprising Theta, Case, Binding, Bounding, Control and X-Bar modules. It is the individual constraints imposed by these modules that the parser has to satisfy. Pritchett concentrated on the effects of the Theta and – to a lesser extent – Case constraints.

As each word is identified, the parser attempts to integrate it into the current analysis in such a way that it will receive a theta role (from the maximal theta grid associated with a verb) and Case. Let us see how his approach accounts for some of the data we have already discussed in relation to Frazier's model:

(3.20) a. Sally was relieved when she found out the answer to the physics problem.
b. Sally found out the answer to the physics problem was in the book.

(3.21) a. While Mary was knitting the sock the jumper fell off her lap.
b. While Mary was knitting the sock fell off her lap.

(3.22) a. The performer sent the flowers to her favourite fan.
b. The performer sent the flowers was very pleased with herself.

(3.23) a. The spy saw the cop with binoculars.
b. The spy saw the cop with a revolver.

[8]Confusingly, Pritchett used the term 'garden-path' to refer solely to these conscious misanalyses, where Frazier and colleagues use it to refer to all types of misanalysis. To avoid confusion, I will follow Frazier *et al*'s, reserving the term 'conscious garden path' for the constructions with which Pritchett is concerned.

In (3.20), the processor projects the maximal theta grid of *find out* when it encounters the verb: [<u>Experiencer</u> Theme]. Generalised Theta Attachment predicts that any NP following the verb should therefore be attached directly as its Theme, thus obtaining a theta role and Case. In (3.20a), this is the correct analysis; in (3.20b), however, the subsequent verb *was* makes this analysis impossible. *Was* also introduces its own theta grid [<u>Theme</u> Location]. At this point, then, reanalysis must take place: the clause must receive a theta role and the external theta role of *was* must be assigned. The theta criterion (and Case theory) can be maximally satisfied by reinterpreting *the answer to the physics problem* as the subject of the embedded clause (and hence its Theme), and the entire clause *the answer to the physics problem was in the book* as the Theme of the main verb. In this way all available theta roles are assigned, and every relevant constituent receives a theta role. Note, however, that this reanalysis is not costly: the ambiguous constituent *the answer to the physics problem* is ultimately assigned to a position which is dominated by its original position. The On-Line Locality Constraint therefore predicts no difficulty.

In (3.21), the situation is somewhat different. When the verb *knitting* is encountered, it projects its maximal theta grid [<u>Agent</u> Patient]. The subsequent NP *the sock* is assigned the Patient role. When the verb *fell* is encountered, projecting a [<u>Theme</u> Goal] grid, *the sock* must now be reanalysed as the Theme of *fell*. However, this has considerable processing cost associated with it: the NP has to move from one government domain (that of *knitting*) to another (that of *fell*), violating the On-Line Locality Constraint.

A similar conscious garden path effect is elicited in (3.22); however, this cannot be explained in terms of the two principles outlined above. The verb *sent* projects its maximal theta grid [<u>Agent</u> Patient Goal]. However, this one grid can be realised in more than one way: as a matrix clause, where *the performer* is attached as the Agent and *the flowers* as the Patient, leaving the Goal role temporarily unassigned; or as a reduced relative clause, where *the performer* is the Goal and *the flowers* is as before the Patient, and the Agent role is discharged on an empty category coindexed with a null operator. We would expect the latter alternative to be chosen, since it allows all three roles to be assigned. However, this is not in keeping with the experimental evidence, which shows a clear preference for the former, main clause analysis. Pritchett argued that the former analysis is pursued because the reduced relative analysis introduces an additional NP node (headed by *performer*) for which no theta role is yet available, since the main verb has still to be encountered. Once the matrix clause analysis has been pursued, subsequent reanalysis is difficult because the NP headed by *performer* must be reanalysed as the subject of the main verb *was* and assigned its Experiencer role. This reanalysis places it outside the governing domain of its initial position, violating the On-Line Locality Constraint.

Crocker (forthcoming)

An alternative content-based approach is offered by Crocker (forthcoming). It shares with Pritchett's approach the assumption of a principle-based grammar within the GB framework and an emphasis upon the satisfaction of the maximum number of grammatical principles at each point in the sentence, in order to maximise comprehension. However, this is achieved in a slightly different way. Crocker suggested that the syntactic processor comprises subprocessors, each of which is associated with a particular informational aspect of the grammar (the phrase structure processor; the coindexation processor; the chain processor; and the thematic processor); moreover, he proposed that these subprocessors are encapsulated and may not access information in any other subprocessor. This precludes explaining any attachment decisions – a decision by the phrase structure module – in terms of thematic structure, as in Pritchett's account. Crocker instead captured the same intuition in terms of a preference for attaching incoming materials as arguments (note that this strategy still makes reference to syntactic *content* rather than representation):

(3.24) A-Attachment:
Attach incoming material, in accordance with $\bar{X}$ theory, so as to occupy (potential) A-positions.

A second principle (3.25) accounts for attachment preferences in verb-final languages such as German, such as the preference to interpret (3.26a) as in (3.26b) rather than (3.26c) (Breidt (1989), cited in Crocker (forthcoming)):

(3.25) DS-Attachment:
When an A-position is unavailable for attachment, prefer attachment of incoming material into its canonical Deep Structure position.

(3.26) a. ...(ich glaube) daß der Junge mit dem Hund einige Zeit gespielt hat.
(I think) that the$_{nom}$ *boy with the*$_{dat}$ *dog some time played has*

b. '(I think) that the boy who had the dog played for a while.'

c. '(I think) that the boy played with the dog for a while.'

The essence of the DS-Attachment strategy is to reduce complexity by preferring a base-generated position rather than one which requires movement and hence the formation of a chain.

One consequence of this approach is that it allows incremental structure-building. In Pritchett's model, arguments can only be attached once a licensing head is encountered, which may permit an arbitrary number of phrases to be left temporarily unstructured. In Crocker's model, top-down prediction of nodes is permitted in cases where the nodes are not lexically selected but are instead functionally required, i.e. the IP complement of CP and the VP complement of IP. This follows from the overriding aim to maximise comprehension: all structure that can be built, must be.

The empirical findings that garden paths may be affected by pragmatic information is captured by suggesting that the degree of commitment to an analysis is determined by its plausibility: if the analysis is plausible in the current context, then the processor commits to it, which makes subsequent reanalysis more difficult. Aside from such pragmatic considerations, Crocker suggested that reanalysis within a module is cost-free but that reanalysis outside a single module becomes progressively harder.

Like Frazier, Pritchett and Crocker's approaches assume a transparent relationship between parser and grammar, and the form of the grammar has a direct bearing on the operation of the parser. In many ways, they assume a grammar which is extremely similar to Frazier's: it too

presupposes the existence of autonomous (to a greater or lesser extent) modules which encode phrase structure information (the X-bar module), thematic role information (theta grids) and so on. However, different weight is assigned to these components in processing. For example, Pritchett's model is to a certain extent lexically driven: whereas Frazier's model denies any role to lexically-specific information in initial structure assignment, Pritchett's model makes reference to lexeme-specific notions such as theta grids in building structure.

Although they differ in the way in which syntactic information is brought to bear upon parsing decisions, the content-based models discussed above also follow Frazier *et al*'s model in being both serial and modular: only one analysis is followed at a time and this analysis is chosen on the basis of purely syntactic information. In all of these models, processing is driven by immutable syntactic strategies which apply in all situations to all input.

Alternative approaches

However, there are a number of alternative approaches to sentence comprehension which deny a privileged place to the use of syntactic strategies in constructing a syntactic representation. These approaches stress instead an interaction between syntactic factors and other, non-syntactic factors. There are two main factions within these approaches. One faction stresses the role of non-syntactic factors in choosing between alternative structures to pursue, after these structures have initially been identified by the application to the input of a set of syntactic rules/principles. The non-syntactic factors may include contextual information (Crain & Steedman 1985; Altmann & Steedman 1988)) or information about the frequency with which specific lexemes appear in particular syntactic contexts.

The second interactionist faction denies *any* privileged role to syntactic factors. Proponents of these interactionist models have argued that all possible sources of information are immmediately brought to bear in analysing the input (Carlson & Tanenhaus 1988; Trueswell, Tanenhaus & Kello 1993; MacDonald, Pearlmutter & Seidenberg 1994; Trueswell, Tanenhaus & Garnsey 1994). Here syntactic factors are just one constraint among many. According to models of this type, there is no autonomous level of syntactic processing; instead, structural decisions are always made on the basis of all the information available. (Note, however, that although non-syntactic information is brought to bear, the output of this level of processing is assumed to be a syntactic representation).

I will discuss exemplars of both approaches below, beginning with the work of Ford and her colleagues (Ford, Bresnan & Kaplan 1982; Ford 1989) as an example of the first faction, and MacDonald *et al*'s (1994) model, perhaps the most detailed interactionist model so far proposed, as an example of the second faction.

Ford, Bresnan & Kaplan (1982), Ford (1989)

Ford, Bresnan & Kaplan (1982) and Ford (1989) proposed a model which assigns an important role to lexeme-specific information. Their approach assumes the existence of a set of phrase structure rules defined over grammatical categories and functions which are responsible for the initial proposal of alternative structures. These alternatives are then chosen between on the basis of the preferences associated with individual lexical items. As each lexical item is identified, the processor reviews the options offered by the set of phrase structure rules. The alternative options are ordered according to a set of principles which are tied to the particular biases of the lexical item. The item is then attached into the current parse in accordance with the most highly ranked option. This type of model still involves pursuing a single analysis at a time, but the choice of analysis is governed by lexical preference rather than a syntactic form- or content-based strategy.

Note that this approach assumes an underlying grammatical framework which, although based on a different linguistic theory (LFG), still has the same basic architecture as that of Frazier's original model: the grammar consists of a set of phrase structure rules defined over grammatical categories and a lexicon. Thus this type of model differs from Frazier's original model with respect to the factors which govern processing, but the overall architecture of the grammar and the representations which are constructed during processing are similar.

MacDonald, Pearlmutter & Seidenberg (1994)

MacDonald *et al* proposed that sentence comprehension is a parallel process during which people concurrently attempt to construct three levels of representation: lexical, syntactic and discourse. Multiple alternatives are accessed and pursued at all three of these levels until one alternative reaches a criterion threshold, at which point that alternative suppresses all its competitors. Among the factors which affect the activation level of a particular competitor are context effects and the frequency with which that lexical item appears in that particular structure. MacDonald *et al* argued that the experimental evidence reviewed above, which was adduced as evidence for a serial approach to syntactic processing, actually confounds structural preferences with lexical preferences and semantic effects. For example, the evidence that reduced relative constructions such as (3.27a) below cause processing difficulty could be explained in terms of the coincidence of statistical factors, e.g. *raced* appears more frequently in its active form, and contextual factors, e.g. if there is only one horse in the discourse model.

(3.27) The horse raced past the barn fell.

They claimed that any apparent garden path effects do not reflect a structure-based preference for an analysis which subsequently turns out to be incorrect, but instead the parallel processing of multiple alternatives in the absence of constraints which are strong enough to suppress all but one competitor. To support their claim, MacDonald *et al* referred to evidence from an experiment by Trueswell, Tanenhaus & Garnsey (1994), which compared reduced relative sentences such as (3.28) below with unambiguous control sentences:

(3.28) a. The evidence examined by the lawyer was useless.

b. The witness examined by the lawyer was useless.

They found that only reduced relative sentences which involved an animate head noun, as in (3.28b), elicited longer reading times than the unambiguous controls; sentences where the head of the reduced relative was inanimate, as in (3.28a), had comparable reading times with the control sentences. They suggested that this was because the inanimate noun promoted the reduced relative reading, implying that semantic/contextual constraints are immediately

brought to bear upon ambiguity resolution.[9]

Although MacDonald *et al*'s model clearly does not have the same *type* of dependency upon the form of the grammar as the other approaches which I have discussed – i.e. a reliance upon specific rules/principles – it nevertheless makes equally strong assumptions about syntactic representation. It assumes that each lexical item is associated with an argument structure, in which the word's potential arguments and their thematic roles are represented. In addition, each lexical entry is associated with X-bar structures which contain slots corresponding to the word and all the nodes contained within its maximal projection. According to MacDonald *et al*, 'With X-bar structure in the lexicon, it is possible to treat the entire process of constructing a syntactic structure as a matter of connecting X-bar structures to each other in the appropriate syntactically required manner,' (p.683). Positions in the argument structure of an entry are directly linked to their appropriate position in the entry's associated X-bar structure. The argument structures also contain links to abstract morphological structures, such as PAST TENSE and voice nodes, such as PASSIVE. These links are weighted to encode the frequency with which the entry appears in that particular form. Thus the lexical entry for an ambiguous word such as *raced* would include links to both PAST TENSE and PAST PARTICIPLE. MacDonald *et al* do not commit themselves as to whether each lexeme is associated with its own dedicated X-bar structures and morphological structures, or whether the structures are shared between all lexical entries with common characteristics.

In the grammar depicted by this model, knowledge of language and use of language are apparently intertwined, since the form of the grammar – a network of nodes associated with each other by weighted links – directly encodes frequency information. Moreover, this network takes part directly in processing, since processing consists of activating the nodes. Hence any clear distinction between grammar and processor is lost. However, MacDonald *et al* also assume the existence of an additional set of grammatical principles (e.g. the Theta Criterion) to ensure that only permissible structures are produced.

Although there is evidence that contextual factors and frequency may have some effect upon comprehension, this model is not entirely convincing. Perhaps the most convincing evidence against it is the existence of apparently distinct syntactic and semantic effects in Event Related Potential experiments. If sentence processing really is a constraint satisfaction process, with all possible factors being simultaneously brought to bear, then we would not expect such clear correspondences between syntactic versus semantic factors and characteristic wave form patterns. I will assume in the remainder of this thesis that syntactic processing is modular in comprehension, as in production: only syntactic information can in principle be relevant to it.

3.3.3 Summary

Language comprehension has been the subject of more extensive study than language production. Perhaps as a result, it has also been the subject of greater disagreement. However, this disagreement seems to be restricted more to the question of how processing occurs than to identifying the appropriate levels of processing or the appropriate representations. There is

[9] Notice, however, that other studies of reduced relative sentences suggest that semantic/contextual information does not affect initial structure assignment (Britt, Perfetti, Garrod & Rayner 1992; Clifton & Ferreira 1987; Ferreira & Clifton 1986).

general agreement that comprehension involves three levels of processing (lexical, syntactic and semantic/discourse). As the discussion above shows, syntactic processing has been the subject of extensive research. Most of this research has concentrated upon process, but we have seen that assumptions about syntactic representation are integral to the processing theories. It is perhaps striking that unlike theories of production, theories of comprehension have tended to draw fairly directly from linguistic theories, in particular Government-Binding theory. As a result, they have made similar assumptions concerning the nature of syntactic representation. However, theories disagree about the factors which govern syntactic processing. In particular, we can distinguish between theories in which processing is guided by immutable principles and those in which lexeme-specific information may come to bear.

3.4 Summary

This chapter has been concerned with theories of language processing. It has presented processing architectures for both production and comprehension in order to establish a framework for the remainder of this thesis. I have also been concerned with some of the theories which have been proposed for syntactic processing and the empirical evidence upon which they are based. In particular, I have tried to highlight the assumptions which they make about syntactic representation. We have seen that there is disagreement concerning the way in which syntactic structure is processed, but that the theories share many representational assumptions, for example the existence of abstract categories which subsume individual lexical items. In the chapters to come, I will be concerned with examining some of these assumptions and also with testing some of the predictions which the theories outlined here make with respect to syntactic processing.

Chapter 4

The Use of Corpora and Theories of Language Production

4.1 Introduction

In recent years, there has been increasing interest in the use of large-scale language corpora as a tool in language research. This interest can undoubtedly be attributed to the recent advances in information technology which have made it possible to collect and analyse data sets of previously unimaginable sizes. Corpora have a number of disadvantages, but they also offer a rich source of data whose potential for psycholinguistic research has been largely overlooked. This chapter is primarily methodological in nature: it is concerned with how corpora can be exploited in the study of language and in particular how they can be used as sources of evidence about language processing.

I will begin by evaluating some current approaches to corpus analysis, and in particular highlighting the assumptions which they make about the data. I will then propose an alternative approach, which uses full text corpora to examine issues relating to language prodction. This approach is exemplified in the second half of the chapter through a case study of relative clauses in the London-Lund corpus (Svartvik & Quirk 1980).

4.2 The Use of Corpora

Corpus-based studies of language typically vary along three dimensions: the type of corpus which is analysed; the particular level of language which is under investigation; and the research goals of the investigator. In the following sections, I will examine the possible parameters of variation and evaluate each alternative.

4.2.1 Types of corpus

The term 'corpus' is somewhat vaguely defined in the dictionary as 'a large body of data'; in practice, it has been used to refer to two types of entity. One type of corpus is the specialised corpus compiled by a researcher who is interested in a particular issue. Typically, whenever the researcher encounters an instance of that particular construction, he/she notes it down and adds it to the corpus. For example, researchers interested in language production, such as Garrett (1980) and Fromkin (1973), have collected corpora of speech errors. Corpora of this type have typically been compiled when the construction of interest occurs infrequently: in order to have enough data to analyse, the researcher must make use of whichever tokens he/she encounters, in whichever context they appear. Although this approach solves the problem of insufficient data, it raises another question. Crucially, these corpora rely upon a researcher noticing an instance of the particular construction and noting it down. This makes it difficult to draw any conclusions about relative frequency: it is impossible to be sure whether the researcher has exhaustively noted every example which occurred in his/her hearing. For example, some speech errors are more salient than others, and the high frequency of one particular type of error in such a corpus may reflect its salience, not its actual frequency of occurrence in language. Thus a major disadvantage of specialised corpora is their selectivity.

The second type of corpus is more common. These corpora consist of texts of continuous spoken or written language from known sources, which can be searched for phenomena of interest. Corpora of this type, which I will term 'full text corpora', offer a number of advantages over the specialised corpora described above. Firstly, they are flexible: whereas a specialised corpus can only provide information about one particular phenomenon of interest (e.g. speech errors), a corpus such as the London–Lund corpus (to be described more fully below) is amenable to analysis from a myriad points of view. Secondly, and more importantly, they allow relativised comparisons to be drawn: it is possible to exhaustively extract all occurrences of a phenomenon of interest, and hence the relative frequency of particular types of token can be discussed with reference to a particular text. Similarly, factors such as the register of speech and the context of utterance can be controlled for, something which is not usually the case with specialised corpora. Corpora of this type are therefore less likely to be subject to selectivity biases. For these reasons, I suggest that full text corpora are more reliable sources of evidence than specialised corpora.

4.2.2 Level of language

The second dimension of variation concerns the level of language under investigation. Depending upon the way in which they have been compiled, corpora can in principle provide information about phonology, morphology, prosody, syntax or discourse structure (for example, the data contained in the London-Lund corpus (Svartvik & Quirk 1980) has been analysed at all of these levels). In fact, most research has tended to concentrate upon discourse structure, with some work on phonology; there has been comparatively little work on syntactic phenomena.

4.2.3 Goals of corpus research

Just as the same corpus can give information about multiple linguistic levels, the results of a corpus analysis can be interpreted from many viewpoints. Although the results of any such analysis are basically sets of statistics, the implications of these statistics are open to interpretation. There seem to be essentially three schools of thought about the function of

corpus analysis. It can be seen primarily as a means of establishing a data set and discovering patterns of data; as a means of inferring the processes which lead to those patterns (hypothesis generation); or as a means of testing hypotheses which have been motivated by data from other sources. To make this clear, I will discuss each possibility in turn.

Identification and characterisation of a data set

Until recently, most corpus analysis was concerned with discovering and characterising patterns of data connected with a particular linguistic phenomenon. Under this type of approach, corpus analysis results in a set of statistics which show the frequency of, and correlations between, particular features.

At its simplest, work of this type is a foundation for further research, since it establishes a basic set of data which should be characterised by any adequate theory. Quirk (1968), for example, took this approach in his study of relative clauses in different types of English texts. His results established the frequency of different features and correlations between the occurrence of different features, but no attempt was made to draw any theoretical conclusions.

Other researchers attach more importance to theoretical issues and view the identification of the data set as a preliminary process. Their principal concern is instead the formulation of declarative theories which characterise the data set. An example of this approach is Stenström's discourse structural analysis of question-answering in English (Stenström 1984). Stenström analysed question–answer sequences in 20 texts of spoken English, categorising which types of answer followed which types of question. She then used the results of the analysis to constrain a descriptive theory of question answering in English conversation. In this case, the existence or non-existence in the texts of particular types of question–answer sequences was used to motivate a specification of possible sequences and a taxonomy of different types of sequence.

While these approaches have been successful in identifying interesting sets of data, they implicitly reify the data by ignoring the psychological context in which it was produced, in other words by treating the data as if it existed independently of the speaker/hearer. Researchers taking the 'identification and characterisation of the data set' approach to corpus analysis are thus overly concerned with *how* the data can be characterised and – in the main – unconcerned with the question of *why* it should pattern in a particular manner.

By reifying the data in this way, however, the object of study becomes Chomsky's E-language (externalised language), in other words the concept of language as an externalised object, 'a construct ... understood independently of the properties of the mind/brain,' (Chomsky 1986b, p.20), rather than language as an expression of human psychology. And as we have already seen, if the object of study is E-language, then questions of truth or falsity do not arise, except insofar as the proposed system correctly characterises the E-language. There is no way – other than on formal grounds such as simplicity – to distinguish between alternative theories.

For any researcher interested in the pyschological aspects of language, then, it is a major failing of corpus analyses taking the above approach that they are ultimately uninformative about how human beings mentally represent and process language, in other words about I-language and its use. Stenström's analysis, for example, gives us a detailed characterisation of the taxonomy of question–answer sequences in English, but it does not tell us about whether this taxonomy has any psychological correlates, nor about the processes which give rise to such regularities.

There is no reason, however, why corpus analysis should be incompatible with research into I-language. Increasingly, research is concerned with how corpora can reflect the knowledge of language which is mentally represented, and how that knowledge is put to use. In other words, recent research recognises that the contents of a corpus do not exist in and of themselves, but are instead the result of people *using their knowledge of language* to produce structured strings of words. Thus an alternative view of corpus analysis is as a means of investigating I-language, by allowing us to generate or test hypotheses about how language is processed. I will examine each of these alternatives in turn.

Corpus analysis and hypothesis generation

Most of the work using corpora to generate new hypotheses has been in the field of language production. As we saw in the previous chapter, most early research into language production focused upon analysing corpora of speech errors and using these to generate hypotheses about the mechanisms which underlie production. Hypotheses about the various levels of processing and the linguistic units which are implicated at these levels were proposed on the basis of the relative frequencies of particular types of error. For example, the low incidence of sound errors occurring across phrase boundaries led Garrett (1980) to propose that the constituent structure-to-phonological structure mapping takes place in phrase-like units. Many of Garrett's proposals – such as the level at which word forms become available – have subsequently been tested and been given experimental support (for example Bock (1987a)). However, as I mentioned above, using specialist corpora can lead to researchers being forced to base theories on (unknowingly) selectively biased data and/or inadequate quantities of data.

Corpus analysis and testing hypotheses

An alternative use of corpora is as a means of testing hypotheses which have been proposed on the basis of other, independent data, such as experimental studies. Most work which has been done in this area has been concerned with the patterns of data found in corpora as a direct, causal factor in language processing. This approach has found particular favour recently with the increasing interest being shown in constraint-based approaches to language processing.[1] As we saw in the previous chapter,these approaches share the assumption that language processing involves the simultaneous satisfaction of multiple constraints.

It is a crucial claim of these models that the relative importance of different constraints is dependent upon their frequency in the input. Processing reflects a person's previous linguistic experience, in that the more frequently a structure has been encountered, the stronger the constraint which it imposes upon new input. In MacDonald *et al*'s (1994) model, for example, these frequencies are encoded into the mental lexicon as weights between lexical entries and

[1] The word 'processing' is used here in its widest sense: constraint-based approaches have been proposed for both language comprehension/production by adults, and the acquisition of language by children (see for example Rumelhart & McClelland (1986), who propose a connectionist model for children's acquisition of the past tense).

abstract morphological entries, such that alternative interpretations of a word are partially activated as a function of their frequencies in the language. Here the frequency of particular structures plays a *causal* role in processing. The same is true of the Tuning hypothesis (Cuetos, Mitchell & Corley, to appear), according to which attachment preferences for ambiguous constituents are set according to the relative frequency with which the alternatives have been encountered. Cuetos *et al* showed that the adult preference in Spanish to high-attach relative clauses in complex NPs could be overridden in children when the children were exposed to proportionally more low-attached relative clauses.

For such theories, where frequency information (partially) determines processing, it is clearly important to be able to show that particular structures do occur more frequently. For this reason, corpus analysis has become important as a way of providing empirical support for frequency-based processing theories. Corpus analyses of this type typically focus upon the occurrence of a particular structure in a full text corpus. The aim is to demonstrate a convergence between observed frequency and processing preferences.

Gibson and Pearlmutter (1994)

A slightly different approach was taken by Gibson & Pearlmutter (1994), who used the Brown corpus of written English to examine PP attachment sites in complex NPs. Like the researchers described above, Gibson and Pearlmutter were concerned with investigating theories of sentence comprehension. However, their research did not investigate a possible causal link between frequency and processing complexity. Instead, they sought to find independent support for an existing parsing theory by hypothesising an inverse correlation between the comprehension-complexity of two (or more) constructions and their frequency. Thus if it could be shown that the relative frequencies of the alternative attachment possibilities were inversely proportional to the comprehension-complexity predicted by the theory, it would provide empirical support for the theory and open up new possibilities for corpus analysis.

Gibson and Pearlmutter offered two possible reasons why comprehension-complexity might be inversely correlated with frequency of occurrence. Firstly, they argued, frequency of occurrence presumably reflects production complexity, since most corpora consist of naturally produced sentences. As yet, nothing is known about the relationship between production-complexity and comprehension-complexity, but they suggested that the null hypothesis would be to assume the same metric for both processes. By hypothesis, then, production-complexity should mirror comprehension-complexity, allowing inferences about comprehension to be drawn from production data. Secondly, the corpus which they analysed consisted of written language and as such had been subject to editing procedures which – they argued – would have acted to facilitate comprehension, filtering out more comprehension-complex structures in favour of less complex ones. As predicted, they found that structures which the theory predicted to be harder to comprehend appeared less frequently than structures which were predicted to be easier to understand. They concluded that '…corpus-based analyses can at least supplement data from comprehension experiments, and, given enough support across a range of comparisons, corpus data could be taken as independent evidence for or against processing hypotheses,' (Gibson & Pearlmutter 1994, p.183).

4.2.4 A hybrid approach

There is something unsatisfying about all of the above approaches to corpus analysis, either in terms of the type of corpus which is employed, or in terms of the inferences which are drawn from it. I have already argued that analyses which concentrate on describing the data are uninformative about I-language. However, even the research which is interested in processing issues has undesirable characteristics. Most existing corpus-based studies which concentrate on production issues are based on specialised corpora, which as we have seen suffer from sampling biases, invalidating any attempt at quantitative comparisons; they also make available only limited amounts of data.

On the other hand, work on full text corpora with a processing focus tends to be interested solely in comprehension. Yet the data in a corpus is clearly the product primarily of *production* processes, with at most a minor role (and only for written corpora) being accorded to subsequent editing (hence presumably comprehension) processes. Hence it would seem more natural to examine these corpora for evidence of production processes rather than comprehension processes, as Gibson and Pearlmutter (1994) themselves acknowledged.

Not only is studying corpora for evidence of comprehension unintuitive, however, it also requires additional assumptions to be made. For data from production to be informative about comprehension, one must either subscribe to the hypothesis that the frequency with which particular structures are encountered directly influences how easy they are to comprehend (this precludes processing theories in which the initial choice of analysis follows fixed syntactic strategies), or that complexity of comprehension influences which structures are produced. There are two possibilities in the latter case: either one assumes (like Gibson and Pearlmutter) that production and comprehension have similar complexity metrics; or one makes the assumption that speakers are sensitive to the processing constraints of their hearers and modify their output accordingly. There is no evidence for the former, and the latter seems extremely unlikely. Not only is there no evidence for it (for example, Craig, Nicol & Barss (1995) found no evidence that speakers take listeners' needs into account in producing sentential complements), but it also seems highly unlikely that speakers have either the insight at a syntactic level into what makes particular structures difficult to parse, or the surplus processing capacity during production, to make the necessary accommodation. [2]

I would like to suggest an alternative approach which combines the use of full text corpora with a focus upon issues of language production. This type of approach makes the best use of the data which corpora provide: it focuses upon the data as evidence about processing issues, hence investigates I-language; unlike specialised corpora, it avoids the problem of selectivity and exploits the maximum amount of data; and it avoids the assumptions about the data which comprehension-based studies require. The following section presents a case study of this approach which examines whether these claims are justified.

[2] Clearly, editing processes may play some part in the production of written corpora, in other words writers may well modify their output in order to be mre comprehensible, but I am concerned here with corpora of (spontaneous) *spoken* language.

4.3 A corpus study of relative clauses

4.3.1 Background to the study

The corpus study reported here is exploratory work, designed to test whether full text corpora are potentially a useful tool for investigating language production. The rationale behind it is essentially the same as that of Gibson and Pearlmutter (1994): there should be a convergence between the theoretical predictions for favoured/disfavoured structures and their relative frequency/infrequency in the corpus. Any such convergence would provide empirical support for those theories. In addition, it was hoped that an analysis of this type might throw up interesting patterns of data which could be used as a basis for future experimental work.

Unlike Gibson and Pearlmutter's work, however, the study reported here does not directly test predictions which were made with respect to a particular structure. Whilst theories of comprehension often make explicit predictions about processing of one particular structure, such as attachment preferences for PPs modifying Ns, the same is not true of theories of production. This makes the choice of structure to study less obvious. Nevertheless, close examination of existing theories of production reveals *implicit* predictions about the factors which may affect the relative distribution of different structures. Below I will justify my choice of which structure to analyse and attempt to make explicit the theoretical predictions which this corpus study tests.

4.3.2 The structure to be studied

The structure under investigation here is the finite relative clause. It was chosen for several reasons. Firstly, finite relative clauses occur relatively frequently, ensuring a reasonably large data set for analysis. Secondly, within the set of relative clauses there are a number of possibilities for variation, for example, in terms of the function upon which relativisation takes place, whether or not the clause is restrictive and so on. This allowed a range of hypotheses to be tested from a single data set. Thirdly, as we saw in the previous chapter, clauses are hypothesised to comprise fundamental processing units in language production, giving rise to an interesting range of hypotheses to examine. They have also been the subject of experimental study (Bock and Cutting 1992; Holmes 1988) and as such were particularly attractive for a corpus study, since this allowed comparison of data collected under natural and experimental conditions: if experimental results really are representative of how processing occurs in real life, as we would hope, then the results of the two approaches should converge.

4.3.3 Predictions

The choice of relative clauses as the object of study allows predictions to be made which relate to theories of both constituent structure generation and functional assignment. In the previous chapter, it was suggested that the processor aims for incremental production, and we would expect the distribution of relative clauses in the matrix clause to reflect this. Hence we can formulate our hypotheses by considering how processing at each level is hypothesised to take place, and how these processes and the desire for incrementality might interact to favour particular patterns of distribution.

Distribution in the matrix clause

The first set of predictions concerns the distribution of relative clauses with respect to positions in the matrix clause. Both functional processing and constituent structure considerations are implicated here.

Hypothesis 1

Theories of both functional level processing and constituent level processing independently predict that there should be a preference in English for relative clauses to appear late – possibly as late as possible – in the matrix clause. As we shall see, functional processing considerations predict that there should be a preference for relativisation to occur on heads low in the functional hierarchy. Given the overall isomorphy between position on the functional hierarchy and word order, this will (indirectly) result in a preference for relative clauses to appear late in the clause. Independently, constituent structure processing considerations directly result in a perference for relative clauses to be associated with heads which appear late in the clause.

At a functional level, we have seen that there is evidence that speech tends to be planned in clausal units. Recall that Garrett (1980) found that 80% of the speech errors in his corpus occurred within a clause and argued on this basis that functional level processing usually takes place one clause at a time; only two clauses at most can be planned simultaneously. Similarly, Bock & Cutting (1992) found in their agreement experiment that few errors occurred after clausal modifiers, which led them to hypothesise that functional assignment takes place in clausal units.

This suggests that processing two clauses simultaneously should cause a greater processing load. If this is the case, then we would expect that speakers will preferentially minimise their processing load by planning one clause at a time. However, the preference to minimise processing load must be balanced against the preference to produce fluent speech. Placing a relative clause in a non-final position forces the speaker to violate one of these preferences. Either he/she has to plan two clauses simultaneously, the matrix clause and the embedded clause, increasing processing load, or alternatively plan one and then subsequently plan the other, leading to dysfluency. To see why, recall that grammatical functions appear to be assigned serially, from the highest function in the grammatical function hierarchy to the lowest. If the Head of the relative clause receives a grammatical function high up the hierarchy (such as the function associated with the subject), then matrix clause functions which are lower down the hierarchy will remain to be assigned subsequently, in addition to the functions associated with the relative clause. The speaker must either simultaneously or serially assign the remaining functions associated with the matrix clause and the functions associated with the relative clause, resulting in either processing overload (simultaneous assignment) or disfluency (serial assignment). If the Head of the clause is assigned the lowest function, however, the processing load is reduced and fluency can be maintained, since the matrix and relative clauses can undergo functional processing serially. All of the other matrix clause functions will already have been assigned by the time the Head is assigned its function and the functions associated with the relative clause are activated. We would therefore expect that grammatical functions will tend to be assigned in such a way that arguments which have a relative clause associated

with them will receive the lowest function in the hierarchy. Given the overall isomorphism between grammatical function and word order in English, this means that relative structures will appear late in the matrix clause.

Although the grammatical function–word order isomorphy makes it difficult to distinguish between functional processing effects and constituent processing effects, there are constituent structure considerations which could affect the appearance of relative clauses. According to Kempen and Hoenkamp's (1987) model of constituent structure generation, individual constituents are constructed in parallel and then attached into a placeholder in the order in which they become available. This approach allows maximal incrementality, since it allows processing to begin at subsequent levels (such as the phonological level) as soon as each constituent becomes available. It also predicts that constituents which require more procedure calls – syntactically complex constituents – should tend to appear later in the sentence wherever possible (i.e. wherever the resulting word order is licensed), since they will become available later than syntactically simpler constituents. Note that this account gives a principled explanation for Yngve's (1960) hypothesis (discussed in the previous chapter) that syntactically complex constituents appear later in the sentence. This account predicts the occurrence of Heavy NP shift, for example, in prepositional object sentences where the NP is syntactically more complex than the PP.

Clearly, relative clauses are syntactically complex and might reasonably be expected to take relatively longer to become available. This could affect word order in two ways. It could result in extraposition, where the Head is produced in an early position but the relative clause only becomes available later and hence appears clause-finally. Alternatively, feedback that there is difficulty in constituent structure generation could result in abandonment of the current structure and development of an alternative where the Head (and hence the relative clause) can appear later in the sentence, much as difficulty at the phonological level can lead to revision of constituent structure (Levelt 1989). Both functional and constituent structure processing limitations therefore militate towards a preference for relative clauses to appear late in the matrix clause.

Although both the functional and constituent level considerations outlined above lead to the same predictions in English because of the overall isomorphy between function and linear position, the same is not true for other languages. This raises the possibility of potentially very interesting cross-linguistic comparisons which might allow us to identify if one processing level imposes stronger constraints than the other. If functional level considerations are stronger than constituent level considerations, then we would expect to find fewer relative clauses associated with the matrix clause subject regardless of its position but no effect of linear order. If however the constituent level considerations are stronger than the functional level considerations, we would expect to find that in languages with a flexible word order relative clauses would appear clause-finally but there would be no effect of the function assigned to the Head.

Hypothesis 2

Although we would expect there to be an overall preference for non-final position, there are also grounds for predicting a difference between restrictive and non-restrictive relative clauses in this regard. Non-restrictive relative clauses are clauses which give additional information about the Head noun; this information is not necessary to uniquely identify the referent of the Head (4.1a). Restrictive relative clauses, on the other hand, restrict the reference of the Head; without the relative clause, the Head cannot be uniquely identified (4.2a). Semantically, non-restrictive relative clauses express an independent proposition to that expressed by the matrix clause. Thus whereas non-restrictive relative clauses can often be paraphrased by a conjunctive expression (4.1b), restrictive relative clauses cannot (4.2b).

(4.1) a. The doctor, who was on duty, answered the phone.
(Only one possible referent of 'doctor'; the clause gives additional information)
b. = The doctor was on duty, and he/she answered the phone.

(4.2) a. The doctor who was on duty answered the phone.
(More than one possible referent of 'doctor'; the clause identifies which one)
b. ≠ The doctor was on duty, and he/she answered the phone.

Hence restrictive and non-restrictive relative clauses fulfill different communicative functions. Crucially, restrictive relative clauses are modifiers (in the semantic sense) of the Head and therefore contribute their semantic content to the meaning of the matrix clause, in a way that non-restrictive relatives do not. As Holmes (1988) noted, '...the functions which restrictive relatives ...serve are fundamental to the higher clauses in which they are embedded, whereas combined clauses [=non-restrictive relatives] have a much more optional role,' (Holmes 1988, p.357). Thus whereas the speaker typically has a choice of whether or not to produce a non-restrictive relative clause, production of a restrictive relative clause may be mandatory in some sense: the information contained in the relative clause may be essential to effective communication of the message.

We would therefore expect there to be at least some cases where the preference against relative clauses in non-final positions will be overridden. In particular, this might occur when there is no alternative functional assignment to compete with the functional assignment which promotes a non-final relative clause, perhaps because the Head of the relative clause is substantially more accessible than other entities and so resolutely claims the subject function. In that case, the absence of a viable alternative will – by default – cause the speaker to persist with the functional assignment which produces a relative clause in non-final position. Note, however, that this should only hold of restrictive relative clauses, whose appearance is mandated by the semantic content of the message. Since non-restrictive relative clauses are never mandatory, the speaker can always choose to produce an alternative type of structure (such as a coordinate structure, as in (4.1b) above) if its potential Head is forced to appear in non-final position.

Given that restrictive relative clauses are susceptible to this influence and non-restrictive relative clauses are not, we would therefore expect that, independent of an overall preference to produce relative clauses finally in the matrix clause, significantly more restrictive relative clauses will appear non-finally than non-restrictive relative clauses.

Relativised function

Hypothesis 3

We can also investigate the grammatical function in the relative clause upon which relativisation takes place: is there any preference for relativisation to take place upon a particular function? This question has been addressed before, but not from a psycholinguistic perspective. Keenan & Comrie (1977) proposed a cross-linguistic Accessibility Hierarchy for restrictive relative clauses. Their hierarchy placed subjects at the top, followed by direct objects, prepositional objects, genitives and objects of comparison. They proposed that any language which permitted relativisation at one level would also permit relativisation at every level higher up the hierarchy, supporting their claim with data from 49 languages. In addition, Keenan (1975) suggested that the *frequency* of relativisation upon particular functions in any given language would mirror the hierarchy. Hence, subject relatives should be more frequent than direct object relatives and so on. However, Keenan and Comrie did not offer a convincing explanation for why this should be so.

I suggest that the model of language production outlined in the previous chapter leads us to make the same predictions, but on a principled psycholinguistic basis. As we saw, Bock (1987b) proposed that function assignment takes place along an obliqueness hierarchy, from the least oblique function (subject) to the most oblique. This hierarchy is essentially the same as that of Keenan and Comrie. Recall also that the subject function is assigned to the most accessible item, then the direct object function to the next most accessible and so on.

The Head of a relative clause should be particularly accessible, since it receives activation from two sources. In addition to receiving activation because of its role in the relative clause, it also – and perhaps more importantly – receives activation because of its role in the matrix clause. All other things being equal, we would therefore expect it to be more accessible than the other items in the relative clause which are not receiving additional activation. As such it should be a good competitor for the subject role of the relative clause, leading to realisation of the relative clause as a subject relative. Following the hierarchy proposed by Bock, then, we would expect there to be more subject relatives than direct object relatives and more direct object relatives than prepositional object relatives.

4.3.4 The corpus

The data was extracted from the London-Lund corpus (Svartvik & Quirk 1980). This corpus consists of a million words of written and spoken English, collected between 1957 and 1975. It is divided into 100 texts of written English and 100 texts of spoken English, each approximately 5,000 words long. The corpus contains a detailed orthographic transcription of each spoken text, which includes some prosodic markings. The spoken texts consist of surreptitiously and non-surreptitiously recorded monologues and dialogues representing a wide range of speech situations, from prepared speeches to casual dinner table conversation. The texts are organised along the dimensions of speech situation (planned versus unplanned speech), personal relationship between the speakers (intimate/distant), and power relationship between the speakers (equal/non-equal).

4.3.5 Extraction of the data set

The main factor which was taken into account when extracting the data set was the naturalness of the data: in order to draw any conclusions about the mechanisms underlying language production, it was important that the data should be as natural as possible, and in particular free from those factors which might lead to conscious monitoring and control over the structures which were produced. Planned speech, for example, is open to editing processes of the type which Gibson and Pearlmutter (1994) noted; similarly, speech in a formal situation such as an interview may be influenced by conscious attention to grammatical well-formedness. In both cases, the speaker's attention is drawn to the act of language production. The language which is produced in these circumstances will not necessarily reflect the normal processes of language production in which we are interested.

For this reason, the data was extracted with reference to two criteria: firstly, only texts which consisted of 'unplanned speech between intimates' were examined; and secondly, only the speech of those people who were unaware of being recorded was examined. The result of these decisions should be to exclude language which was produced with any degree of self-consciousness. In all, 14 texts were examined (= 70,000 words), giving data for 26 speakers.[3] Since the London-Lund corpus is not tagged for parts of speech, the texts were searched by hand to extract every instance of a finite relative clause (infinitival relatives, free relatives, pseudo-free relatives and cleft structures were not included in the data set). In all, 561 tokens were extracted.

4.3.6 Categorisation of the tokens

Each token that was identified in the text was given an identifying tag. It was then categorised according to a number of fields of interest. Descriptions of these fields are given below, together with examples taken from the corpus (The examples are given verbatim, including hesitations, repetition of words etc). The relative clause is highlighted in italics; the # symbol marks a tone unit boundary.

- Restrictiveness:
  This field identified whether the relative clause restricted the possible referents of the Head (*restrictive* relative clauses) or whether it provided additional information about the Head (*non-restrictive* relative clauses). In most cases it was clear which category the clause fell into; in a few cases, it was less clear but the context was usually sufficient to disambiguate. In the very small minority of cases where it was not clear, I asked independent judges for their opinion.
  - Possible values: *Restrictive/Non-restrictive*

(4.3) a. well surely it was *an option # they had open* wasn't it # *(Restrictive)*
b. it had all been laid down by *Schlieffen # who was dead # (Non-restrictive)*

[3] Unfortunately the coding system used in the London–Lund corpus only identifies speakers uniquely *within* a text. Although it is therefore possible that the same speaker may have been recorded more than once, I have assumed in the analyses that each speaker is unique.

- Relative element:
  This field identified the relative element (if any) which appeared following the Head.
  - Possible values include: *who, which, that, 0.*

(4.4) a. I had *a corporal # who stupid man got tight # coming back from leave # (who)*
b. so it was to release twelve masters # or twelve teachers to # work on *the play # which starts tonight # (which)*
c. we just couldn't stop to hear *the serial that was going on # at that particular time # (that)*
d. and the second Belfast blitz # was the *the mistake the Germans made # (0)*

- Function of the Head:
  This field identified the function in the matrix clause associated with the Head of the relative clause. The possible functions included arguments – such as *subject, direct object, prepositional object* – where the Head was an argument of the verb (following standard syntactic tests for argumenthood such as those in Pollard & Sag (1987)); and adjuncts – which included subdivisions such as *temporal adjunct, locative adjunct* – where the Head was a non-argument. In a substantial number of cases the Head did not appear as part of a matrix clause – instead it appeared as an independent constituent, often elaborating on a previous clause, as example (4.5e) below shows. I termed examples of this type *independent topics*.
  - Possible values include: *subject, direct object, prepositional object, adjunct, independent topic.*

(4.5) a. *the last time I was in the Ministry of External Affairs in Dublin #* was on a congress # *(Subject)*
b. because I often say *things that are very similar* when I think back on them # *(Direct object)*
c. hardly versed # in *the language he's communicating in # (Prep. object)*
d. the dear little Devlin girl # was brought up # in *one of those little shacks # with a half door across # which had probably been pulled down in your day # (Adjunct (locative))*
e. I don't know how she's packed it all in # (LAUGHS) *the things she's done # (Independent topic)*

- Position of Head/Relative clause in the matrix clause:
  In many cases, the previous field, Function of Head in the matrix clause, identified both grammatical relation and linear position: a Head with the matrix subject function was usually clause-initial, and – it turned out – a Head with any other function was usually clause-final. In a few cases, however, it did not identify linear position, for example where the Head and clause were separated by extraposition, or where a direct object

Head was topicalised. Each token was therefore additionally tagged for matrix clause position of the Head and matrix clause position of the relative clause.

  - Possible values: *Non-final, Final.*

(4.6) a. *the one I remember best* # was lemon sole # *(Non-final)*
  b. that's *the sort of young chap you never meet in sort of London* # *(Final)*

- Relativised function in the embedded clause:
  This field identified the function in the relative clause which had been relativised. Again, the possible values included arguments and non-arguments.

  - Possible values included: *subject, direct object, prepositional object, adjunct.*

(4.7) a. because I often say *things that are very similar* when I think back on them # *(Subject)*
  b. you could do *anything you wanted* # without fear # of something terrible # *(Direct object)*
  c. and gave Moltke the younger # *a nervous breakdown # from which he never really recovered* # *(Prep. object)*
  d. cos he nearly killed himself *last time she did* # *(Adjunct)*

- Identity of the Head:
  This identified the Head of the relative clause.

  - Possible values: *Any noun, any clause.*

(4.8) a. *that story I've just gave given you* # has made me think of another one # *(Noun)*
  b. there was nobody in the street # *which is always the thing to notice in Ireland* # *(Clause)*

4.3.7 Results

Testing the hypotheses

A survey of this type naturally produces a large amount of data. To give an overall picture, I will begin by presenting the results for the entire corpus of relative clauses in terms of the function of the Head in the matrix clause (Table 4.1).[4]

Subj	*DObj*	*PObj*	*Adj*	*Clause*	*Ind. topic*
63 (11.2%)	279 (49.7%)	50 (8.9%)	61 (10.9%)	46 (8.2%)	60 (10.7%)

Table 4.1: Relative clauses by matrix clause function of Head: Total tokens

[4] The figures do not add up to 100% because of rounding to one decimal place.

In the remainder of this section, I will only be concerned with those results which have a direct bearing upon the three hypotheses outlined above. The results will be presented in two forms. I will begin by presenting the data in terms of the absolute number of tokens falling into each relevant category. However, although these gross comparisons give us an intuitive idea about differences between categories, it is not possible to draw any firm conclusions from these absolute figures, for reasons which I will make clear. I will therefore also present the results of statistical analyses upon the data. Where necessary, I will explain why a particular procedure was used and how the figures which were used in the analysis were calculated.

Hypothesis 1

The first figures of interest are those which relate to the position of the relative clause structure in the matrix clause: is there a tendency for relative clauses to appear clause-finally ? Table 4.2 shows the position in the matrix clause of the Head of the relative clause. Note that the number of tokens/percentages given in the table do not add up to 561/100%, i.e. do not include all of the data from the database. This is because to make the comparison as conservative as possible, one category of relative clause was excluded from the analysis. Relative clauses with clausal Heads (46 tokens) were excluded because such relative clauses must by their very nature appear following a clause. Hence there is no way in which a relative clause with a clausal Head can appear in a non-final position.[5] However, relative clauses with independent topic Heads were not excluded, although they are not – by definition – associated with a matrix clause position. The hypothesis under investigation predicts that producing a relative clause in a non-final position is difficult because more than one clause must be processed simultaneously. Clearly, since independent topics are not associated with a matrix clause, they should not – by hypothesis – be difficult to process and hence are comparable with matrix clause-final relative clauses.

Non-Final Head	*Final Head*
81 (14.4%)	431 (76.8%)

Table 4.2: Matrix clause position of Head: Total tokens

The figures suggest strongly that there is a tendency for the Head of the relative clause to appear clause-finally. However, this is a conservative analysis, since it codifies the data in terms of the Head's position, whereas the hypotheses are couched in terms of position of the relative clause itself. Table 4.2 does not take into account the possibility of a non-final Head being associated with a final relative clause, i.e. cases where speakers extraposed the relative clause, as in the following example:

(4.9) a. because in *nothing* had ever happened # including the troubles # *that had killed so many Holy Roman Catholics in one moment*

A truer picture emerges if we instead analyse the data in terms of position of the relative clause itself rather than position of the Head (Table 4.3).

[5] Relative clauses with clausal Heads are excluded from all of the following analyses, except where otherwise indicated

Non-Final Clause	*Final Clause*
63 (11.2%)	449 (80.0%)

Table 4.3: Matrix clause position of relative clause: Total tokens

Analysis
Statistical analysis of the results in Table 4.3 – as with most corpus analysis – is not entirely straightforward: a chi-square analysis would not be valid, since the data is not independent within cells (each speaker contributed more than one observation to each cell). It should also be taken into account that individual speakers varied greatly in their overall contributions to the 5,000 words which make up each text, precluding any possibility of making a direct comparison between subjects. Before any analysis could take place, it was necessary to relativise the data so that results for individual subjects were comparable.

Following Hatch & Lazaraton (1991), I therefore calculated how many tokens of each type of relative clause each subject produced relative to his/her overall contribution to the text. Because the corpus is transcribed in terms of tone units, this contribution was measured in terms of the number of tone units which he/she produced (tone units largely correspond to clausal units). These calculations yielded a relative clause/100 tone unit rating for each category of relative clause for each subject. These ratios were then used as the dependent variables in a Wilcoxon signed-ranks test. The test revealed that the difference between the two categories, Non-Final versus Final, was strongly significant ($T = 0$, $p < .001$). As predicted, there was a significant preference to produce relative clauses in clause-final position. The corpus data is therefore consistent with the theoretical prediction.

Hypothesis 2

The second hypothesis to be tested predicted that more restrictive relative clauses than non-restrictive relative clauses would be found in non-final matrix clause positions. The relevant figures are presented in Table 4.4.

Restrictive relatives	*Non-restrictive relatives*
74 (13.2%)	7 (1.35%)

Table 4.4: Restrictive and Non-restrictive relatives in Non-Final position: Total tokens

However, these absolute figures could be misleading, because they do not take into account that there are differences in the overall frequency of restrictive and non-restrictive relative clauses. In fact, restrictive relative clauses occur more than twice as frequently in the database as non-restrictive relative clauses (382 tokens versus 128 tokens). At least part of this disparity in frequency is predicted on processing grounds: as I have already suggested, production of a non-restrictive relative clause is optional in a way that production of a restrictive relative clause may not be. Hence one effect of processing difficulty associated with producing a clause in a non-final position will be to depress the overall incidence of non-restrictive relative clauses,

since the speaker can produce an alternative structure.

A more accurate way of presenting the data would be to compare the proportion of restrictive relative clauses which occur non-finally with the proportion of non-restrictive relative clauses which occur non-finally. Table 4.5 therefore presents the incidence of non-final relative clauses as proportions of the total number of relative clauses produced in each category.

Restrictive relatives	*Non-restrictive relatives*
14.7%	5.5%

Table 4.5: % of total Restrictive and % of total Non-restrictive relatives in Non-Final position

Analysis
As before, it would not be valid to carry out a statistical analysis of these results based on the absolute number of tokens produced by each speaker. Nor, for the reasons given above, could a comparison be carried out between the number of non-final relative clauses in each category as a percentage of each speaker's overall contribution: the prediction related to the *relative* proportions of non-final versus final relative clauses *within* each category. For this reason, a Wilcoxon signed-ranks test was carried out which compared, for each speaker, the proportion of his/her restrictive relative clauses which were non-final with the proportion of his/her non-restrictive relative clauses which were non-final. The test was strongly significant ($T = 7$, $p < .001$). As predicted, significantly more restrictive relative clauses were produced non-finally than non-restrictive relative clauses. Again, the data found in the corpus is consistent with the theoretical predictions.

Hypothesis 3

The third hypothesis related to how frequently relativisation would take place upon different grammatical functions. Since all proposals for grammatical function hierarchies have restricted themselves to arguments, I will only consider subjects, direct objects and prepositional objects. Table 4.6 gives the total number of tokens for each category (relative clauses with clausal Heads were included in the analysis).

Subject	*Direct Object*	*Prep. Object*
309 (55.1%)	137 (24.4%)	34 (6.1%)

Table 4.6: Relativised function: Total tokens

Analysis
For each speaker, the number of subject, direct object and prepositional object relative clauses which he/she produced was calculated as a proportion of his/her overall contribution. Wilcoxon signed-ranks tests were then carried out using these proportions as the dependent variables. Significant differences were found when subject and direct object relative clauses

(T = 24, $p < .001$), subject and prepositional object relative clauses (T = 0, $p < .001$), and direct object and prepositional object relative clauses (T = 16, $p < .001$) were compared. The pattern of relativisation found in the corpus is therefore consistent with that which was hypothesised: the frequency with which a particular function is relativised is linked to the position in which it appears in the grammatical function hierarchy.

Summary

The results presented here support the theoretical hypotheses: relative clauses occur more frequently in clause-final position than in non-final positions; this tendency is stronger for non-restrictive relative clauses than for restrictive relative clauses; and relativisation takes place more frequently on functions which occur at the top of the grammatical function hierarchy. By extension, then, the corpus data supports the production theories on which the hypotheses were based. This in itself is an important result, since it strengthens the empirical basis for the theories, but such a convergence between theoretical prediction and corpus data is also important on a *methodological* level. That is, it not only supports the use of corpora as evidence about language processing; but more importantly, it suggests that full text corpora can validly be used to supplement experimental evidence in evaluating theories of language production.

Generating new hypotheses

So far, the results of the corpus analysis have been evaluated only insofar as they confirm or disconfirm the hypotheses. However, as I noted in Section 4.2.3, a further use of corpora is as an inspiration for new research. In this section, I would like to describe two intriguing (and unexpected) results which emerged during the same corpus analysis. My concern here is again primarily methodological: I will explore how data of this type can be evaluated in conjunction with data from other sources to highlight areas for future research. I should therefore make it clear at this point that this section raises and discusses various possible hypotheses but no attempt is made to evaluate them in depth; in particular, there are too few tokens in the relevant categories to permit statistical analysis.

Position of relative clauses without a relative marker in the matrix clause

Both of the results of interest are concerned with relative clauses without an overt relative element, as in *the man I saw yesterday*. These 'zero relative clauses' contrast with 'full relative clauses' (relative clauses containing an overt relative element, such as *who, which, that*). The first result of interest relates once more to the position of the relative clause with respect to the matrix clause. Analysis of the non-final relative clauses revealed an apparent difference between the frequency of full relative clauses and non-final zero relative clauses in this position. A greater proportion of zero relative clauses appear in non-final positions than full relative clauses, as Table 4.7 below shows. It presents the data for zero relative clauses and full relative clauses by matrix clause position; the percentages are defined over the total number of zero relative clauses and the total number of full relative clauses.

Zero relatives		*Full relatives*	
Non-Final	*Final*	*Non-Final*	*Final*
24 (23%)	79 (77%)	39 (9.5%)	370 (90.5%)

Table 4.7: Zero and Full relatives by matrix position: Total tokens

This may be a misleading comparison, however: all zero relative clauses are restrictive, whereas at least a proportion of the full relative clauses are non-restrictive, and as we have already seen, non-restrictive relative clauses are particularly rare in non-final position. This would have the effect of depressing the overall proportion of non-final full relative clauses. Instead of directly comparing the proportion of zero relative clauses in non-final position with the proportion of *all* full relative clauses, it might be more accurate to compare the zero relative clauses with only those full relative clauses which have the same semantic function (i.e. as modifiers), in other words restrictive full relative clauses. Table 4.8 presents the relevant comparison when only restrictive full relative clauses are taken into account. Even

Zero relatives		*Full relatives*	
Non-Final	*Final*	*Non-Final*	*Final*
24 (23%)	79 (77%)	32 (11.6%)	244 (88.4%)

Table 4.8: Zero and restrictive Full relatives by matrix position: Total tokens

when only those relative clauses which have the same semantic function are compared, zero relative clauses seem relatively more frequent in non-final position than full relative clauses.

Identity of the Head in zero relative clauses

A second disparity between the two categories of relative clause lies in the identity of the Head. In theory, any NP can head a relative clause. We would therefore expect to find both types of relative clause appearing with a wide range of Heads. This is indeed the case for full relative clauses. But when the Heads of the zero relative clauses are examined, an unexpected picture emerges: of the 103 zero relative clause tokens identified in the corpus, almost half (50 tokens) are associated with just four Heads – *thing(s), time(s), way* and *one(s)* – as Table 4.9 below shows. (For interest, I also include the figures for how frequently these Heads appeared in full relative clauses). Zero relative clauses headed by these four nouns correspondingly account for just over half of the non-final zero relative clauses (13/24).

Possible implications of the data

These two patterns – the higher proportion of zero relative clauses which occur non-finally and the frequency with which particular Heads appear in zero relative clauses – are striking. If corpora do reflect underlying patterns of processing, as I have argued so far, then this data could be symptomatic of underlying differences between the processing of full relative

Head	*Zero rel. tokens*	*Full rel. tokens*
thing(s)	16	34
time(s)	16	6
way	10	4
one(s)	8	37
other	53	n/a

Table 4.9: Zero relative clause Heads: Total tokens

clauses and zero relative clauses. This section explores how this data could be evaluated, in conjunction with independent data, to identify possible areas for experimental research.

We have seen that there are two idiosyncratic patterns of data associated with zero relative clauses, one associated with matrix clause position and one with identity of the Head. These patterns may be related to the same underlying processing phenomenon, or they may be simply be independent patterns of data which are coincidentally linked to a single syntactic structure. I will begin by making the default assumption, that they are unrelated. Let us therefore examine one set of data at a time, beginning with the differing proportions of non-final full and zero relative clauses.

One possibility which should not be ignored is simply that this data is not indicative about *processing* issues. Table 4.8 merely reports differences in the proportions of zero/full relative clauses appearing in non-final position; any language-internal differences between the positions where each structure is licensed to appear could result in such a proportional imbalance. More specifically, the apparent disparity between zero relative clauses and full relative clauses could result from the fact that zero relative clauses do not allow extraposition, whereas full relative clauses do. Whereas it is possible to avoid producing a full relative clause in non-final position by extraposing, this option is barred in zero relative clauses:

(4.10) a. The author just phoned up who I interviewed last month.

b. *The author just phoned up I interviewed last month.

This could lead to an increase in the proportion of final full relative clauses and a corresponding decrease in the proportion in non-final position, resulting in a lower proportion of non-final full relative clauses compared to zero relative clauses. If that is the case, then a linguistic fact about the possibility of extraposing with different types of relative clause has given rise to an apparent difference in distribution. This highlights the methodological point that any corpus analysis which is concerned with processing must also be aware of other issues which could have a bearing upon the patterns of data which are found.

In this case, the hypothesis can be tested straightforwardly: if the disparity is solely due to extraposed relative clauses depressing the proportion of non-final full relative clauses, then it should disappear if the extraposed relative clauses are excluded from the comparison. Table 4.10 therefore compares zero relative clauses with restrictive non-extraposed full relative clauses.

As Table 4.10 shows, it does not seem to be the case that the disparity is solely attributable to the possibility of extraposition: even when extraposed full relative clauses are not included

Zero relatives		*Full relatives*	
Non-Final	*Final*	*Non-Final*	*Final*
24 (23%)	79 (77%)	32 (12.2%)	231 (87.8%)

Table 4.10: Zero and restrictive non-extraposed Full relatives by matrix position: Total tokens

from the analysis, a disparity still remains. If that explanation can be excluded, it seems reasonable to assume that the disparity does reflect processing differences between the two types of relative clause. The question with which we are then left is what inferences we can draw about the mechanisms of language processing on the basis of the disparity.

In the previous section, I demonstrated that relative clauses tend not to appear in non-final position. By hypothesis, this is because they are difficult to produce in that position. Thus the fact that zero relative clauses apparently appear more frequently non-finally seems to suggest that zero relative clauses are in some sense easier to produce there than full relative clauses. Hence the most general hypothesis which can be proposed on the basis of this data is that zero relative clauses are easier to produce non-finally than full relative clauses.

However, this hypothesis is not in itself very interesting. A more interesting question is why this should be so. That is, what is it about zero relative clauses which makes them easier to produce non-finally than full relative clauses, and what does this tell us about the mechanisms which underlie language production? In Section 4.3.3, I attributed any processing complexity associated with relative clauses in non-final position to both functional level and constituent level factors. If zero relative clauses differ in their processing complexity from full relative clauses, it suggests that the difference must be located at one (or both) of these levels. Hence any hypotheses which we propose on the basis of this data will relate to the way in which functional level and/or constituent level processing takes place.

Differences in functional level processing

By hypothesis, non-final relative clauses lead to processing complexity at functional level processing because relative clauses form separate planning units and therefore trigger the assignment of a set of grammatical functions; if the Head is assigned a high matrix clause function – which usually equates in English with an early position in the matrix clause – both sets of functions must be assigned simultaneously, leading to processing difficulty. If the difference between full and zero relative clauses is located at the functional level, then, it could be because they differ in their status as planning units. That is, zero relative clauses might not count as independent planning units. Hence producing a zero relative clause will not claim the same functional level resources as a full relative clause, and as a result they will be easier to produce in a non-final position.

This hypothesis could be tested straightforwardly: if they do not constitute separate planning units, zero relative clauses in subject position will be planned as part of the same unit as the matrix verb. Hence they should be able to influence its agreement features in a way which full relative clauses, as independent planning units, cannot. As we saw in the previous chapter, Bock and her colleagues (Bock & Miller 1991; Bock & Cutting 1992; Bock & Eberhard 1993) found evidence that the incidence of agreement errors is related to the number of planning units involved in producing the subject NP: subject NPs which involve two planning units (e.g. subjects with complement clause modifiers) elicited fewer errors than subject NPs involving a single planning unit (e.g. subjects with PP modifiers). Hence if we compared the incidence of errors following zero relative clause subjects and full relative clause subjects, we would expect – under the hypothesis outlined above – to find significantly more agreement errors following zero relative clauses than following full relative clauses.

This hypothesis has implications beyond simply the way in which relative clauses are processed: if such a pattern were found, it would imply that the units of processing at the functional level cannot be equated with the linguistic notion of a clause or a predicate+argument cluster, but instead must be defined in some other way. Hence it would be informative about the nature of the linguistic units which take part in functional processing. This issue will be discussed further in Chapter 5. On the basis of the evidence presented in Chapter 5, I think it is unlikely that zero relative clauses will turn out to have a different status from full relative clauses at the level of functional processing; nevertheless it is a testable hypothesis which is consistent with the data.

Differences in constituent level processing

An alternative is that the disparity in distribution is symptomatic of differences in processing at the level of constituent processing. If difficulty usually results because relative clauses are syntactically complex and so take longer to encode, could the difference between zero and full relative clauses be that zero relative clauses do not have the same syntactic complexity ? There is some linguistic evidence that full and zero relative clauses involve different syntactic structures. In an analysis of relative clause structure in English, Adger & Flickinger (1993) noted that zero relative clauses differ from full relative clauses in a number of important ways: they cannot iterate (4.11); they do not allow extraposition, as we have seen (4.12); they cannot follow full relative clauses (4.13); they cannot appear with sentence-initial modifiers (4.14); and they cannot coordinate with full relative clauses (4.15):

(4.11) a. The musician that I met that you interviewed has just been fired.

b. *The musician I met you interviewed has just been fired.

(4.12) a. The woman entered who I had seen at the exhibition.

b. *The woman entered I had seen at the exhibition.

(4.13) a. The book I reviewed that you liked has just been reprinted.

b. *The book that I reviewed you liked has just been reprinted.

(4.14) a. The issue that last week no-one could ignore has been forgotten.

b. *The issue last week no-one could ignore has been forgotten.

(4.15) a. The magazine that David bought and that Rebecca read was on the table.

b. *The magazine David bought and that Rebecca read was on the table.

Adger and Flickinger argued that these alternations reflect a difference in the syntactic status of zero relative clauses and full relative clauses. In particular, lack of iterability and the requirement to appear next to the Head (examples (4.12), (4.13) and (4.14)) are characteristics of *complements*, whereas full relative clauses bear the characteristics of *adjuncts*. Hence, Adger and Flickinger argued, zero relative clauses must be complements of the Head whereas full relative clauses are modifiers. The proposal that zero relative clauses are complements receives support from an unexpected source. If zero relative clauses are complements selected by the Head, we might expect to find them associated particularly with certain Heads – which is exactly what we find: a limited number of Heads appear disproportionately frequently in zero relative clauses. Thus the two patterns of data under scrutiny here may actually be related.

If zero relative clauses are complements of the Head whereas full relative clauses are adjuncts, this might translate itself into differences in their syntactic representations: complements are usually analysed in theoretical linguistics as sisters of a lexical Head, whereas adjuncts are analysed as sisters of an $\bar{X}$. In this case, a zero relative clause would be sister to an N, whereas a full relative clause would be sister to an $\bar{N}$. Furthermore, in Adger and Flickinger's analysis at least, the actual clause in a zero relative clause structure involves fewer nodes than in a full relative clause, since the latter requires a node for the relative element. It therefore seems feasible that zero relative clauses have a simpler syntactic structure than full relative clauses. As I have already noted, any difference in syntactic complexity could have processing implications, since a less complex structure should require less processing. Hence zero relative clauses may become available earlier than full relative clauses. In that case, zero relative clauses in non-final positions would trigger revision of the constituent structure less frequently than full relative clauses, ultimately resulting in the observed disparity in distribution.

It could be, then, that the pattern of data found in the corpus is indicative of differences in the underlying syntactic structure of zero and full relative clauses. Again, the implications of this hypothesis, were it to be accepted, are not limited to the processing of relative clauses. Instead it would suggest that theoretical linguistic notions such as the distinction between complements and adjuncts may have observable processing effects and thus that theoretical linguistic analyses can make an important contribution to the study of language processing. And, by providing empirical data which converges with a particular linguistic analysis, corpus data such as this can in turn benefit conceptualist linguistic theories.

Alternatively, complements could have a processing advantage over adjuncts because they are specified in the lexicon as part of their Head's lexical entry. In a framework such as that of Lapointe & Dell (1989), where lexical entries contain compiled-out fragments of phrase structure, retrieval of the Head could automatically trigger retrieval of a partial structure for the relative clause. This seems unlikely on the face of it, since it predicts that retrieval of *any* noun will lead to retrieval of an associated zero relative clause structure, and in most cases, nouns do not appear with a zero relative clause. However, it could be that phrase structure fragments are only associated with Heads when those Heads occur with that complement particularly frequently. In other words, fragments of structure which co-occur particularly frequently (such as a Head and its complements) may be stored as a single unit. This is a somewhat radical possibility, since it would suggest that our knowledge of language at the syntactic level includes both rules, from which most structure is generated, and – for a small quantity of elements which co-occur frequently – unanalysed chunks of structure.

The main evidence supporting this proposal is that, as we have seen, zero relative clauses occur extremely frequently with just four Heads. More importantly, however, it becomes apparent when we examine the semantic content of the four Heads that they share a feature in common: they are all semantically vacuous. *Thing* is to all intents and purposes a variable over objects – without some form of modifying information, it conveys no information beyond the fact that its referent is an object. Similarly, the remaining three Heads (*way, time* and *one*) are semantically minimally specific and seem to require some sort of modification to be informative. This could explain why they co-occur so frequently with a relative clause: compared with other Heads, where the appearance or non-appearance of a relative clause is contextually driven (i.e. whether or not there is more than one possible referent of the Head in the current discourse content), a relative clause is in some sense *required* by the semantically vacuous Heads to give them semantic content. It would therefore make sense for the lexical entry for the semantically vacuous Heads, though not more contentful Heads, to contain a default specification for a relative clause complement.

More than the previous two possibilities which I have discussed here, this last possible explanation for the disparity in zero/full relative clause distribution shows that corpus data can inspire hypotheses which have far-reaching consequences for processing theories. In this case, the proposal outlined above would suggest a model of language processing in which constituent structure may be elaborated partially by the retrieval of compiled-out fragments of structure and partially by the dynamic application of a set of rules.

Summary

In this section I have explored how unanticipated patterns of data identified by a corpus analysis can raise possibilities for future research. Clearly, careful experimental research would be needed to test the various possibilities. However, this section has shown that corpus data can be an interesting source of new hypotheses when evaluated in the context of existing theories. The discussion above also showed how data from theoretical linguistics may be brought to bear upon theories of language processing, and demonstrated how theoretical linguistics may benefit from psycholinguistic research: the convergence between the corpus data and theoretical linguistic analyses simultaneously casts new light upon the empirical data and provides support for the linguistic analysis.

4.4 Summary

As I noted in the introduction to this chapter, my main concern here has been methodological, to explore the possibilities which corpora offer for research into the processing of language. Corpora should not be viewed merely as collections of E-language statements which can form the basis of descriptive theories; rather, they are informative about I-language and the processes in which I-language is implicated. The data found in corpora can be used both to

provide empirical support for a processing theory (and in certain circumstances for a theoretical linguistic analysis) and as an inspiration for new hypotheses about language processing. More specifically, I argued that the most principled approach to corpus analysis, which makes the fewest additional assumptions about the data, is one which employs full text corpora to examine language production.

The results of the analysis of relative clauses in the London-Lund corpus suggest that this approach is valid: they provided new evidence in support of particular hypotheses about syntactic processing in language production; and they also highlighted unexpected new data which suggests directions for future research.

Chapter 5

Subject–verb agreement errors and functional level processing

5.1 Introduction

In the previous chapter, I explored how corpora could be used to test and to generate hypotheses about language production. In this chapter, I will be concerned with an experimental method, agreement error elicitation, which can be used to investigate some of the same issues. I begin by reviewing previous work using this method and the conclusions which have been drawn from it. I then show how the method can be used as a tool to investigate not just processing issues, but also representational issues. In the remainder of the chapter, I present the results of two experiments which explore agreement error phenomena in written language production. I will argue that these experiments provide evidence that there are units in language processing which correspond to the theoretical linguistic notion of the clause. However, the results of the second experiment are puzzling in a number of ways and raise several issues for future research.

5.2 Agreement errors and planning units

The previous chapter was concerned with the use of corpora as a means of examining hypotheses about functional level processing and constituent level processing. At the functional level, I examined the hypothesis that the units of functional processing correspond to clauses, following proposals by (among others) Garrett (1980) and Holmes (1988). The corpus study revealed that the distribution of relative clauses which we would expect on the basis of this hypothesis actually occurs within a large corpus of natural speech. Such hypotheses about the nature of functional level processing can also be tested using experimental methods. The experimental method with which I am concerned in this chapter is the experimental elicitation of subject–verb agreement errors.

5.2.1 Subject-verb agreement errors in language production

Subject–verb agreement errors are a common form of error in language production. They occur when the speaker fails to produce the appropriate number inflection on the verb, as in the following example taken from a radio interview:

(5.1) If the rumour about the events are correct, there will soon be some resignations.

In this case, the speaker produced a plural inflection where a singular inflection should have appeared. In English, subject–verb agreement can usually be characterised in terms of the verb bearing the same number marking as the syntactic number of the head noun in the subject NP. There are some circumstances where this is not the case, for example in British English where syntactically singular nouns such as *committee* can appear with either a singular (5.2a) or a plural (5.2b) verb inflection.

(5.2) a. The committee has accepted responsibility for the losses.
b. The committee have accepted responsibility for the losses.

Which inflection is produced apparently depends upon whether the speaker is focusing upon the entity denoted by the noun in its entirety or the individuals which make up the collective entity. For example, (5.2b) above would be interpreted in terms of each member of the committee accepting his/her personal responsibility. The diference in interpretation is clear if we examine the interaction of verb agreement and relative pronouns in relative clauses headed by such nouns:

(5.3) a. The committee which is meeting tomorrow will consider the options.
b. *The committee which are meeting tomorrow will consider the options.
c. The committee who are meeting tomorrow will consider the options.
d. *The committee who is meeting tomorrow will consider the options.

The examples in (5.3) show that singular verb agreement coincides with use of the non-human relative pronoun (*which*), implying that the noun is considered as an inanimate entity (i.e. the collective entity) in these cases, whereas plural verb agreement coincides with use of the human relative pronoun (*who*), implying that the noun is considered here to refer to a set of individuals.

Plurally inflected verbs may also optionally appear in some dialects of British English with singular head nouns which have a quantificatory function, as in (5.4) below.[1]

(5.4) a. This group of students is always arguing.
b. This group of students are always arguing.

These examples aside, however, a commonly accepted generalisation is that the number inflection on the verb should agree with the syntactic number of the head noun. In (5.1), this did not occur, leading to an agreement error. As in this example, agreement errors seem to occur

[1] See also Pollard & Sag (1994), Chapter 2, for some other examples of subject–verb agreement in English which are not based on the syntactic features of the head noun.

particularly often where the head noun and the verb are separated by an intervening noun whose syntactic number disagrees with that of the head noun. Agreement errors of the type (5.1) are instances of a phenomenon which has been termed 'proximity concord', because the verb agrees with a proximal noun (here, *events*) rather than the head noun *rumour* (Quirk, Greenbaum, Leech & Svartvik 1972).

Like other types of speech error, subject–verb agreement errors are in principle informative about the processes which underlie language production. By investigating the circumstances under which such errors occur, inferences can be drawn about the way in which subject–verb agreement is computed and, under the assumption that it is computed over functional level representations (Bock & Miller 1991), about the way in which functional level processing takes place.

The linguistic characterisation of subject–verb agreement

In the previous section, I suggested that the pattern of subject–verb agreement in English could largely be described in terms of the syntactic features of the head noun. However, I did not claim that such an approach was necessarily the most appropriate way to capture the phenomenon within a linguistic theory. In fact, although the view that agreement should be characterised in terms of syntactic features is a commonly held view, it is not one which is unanimously accepted. As I have shown, there are circumstances where a syntactically-based approach seems inadequate to explain the actual agreement which appears on the verb, and a number of researchers have proposed alternative formulations of the relationships underlying subject–verb agreement which focus on the role of semantic factors. These are reviewed in some detail, together with Pollard and Sag's own composite syntactic/semantic/pragmatic approach, in Pollard & Sag (1994).

As a result, it is a matter of some linguistic interest how subject–verb agreement actually occurs in language production. For those linguistic theories which claim to be concerned with language as a psychological construct, studying the way in which subject–verb agreement is implemented in production is an obvious way to choose between the alternative approaches. One way of achieving this would be to examine the factors which affect the incidence of agreement errors. If semantic factors turn out to have a strong effect, for example, it would suggest that the characterisation of subject–verb agreement in the linguistic theory should include a semantic element.

Subject–verb agreement and functional level processing

These theoretical questions are also related to some fundamental issues concerning the architecture of the processing system. In the model of language production which was outlined in Chapter 3, it was assumed that the modules which comprise the production system are encapsulated, in the sense that information which is relevant at one level of processing cannot directly affect processing at subsequent levels. In particular, the model assigns a restricted role to semantic information in language production. Semantic factors may play a part during the mapping from the pre-verbal message to a functional representation, but once an entity has been assigned a function, its semantic features should not affect its syntactic elaboration.

This contrasts with models of production where semantic features play a role at all levels in the elaboration of a message.

Any finding that subject–verb agreement cannot be affected by semantic factors and is computed on the basis of syntactic factors only would support the modular model. If both syntactic and semantic factors can affect agreement processes, however, it suggests that both types of information may be active at the same level of processing, contra the modular model.[2] Evidence that agreement is sensitive to semantic information only could not be construed as support for either model, since it is compatible with both.

Additionally, studying agreement errors could cast light upon the units which participate in functional processing. As we have seen, there is evidence that functional processing takes place in clause-like units. If that is the case, and agreement is computed at the level of functional processing, then we would expect to find differences in the agreement error patterns associated with clauses and sub-clausal units. This will become clearer below.

5.3 Experimental studies of agreement errors

Although it is in principle possible to study agreement errors using corpora, there are practical reasons which make it difficult. The most serious problem is that of obtaining a large enough data set. Agreement errors seem to occur particularly frequently in contexts where the head noun is modified by a constituent which contains an NP which has different number features. Furthermore, they can only be detected with verb forms which are inflected for number, and in English this is a restricted set, i.e. irregular verbs (such as *be* and *have*) or present tense verb forms. Examples of sentences which conform to these two criteria are not particularly common in corpora, and given the low rate of occurrence of such errors, extracting a large enough set to be able to carry out an analysis would require an extremely large corpus. Furthermore, we have seen that there are circumstances in which a plural verb may quite legitimately follow a singular head noun. Any such examples would either have to be excluded from consideration, or a decision made about whether to classify them as errors, either of which could affect the eventual results. Hence whilst the occurrence of agreement errors could be studied using corpora, such a study would have to overcome serious practical difficulties.

Experimental studies can avoid these problems by focusing on those constructions which are most likely to cause errors whilst avoiding the problem cases, and by allowing the explicit manipulation of factors of interest. A number of recent studies of agreement errors have therefore used an experimental method which elicits agreement errors.

Bock and Miller (1991)

Bock & Miller (1991) developed a sentence completion method for eliciting agreement errors. Subjects heard the beginnings of sentences and were asked to repeat them and then complete the sentence in any way that they liked. For example, they might hear and repeat (5.5a), completing it as in (5.5b).

[2] The alternative, that agreement is successively computed at two levels of processing, where semantic information is only available at the first level and syntactic information at the second level, seems highly implausible.

(5.5) a. The girl ...

b. The girl started laughing.

Interspersed throughout the list were sentence fragments which were designed to cause agreement errors. They consisted of NPs where the head noun was followed by another noun (the local noun) which mismatched the head noun in syntactic number, as in (5.6a) below. Hence, an NP with a plural head noun contained a singular local noun and vice versa. These materials were paired with control materials where the head and local noun matched in number, as in (5.6b).

(5.6) a. The key to the cabinets ...

b. The key to the cabinet ...

By manipulating the characteristics of the head/local noun and the modifier, Bock and Miller were able to explore which factors contributed to the processes of subject–verb agreement.

Bock and Miller were concerned with the effects of various conceptual features and different types of modifier on agreement. In their first experiment, they compared the incidence of errors when the head and local nouns matched or mismatched in number, and whether this effect was mediated by the length of the modifier; (5.7) gives examples of short and long modifiers in the mismatch condition. They reasoned that if agreement errors were caused by memory limitations, more errors should be found following long modifiers than following short modifiers.

(5.7) a. The key to the cabinets ...

b. The key to the ornate Victorian cabinets ...

In addition, they examined whether there were differences in the frequency of errors following PP modifiers (5.8a) versus relative clause modifiers (5.8b).

(5.8) a. The key to the cabinet ...

b. The boy that liked the snakes ...

They also manipulated the semantic characteristics of the PP modifiers. In half of the PP materials, the head noun was single-token, in that its referent was a single object distributed over the objects mentioned in the PP (5.9b). In the other PP materials, the head noun was multiple-token: its referent, although a single abstract entity, required a different token of that entity to be associated with each object in the PP (5.9b).

(5.9) a. The key to the cabinets ...

b. The label on the bottles ...

Bock and Miller found that more errors occurred when the head noun and the local noun mismatched in number than when they matched. This effect was particularly strong for preambles with singular heads. There was no effect of modifier length, nor of single versus multiple tokens. However, the type of modifier affected the incidence of errors: errors occurred

more frequently following PPs than following relative clauses. Bock and Miller concluded from these results that agreement errors are probably not the result of a failure to identify the subject of the sentence, since this would have predicted equal numbers of errors with singular heads and plural heads in the mismatch condition, rather than a concentration of the effect upon singular heads. For the same reason they argued against any explanation in which the local noun, regardless of its number, is granted control of agreement.

Their second experiment examined PP modifiers only. In it they examined whether agreement errors were affected by differences in animacy between the head and the local noun, given the strong tendency for animate entities to appear as subjects. They also manipulated the concreteness of the head and local nouns, to see whether the relative definiteness or specificity of the nouns competing for agreement had any effect upon the number of errors produced. (5.10) below exemplifies their materials, with an animate/concrete head (5.10a); an animate/non-concrete head (5.10b); an inanimate/concrete head (5.10c); and an inanimate/non-concrete head (5.10d). (All of the examples are taken from the mismatch condition).

(5.10) a. The author of the speeches ...

b. The nomad of the mountains ...

c. The mountain of the nomads ...

d. The speech of the authors ...

As before, more errors occurred in the mismatch condition than in the match condition, particularly in the singular head/plural local noun condition. However, this pattern of errors was unaffected by the animacy and the concreteness of the local noun.[3] Bock and Miller concluded from this that agreement processes have access to syntactic information only and are blind to the conceptual features associated with nouns which are competing for agreement.

A third study examined the incidence of agreement errors following preambles involving relative clauses of the type exemplified below.

(5.11) The politicians that the flag ...

In this case, the subject of the matrix clause (*the politicians*) must correspond to a non-subject position in the relative clause (e.g. *The politicians that the flag horrified ...* or *The politicians that the flag fell upon ...*). Bock and Miller reasoned that subjects might reinterpret the relationship between the entitities *politicians* and *flag* so that the mental representation of the preamble is something like *the flag that the politicians ...*, because there are relatively few verbs which license an inanimate subject and an animate object. Reassigning the subject relation would allow the animate entity to control the embedded verb. However, where the number of the animate and inanimate entities disagree, as in (5.11) above, reassignment of the subject relation to the matrix subject would result in an agreement error, as in *The politicians that the flag were ...*. Hence Bock and Miller predicted that more agreement errors would occur with sentences like (5.11), where the animate entity forms the matrix subject, than in (5.12), where it is the embedded subject and hence should not trigger reassignment of the subject relation.

[3] There was a suggestion of a concreteness effect in the mismatch condition, but this disappeared in a better controlled replication study.

(5.12) The flag that the politicians ...

They found that, as predicted, more errors occurred following animate matrix clause subjects; in at least some of these errors, speakers were incorrectly identifying the matrix subject as the subject of the relative clause.

Bock and Miller suggested that this is evidence that animacy influences the assignment of the subject relation to arguments. Agreement processes operate with respect to this assignment, but have no access to the conceptual features which originally brought about that assignment. According to this, agreement errors do not arise from misidentification of the noun phrase with which the verb should agree, but from errors in the initial assignment of the subject relation. Hence where there is no difficulty in identifying the subject (as in the second study), there is no effect of animacy. Where subject identification is difficult, however, as in the third study, agreement errors increase and animacy is correlated with the increase. Bock and Miller concluded from their experiments that subject–verb agreement in English is governed by abstract syntactic relations. They suggested that the absence of modifier length effects points to a level of processing prior to the assignment of word order and phonological form, i.e. functional processing.

Overall their experiments suggest that agreement errors can be induced experimentally and cast some light on the factors which are implicated in computing subject–verb agreement. Perhaps most interesting is the suggestion that modifiers of different syntactic types induce different patterns of errors.

Bock and Cutting (1992)

Bock & Cutting (1992) used the same task to investigate the effect of syntactic factors on the incidence of agreement errors. Their first experiment investigated whether relative clause modifiers and PP modifiers acted differently in eliciting agreement errors, as Bock and Miller's (1991) first experiment suggested. According to the model of language production outlined in Chapter 3, functional level processing appears to take place in roughly clause-like units. This means for each clause, the verb and all of its arguments are processed together. Thus whereas PPs are processed as part of the main clause unit, clausal modifiers will form a unit distinct from the main clause. Bock and Cutting suggested that as a result, more errors would occur following PP modifiers than following clausal modifiers, because the local nouns in the PP modifiers would be specified as part of the same planning unit as the verb and hence would be available to influence its agreement features. A local noun in a clausal modifier, however, would be part of a separate unit and hence less available to influence the main verb.

Subjects completed preambles with either relative clause (5.13a) or PP modifiers (5.13b). The plurality of the head noun and the local noun embedded in the modifier was systematically manipulated.

(5.13) a. The editor who rejected the book ...
b. The editor of the history book ...

As predicted, Bock and Cutting found more errors after PPs than after relative clauses. Again, errors were concentrated in the mismatch condition.

Bock and Cutting noted that the embedded verb in the subject relative clauses used in the first experiment agreed with the head noun, i.e. there was a dependency between the head noun and the embedded verb. This might have aided subjects in producing their completions. Their second experiment avoided this problem by comparing PP modifiers (5.14a) with complement clause modifiers (5.14b). Like relative clauses, complement clauses should comprise planning units, but the embedded verb in such structures does not agree with the head noun. In this and the following experiment, they used only singular headed NPs, since the first experiment suggested that the results would be clearer with these than with plural headed NPs. Examples of their materials are given below.

(5.14) a. The report of the forest fires ...
b. The report that they controlled the fires ...

As before, they found more errors in the mismatch condition following PP modifiers than following clausal modifiers.

Their third experiment investigated the effect of modifier length on the incidence of agreement errors, using the same two modifier types. They predicted that the length of clausal modifiers should have no effect on agreement of the main verb. However, longer PP modifiers would increase the amount of material which had to be processed within a single planning unit and this could lead to processing disruption, resulting in more errors. They therefore compared preambles which contained short modifiers (the (a) examples) with preambles containing long modifiers (the (b) examples).

(5.15) a. The report of the destructive fires ...
b. The report of the destructive forest fires ...

(5.16) a. The report that they controlled the fires ...
b. The report that they controlled the forest fires ...

As before, there were more errors following PPs than following complement clauses. There was also the predicted effect of modifier length for PP modifiers though not for clausal modifiers.[4] They suggested that the difference between clausal and PP modifiers in this regard implied that agreement errors were not caused simply by a failure to remember the head noun. Overall, Bock and Cutting argued that their results supported a hierarchical model of production where clause boundaries delimit and partially insulate the domain of subject–verb agreement processes. However, note that their experiments were restricted to examining finite clauses and so can only be construed as evidence that *finite* clauses form processing units at one level of language production.

Bock and Eberhard (1993)

Bock & Eberhard (1993) investigated the effects of conceptual, lexical and morphophonological features on the occurrence of agreements errors. All of their experiments involved subject NPs

[4] They suggested that the reason why a comparable modifier length effect was not found in Bock & Miller (1991) was because PP and clausal modifiers were analysed together in that experiment, obscuring any effect.

with PP modifiers. The third experiment examined both singular- and plural-headed NPs, but the remaining experiments examined singular-headed NPs only. The first two experiments explored the possibility that plural agreement on the verb is not governed by syntactic factors, but rather triggered by plural morphology on a pre-verbal noun. Using the sentence completion task, they examined whether local nouns which phonologically resembled plurals (5.17a) would elicit more errors than phonologically unambiguous singular local nouns (5.17b). They were compared with phonologically unambiguous plural local nouns (5.17c).

(5.17) a. The player on the course ...
b. The player on the court ...
c. The player on the courts ...

They found that singular local nouns which phonologically resembled plurals did not cause errors; errors only occurred after syntactically plural local nouns.

In a second experiment, they explored the same hypothesis but this time using local nouns (5.18a) which, while syntactically singular, were homophones of plural nouns (5.18b). Subjects were visually presented with the preambles for oral repetition and completion, since the critical words were homophones.

(5.18) a. The reason for the big size ...
b. The reason for the big sighs ...

Again, only truly plural local nouns elicited agreement errors. Bock and Eberhard concluded that phonological similarity to a plural noun did not increase the likelihood of a local noun inducing an agreement error and hence that phonological factors do not appear to be implicated in subject–verb agreement processes.

Their third experiment also investigated the influence of morphology on agreement by comparing the incidence of agreement errors following two classes of syntactically plural local nouns, those with regular and those with irregular plural morphology. They reasoned that if agreement is implemented on the basis of overt morphology, more errors would occur after regular plurals (5.19a) than irregular plurals (5.19b).

(5.19) a. The trap for the rats ...
b. The trap for the mice ...

This experiment also tested whether the higher incidence of agreement errors following plural local nouns could be attributed to the atypicality of those nouns in the plural form. If so, then the occurrence of errors should be modulated following local nouns which are more frequent in the plural form than in the singular form. For example, *mice* is more common than *mouse* and so one might expect more errors following *mouse*. Bock and Eberhard found that regular and irregular plural local nouns elicited comparable numbers of agreement errors and that differences in the frequency of use of the singular/plural form had no reliable effect. They argued that agreement is governed by an abstract specification of number and not by overt morphological marking.

A fourth experiment explored two possibilities of how this abstract specification might be defined. They compared the behaviour of notionally plural (i.e. collective) local nouns when they were syntactically singular (5.20a) and syntactically plural (5.20b). If agreement is based upon notional plurality, both conditions should elicit comparable numbers of errors.

(5.20) a. The condition of the fleet ...
b. The condition of the fleets ...

Bock and Eberhard found that the syntactic plurality of the local noun had a reliable effect upon agreement. They concluded that differences in verb agreement was primarily associated with the syntactic number of the local noun and hence that subject–verb agreement is usually computed on the basis of a lexical specification of plurality which cannot be conflated with phonological, morphological or notional plurality.

Vigliocco, Butterworth and Semenza (1995)

Vigliocco, Butterworth & Semenza (1995) used the same task as Bock and her colleagues to study agreement errors in Italian. They found that the morphological characteristics of the head noun affected the incidence of agreement errors. They used preambles such as those in (5.21) below. Many more errors were produced following preambles like (5.21a), where the form of the head noun is the same in both plural and singular, than following preambles like (5.21b), where the head noun has different forms in singular and plural (note that the form of the determiner associated with the head noun always marked whether the head noun was singular or plural; for example, *la* in (5.21a) indicates that *città* is singular).

(5.21) a. La città sulle colline ...
the$_{sg}$ *town*$_{sg/pl}$ *on-the hills*
'The town on the hills ...'
b. Il gatto sui tetti ...
the$_{sg}$ *cat*$_{sg}$ *on-the roofs*
'The cat on the roofs ...'

They also studied whether semantic characteristics of the head affected the occurrence of agreement errors by comparing preambles where the head was syntactically singular but had multiple referents (as in (5.22a) below, where each bottle has its own label), with preambles where the head was both syntactically and referentially singular. They found that there was a semantic effect: more errors occurred following multiple token head nouns as in (5.22a) than following singular tokens (5.22b); this effect was distinct from the effect of morphological marking.

(5.22) a. L'etichetta sulle bottiglie ...
the-label on-the bottles
'The label on the bottles ...'
b. Il viaggio verso le isole ...
the journey towards the islands
'The journey to the islands ...'

In a further experiment, Vigliocco *et al* studied whether the effect of overt morphological marking was limited to head nouns. They compared the incidence of errors following preambles where both the head and local nouns were overtly marked for number (5.23a); neither noun was overtly marked for number (5.23b); only the head noun was overtly marked (5.23c); and only the local noun was overtly marked (5.23d):

(5.23) a. La melodia delle musiche ...
the$_{sg}$ *melody*$_{sg}$ *of-the*$_{pl}$ *pieces-of-music*$_{pl}$
'The melody of the pieces of music ...'

b. La radio sulle auto ...
the$_{sg}$ *radio*$_{sg/pl}$ *on-the*$_{pl}$ *car*$_{sg/pl}$
'The radio on the cars ...'

c. La festa nelle tribù ...
the$_{sg}$ *celebration*$_{sg}$ *in-the*$_{pl}$ *tribe*$_{sg/pl}$
'The celebration in the tribes ...'

d. La città sulle colline ...
the$_{sg}$ *town*$_{sg/pl}$ *on-the*$_{pl}$ *hills*$_{pl}$
'The town on the hills ...'

Vigliocco *et al* found that the presence or absence of a morphological number marking on the head noun (but not the local noun) had a significant effect on the occurrence of errors.

They also analysed the incidence of repetition errors (where subjects incorrectly repeated the preamble) in their experiments. They found that repetition errors patterned differently from agreement errors. For example, repetition errors showed no effect of distributivity (i.e. whether the head was single- or multiple-token) and did not show the same head/local noun asymmetry with respect to the presence/absence of morphological markings. Vigliocco *et al* concluded that the processes which gave rise to repetition errors were distinct from those involved in generating a completion. Presumably, the former were primarily comprehension processes involved in initial comprehension of the preamble whilst the latter were production processes.

Overall, Vigliocco *et al* concluded from their experiments that in Italian (and perhaps pro-drop languages in general), the speaker frequently has to compute the agreement on the verb without any assistance from number/gender markings on the head noun, either because the subject is a null pronoun, or alternatively because the subject appears post-verbally. In order to generate the correct inflection in these contexts, the speaker needs to draw upon discourse information. They suggested that speakers of Italian can retrieve such features as person and number directly from the conceptual representation and base verb agreement on these conceptual features. In this way conceptual features (such as distributivity) can affect verb agreement in Italian, unlike in English. Their approach predicts that the same effects will be found in other pro-drop languages and possibly other verb-initial languages. Vigliocco *et al* also suggested that the morphological effects argue for a model in which there is feedback from morphological encoding to grammatical encoding.

Their work suggests that it might be misleading to attempt to provide a single cross-linguistic account of subject–verb agreement processes, since different factors may assume

importance in different languages. Furthermore, if their hypothesis concerning feedback from a level of morphological encoding to grammatical encoding is correct, it would mean that the modular architecture for the production system which I am assuming here would also be untransferable across languages, in other words that different languages might have different processing architectures. The issue of whether the same architectures and processes are implicated in language processing cross-linguistically has not been explored in production in great detail (though see MacWhinney & Bates (1989)), although it has been the subject of some discussion with respect to comprehension (see for example Frazier & Rayner (1988) and Crocker (forthcoming)); evidence of the sort outlined here could be important in casting light upon this question.

Fayol, Largy and Lemaire (1994)

Fayol, Largy & Lemaire (1994) reported a series of experiments which examined subject–verb agreement errors in written French. They investigated the hypothesis that these errors occur because of cognitive overload. In their experiments, subjects listened to sentences and then wrote them down. The first two experiments involved sentences with modified subject NPs, as in (5.24) below. As in the experiments reported above, the number of the local NP either matched (5.24a) or mismatched (5.24b) that of the head noun; since the singular and plural forms of a noun are usually homophonous in French, the syntactic number of each noun was identified by the form of the determiner associated with it (e.g. *le* is a singular form, whereas *les* is a plural form).[5]

(5.24) a. Le père de l'enfant s'inquiète.
the father of the$_{sg}$*-child worries*
'The child's father worries.'

b. Le chien des voisins arrive.
the dog of-the$_{pl}$ *neighbours arrives*
'The neighbours' dog arrives.'

Note that in French, the singular and plural forms of regular verbs are homophonous but not homographic in the present tense. Hence the stimuli which the subjects listened to were ambiguous with respect to verb agreement but their responses were not. Fayol *et al* compared the number of verb agreement errors which subjects produced when simply transcribing what they had heard, with the number of errors when subjects also had to carry out a secondary task. In the first experiment the secondary task was remembering a set of words; in the second experiment, it was counting clicks. They made two predictions: that there would be more errors in the mismatch condition than in the match condition; and that more errors would occur when subjects had to fulfill two tasks, since in this case subjects would have a heavier cognitive load. As predicted, significantly more errors occurred in the mismatch condition. Also as predicted, the number of errors increased substantially in both experiments when subjects had a secondary task.

[5] It is not entirely clear from their discussion, but it appears that Fayol *et al* used different items in each condition.

Their third experiment investigated whether the same effects would occur with pre-verbal clitic pronouns rather than PP modifiers. They also examined whether the number of errors would increase when the verb appeared sentence-finally than when it appeared non-finally, arguing that cognitive load increases towards the end of a sentence, perhaps while planning of the next sentence takes place (although note that in this case, there was no following sentence to plan). To test this, they compared sentences where the pre-verbal pronoun matched the subject pronoun in number (5.25a) with sentences where they did not match (5.25b). They also manipulated the position of the verb so that it appeared sentence-finally (5.26a) or non-finally (5.26b). In order to make the sentences more plausible, they preceded them with a context sentence, given here in parentheses.

(5.25) a. (Le soldat perd un gant). Il le ramasse.
(the soldier loses a glove). He it picks-up.
'(The soldier loses a glove). He picks it up.'

b. (Les vieux ont un journal). Ils le consultent.
(the old-people have a newspaper). They it read.
'(The old people have a newspaper). They read it.'

(5.26) a. (Les vieux ont un journal). Ils le consultent chaque jour.
(the old-people have a newspaper). They it read every day.
'(The old people have a newspaper). They read it every day.'

b. (Les vieux ont un journal). Chaque jour ils le consultent.
(the old-people have a newspaper). Every day they it read.
'(The old people have a newspaper). Every day they read it.'

Again, Fayol *et al* found more errors in the mismatch condition and when subjects had a secondary task. As predicted, they also found that errors increased when the verb was sentence-final. Fayol *et al* concluded on the basis of their experiments that agreement errors occur in written language as well as spoken language. They proposed that errors occur during periods of cognitive overload, when the speaker/writer loses track of the number of the head noun and resorts to a strategy of agreement based on the most recent noun.

Fayol *et al*'s work is valuable in demonstrating that agreement errors can be elicited in written language, and also in highlighting the role of working memory limitations. Furthermore, although they did not note the fact, their third experiment suggests that agreement errors are not caused solely by competition from a noun embedded in the same NP as the head noun: pronouns associated with the verb also caused errors. In other words, *object* NPs within the same planning unit may also interfere with the computation of subject–verb agreement. However, their proposal concerning the mechanism by which errors arise is less convincing, since errors also occurred in the match condition. If their experimental subjects simply made the verb agree with the most recent noun, there is no explanation for why errors occurred when both nouns agreed in number.

5.3.1 Summary

The experiments outlined above suggest that agreement errors which are qualitatively similar to those produced in spontaneous speech and writing can be elicited experimentally. The results suggest strongly that subject–verb agreement in English is essentially syntactically-controlled: conceptual/semantic and morphophonological factors are not implicated in the causation of agreement errors, nor, by extension, in normal subject–verb agreement processes. On the one hand this is support for linguistic theories which take a syntactic approach to subject–verb agreement; on the other, it argues that the architecture of the language production system is at least partially encapsulated, with restrictions on which information is available at which point in processing. However, Vigliocco *et al*'s research is a reminder that these conclusions hold for English only, and that other languages might produce quite different results. The evidence also supports the hypothesis that functional level processing takes place in approximately clausal units.

5.4 Written subject–verb agreement errors: Experiment 1

5.4.1 Agreement errors and representation

All of the experiments outlined above have – unsurprisingly – focused on the processes by which subject–verb agreement is produced, in particular the types of information which may affect them and the domain over which they act. These issues are of considerable theoretical interest. However, the occurrence of agreement errors has wider relevance than simply betraying the processes by which agreement is computed: agreement error phenomena could also be informative about the representation of language.

Bock & Cutting (1992) showed that local nouns cause differential problems for subject–verb agreement processes, depending on the syntactic context in which they are embedded: local nouns in PPs cause relatively greater difficulty than local nouns in relative or complement clauses. That is, relative and complement clauses form a class of constituents which pattern alike, suggesting that relative and complement clauses are processed in a similar way, whilst PPs form a separate class. This implies that at the level of processing where subject–verb agreement is computed, relative and complement clauses but not PPs have representations which share something in common. Hence differences in the incidence of agreement errors associated with different types of modifier could in principle be informative about which types of constituent are processed similarly and so form a natural class.

The focus on the processes of agreement has meant that this hypothesis has not yet been explored. The remainder of this chapter presents two experiments which are concerned with this question. The first aims to establish the efficacy of a particular experimental method; the second uses this method to approach the question directly.

5.4.2 Experimental issues

Apart from Fayol *et al*'s paper, all of the experimental work reviewed above has concentrated on agreement errors in spoken language. However, Bock and Miller (1991) noted a study of agreement errors in written English by Strang (1966), which suggests that similar effects are found in written language. It is unclear whether agreement errors in these circumstances can be equated with those found in spoken language. The aim of the experiment reported here was to investigate whether a sentence completion task similar to that used by Bock and her colleagues would elicit comparable results in written language. If written language and spoken language production involve the same processes up to the point where motor processes are initiated, as seems reasonable, then we would expect to find the same pattern of errors in writing as in speech.

More specifically, following Bock & Cutting (1992), we would expect to find that subjects would be more likely to produce agreement errors following preambles where the head noun and local noun mismatch (5.27a) in syntactic number than when they match (5.27b). We would also expect to find more errors following PPs (5.28a) than following clauses (5.28b), under the assumption that each clause forms a planning unit and that subject–verb agreement is specified within a planning unit.

(5.27) a. The report of the forest fires ...
b. The report of the forest fire ...

(5.28) a. The report of the forest fires ...
b. The report that they caused the fires ...

However, if production processes are not the same in written and spoken language, then we might expect to find a different pattern of errors to that found in speech.

This method could also cast some light upon the extent to which agreement errors occur without the subject's awareness of a mistake in processing. If subjects are aware that there is a problem, we might expect to find fewer errors in the written sentence completion task: since the preamble is printed, the writer can easily remind him/herself of the head noun. On the other hand, if the writer is unaware of a problem, then the fact that the preamble is available for re-inspection should have little effect.

In putting together the materials, several criteria were taken into consideration. Previous experiments (Bock & Cutting 1992) showed that the strongest effects occurred with PPs and complement clauses, as in (5.27) and (5.28) above and so these two types of modifier were used. Long modifiers were used because Bock and Cutting's third experiment suggested that they magnified the number of errors found with PPs. In order to ensure that any differences between the two modifier types could not be attributed to differences in the relationship between head and modifier, both the PP and clausal modifiers were complements of the head. The requirement that the head license both PP and clausal complements necessarily restricted the heads which could be used, but this had the desirable side-effect of excluding quantificatory heads of the type exemplified in (5.4) above, which allow both singular and plural agreement in some dialects. Collective nouns were also excluded from the materials, for the same reason. A final criterion governing the choice of head noun was that it be fairly abstract. One problem

which is evident in previous experiments is the difficulty of eliciting sentence completions which involve inflected verb forms, where agreement is overtly marked and hence any agreement error can be detected. Abstract nouns are of low predicability (Bock & Warren 1985), which means that they tend to occur with forms of *be*, one of the very few verbs in English which is marked for number in both the present and past tenses.

Previous experiments showed that although they occurred with both singular and plural heads, the effects were clearest with singular heads – several of the experiments reported in Bock and Cutting (1992) and Bock and Eberhard (1993) used only singular heads for this reason – but I was concerned that subjects might realise that all of the complex subject NPs had singular heads and would settle into strategic use of only singular verbs following materials of this type. For this reason, I decided to use mostly singular heads but to include a proportion of plural heads. It was anticipated that these might add noise to the results but would not substantially alter the pattern of agreement errors. The singular-headed items could in any case be considered separately.

5.4.3 Method

Subjects

The subjects consisted of 64 unpaid volunteers from a pre-university summer school held at the University of Glasgow.

Materials

The materials for the experiment consisted of 24 sets of materials, consisting of a subject NP that included two nouns, a head noun and a local noun. The local noun was embedded in a PP or a complement clause that modified the head noun. There were four versions of each preamble, corresponding to the four conditions: PP modifier, head–local noun match (5.29a); PP modifier, head–local noun mismatch (5.29b); clausal modifier, head–local noun match (5.29c); and clausal modifier, head–local noun mismatch (5.29d).

(5.29) a. The report of the fast spreading forest fire ...
b. The report of the fast spreading forest fires ...
c. The report that they started the forest fire ...
d. The report that they started the forest fires ...

All versions of a preamble had the same head and local nouns, the same number of syllables and – as far as possible – approximately the same stress pattern and length in terms of number of characters. Twenty of the materials had singular head nouns; the remaining four materials had plural head nouns. A complete list of materials is given in Appendix A.

An additional 84 filler materials were constructed. Thirty-six of these consisted of fragments of varied types, including bare NPs and NPs followed by transitive and ditransitive verbs (e.g. *The rock star photographed ...*); 24 were NPs followed by a ditransitive verb and an NP (e.g. *The boy gave the girl ...*); and 24 were relative clause fragments (e.g. *The sentry who was woken by ...*).[6]

Two presentation lists were constructed from these materials. Each list contained six materials of the type shown in (5.29a), six of the type shown in (5.29b), six of the type in (5.29c) and six of the type in (5.29d). The order of presentation was randomised for each subject with the constraint that at least three filler sentences intervened between each experimental material. The sentence fragments were then printed out as eight page booklets.

The instructions on the cover of each booklet explained that we were interested in seeing what sorts of sentences people produced. The instructions asked the subjects to complete the sentence fragments in any way that they liked, as quickly as they could, with the first completion that came to mind. It was stressed that subjects should ensure that their completion formed a grammatical sentence, that they should fill in the sentences in order, and that they should not leave some sentences out and go back to them later.

Procedure

Subjects were each given a booklet to complete and told to hand it back to the experimenter when they had finished. The experimenter answered any questions that the subjects had about the task. The experiment took place during a practical class and took about 20 minutes to complete.

Scoring

The completions were assigned to one of four scoring categories. In each case, the first (legible) completion for each sentence fragment was scored. (Hence if a subject crossed out his/her original completion and produced another completion but left the original completion legible, the original completion was scored). A completion was scored as correct if the verb was inflected correctly for the singular or plural. Completions were scored as agreement errors if they met the criteria for a correct response, but the verb form failed to agree in number with the head noun. Completions were scored as unmarked if the verb was uninflected and hence indistinguishable between singular and plural. Application of these criteria yielded 1026 corrects (67% of all responses), 95 (6%) agreement errors and 379 unmarked (25%) responses. Finally, all completions not fitting these criteria were scored as other. These included preambles which were not completed and sentences which were ungrammatical for reasons other than an agreement error.

Design and data analyses

The two independent variables were the type of modifier (PP versus complement clause) and the number match of the head/local nouns (match versus mismatch). These were crossed to yield four conditions. Each subject completed 6 preambles in each of the four conditions and each preamble was completed by 16 subjects in each condition.[7]

[6] This experiment was run in conjunction with the first production priming experiment, to be described in the next chapter, hence some of these filler materials constituted a priming experiment.

[7] Because of an error during compilation of the booklets, one preamble was not presented in the mismatch clausal condition and another preamble was not presented in the match clausal condition. Although this means that each of these preambles was seen by 32 subjects in one condition and none in another, overall they balanced each other out and there were the same number of observations in each cell in the design.

The dependent variable in the statistical tests was the number of agreement errors produced in each condition. Analyses of variance were performed on the data, with separate analyses treating subjects and items as random variables.

5.4.4 Results

In analysing the results, it appeared that the four plural-headed items did not induce the same pattern of errors as the singular-headed items. I will therefore present the results for each set of items separately. Table 5.1 presents the number of responses in each condition following singular-headed items. They are presented as proportions in Table 5.2. (In this chapter, I will present the results to two significant figures).

Modifier	*Condition*	*Correct*	*Agr error*	*Unmarked*	*Other*
PP	match	232	3	78	7
	mismatch	200	29	88	5
Clause	match	227	5	78	10
	mismatch	231	19	60	10

Table 5.1: Responses by scoring category and condition, singular heads only

Modifier	*Condition*	*Correct*	*Agr error*	*Unmarked*	*Other*
PP	match	73%	0.94%	24%	2.2%
	mismatch	63%	9.1%	28%	1.6%
Clause	match	71%	1.6%	24%	3.1%
	mismatch	72%	5.9%	19%	3.1%

Table 5.2: % Responses by scoring category and condition, singular heads only

The overall proportion of agreement errors was following singular heads was 3.7%. The results show a clear effect of number match: agreement errors occurred more frequently in the mismatch condition than in the match condition, leading to a significant main effect of number match ($F_1(1,63) = 36.63$, $p = .0001$, $F_2(1,19) = 15.83$, $p = .001$). There was some suggestion that errors occurred more frequently after PP modifiers than after clausal modifiers, yielding an interaction between number match and modifier type, marginal by items and non-significant by subjects ($F_1(1,63) = 2.03$, $p = .16$, $F_2(1,19) = 3.72$, $p = .07$). There was no effect of construction type ($F_1(1,63) = 1.24$, $p = .27$, $F_2(1,19) = 1.36$, $p = .26$).

A substantially higher proportion of errors was found following plural heads (15%). Tables 5.3 and 5.4 below present the results following plural heads. However, the number of items was too small to permit statistical analysis.

Modifier	*Condition*	*Correct*	*Agr error*	*Unmarked*	*Other*
PP	match	34	6	23	1
	mismatch	29	8	26	1
Clause	match	34	16	14	0
	mismatch	39	9	12	4

Table 5.3: Responses by scoring category and condition, plural heads only

Modifier	*Condition*	*Correct*	*Agr error*	*Unmarked*	*Other*
PP	match	53%	9.4%	36%	9.4%
	mismatch	45%	13%	41%	1.6%
Clause	match	53%	25%	22%	0.0%
	mismatch	61%	14%	19%	6.3%

Table 5.4: % Responses by scoring category and condition, plural heads only

5.4.5 Discussion

This experiment demonstrated that agreement errors can be induced in written language using essentially the same method as that used by Bock and her colleagues in spoken language. Moreover, the pattern of errors which was found is comparable with that found in spoken language. More errors occurred when the local noun mismatched the head noun in number. However, there was some suggestion that this effect was moderated by the nature of the modifier in which the local noun was embedded: more errors tended to occur in the mismatch condition after PP modifiers than after clausal modifiers, although this effect was not reliable following singular heads.

The high proportion of errors which occurred in the number mismatch condition is compatible with an account where the nouns which are associated with the subject NP (or, if Fayol *et al*'s (1994) findings carry over to English, potentially any noun in a clause) compete to control verb agreement. In most cases, the head noun successfully controls agreement, but occasionally the local noun inappropriately gains control. If the local noun does not match the head noun in number, agreement of the verb with the local noun results in an agreement error.

If reliable, the pattern of errors which occurred following the different types of modifier cannot be attributed to differences in length between the two types of modifier, since the materials were controlled for length. Nor can it be attributed to differences in the relationship between the modifier and the head; in each case, the modifier was a complement of the head. Instead it must reflect an underlying difference in the way in which the two types of modifier were processed. The results are compatible with Bock and Cutting's (1992) hypothesis that subject–verb agreement is defined within clauses before the components of the clause are assigned a linear structure. Hence clause boundaries delimit the processes of verb agreement. This means that components within a clause can affect agreement on the verb associated with that clause, but have limited access to, and so limited influence on, a verb in a different clause. In preambles with PP modifiers, the head noun and the local noun formed part of the same

clause, allowing the local noun to compete for control of the verb. In preambles with clausal modifiers, however, only the head noun was in the same clause as the main verb; the local noun formed part of a separate clause and hence had a limited influence on the main verb, resulting in fewer errors.

Errors which occurred in the number match condition clearly did not have the same origin as errors in the mismatch condition; Bock & Miller (1991) suggested that errors in this condition reflect random mistakes, resulting from lapses in concentration etc. There was one slightly puzzling finding in this respect. The incidence of errors in the match clausal modifier condition was almost as high as in the mismatch condition (21 compared with 28). This was unexpected, since we would expect errors to occur relatively infrequently in the match condition. However, closer inspection of the results revealed that over half of the errors in the clausal match condition were associated with a single item (*The legends that ghosts live in the graveyards ...*), suggesting that this might not be a systematic effect, although it is not clear why this particular item should cause so many errors.

Perhaps largely due to this one item, the number of errors following items with plural heads was also unexpectedly high, considering that there were only four such items (39 errors from a total of 95). One factor which might have had some influence is that most of the items (both experimental materials and fillers) in this experiment involved singular heads. This could have had an effect in two ways: it might have generated an expectation for the head to be singular and it could have led to a lexical priming effect for *was* over *were* (most of the inflected completions involved the past tense of *be*). The combination of these two influences could have militated towards production of *was* as a default when subjects' concentration lapsed. Following a plural head (though not following a singular head), this would result in an agreement error, regardless of the number of the local noun. In that case, whereas errors following singular heads would arise from interference by a local noun, at least some of those following plural heads would arise from random lapses in concentration etc. This problem could be addressed in future by avoiding such an imbalance in the number of singular/plural headed preambles (both experimental items and fillers). I will return to this issue during discussion of Experiment 2.

There are two conclusions which can be drawn from the overall convergence found in this experiment between the pattern of agreement errors in spoken and written language production. Firstly, it suggests that written and spoken production are both subject to the same processes, despite the difference in modality. Hence studying production in one modality can in principle be informative about processes common to both modalities. Secondly, it suggests that the particular experimental method used here, sentence completion, is a valid way of exploring those processes. In particular, the fact that the subject NPs were printed and so the head nouns were available for re-inspection did not seem to prevent errors from occurring, suggesting that subjects were unaware of any problem in processing. The overall error rate found here was higher than that found in Bock and her colleagues' experiments (for example, Bock and Cutting (1992) reported error rates of between 2% and 3%).

5.4.6 Summary to Experiment 1

This experiment suggests that subject–verb agreement errors occur in written language and can be elicited by asking subjects to complete sentence preambles which contain head nouns with post-nominal modifiers. The pattern of agreement errors found using this technique was similar to that observed in spoken language. In particular, there is some suggestion that PP modifiers and complement clauses cause different patterns of agreement errors. This suggests that the experimental method used here is effective in eliciting agreement errors and that it could be used to investigate new issues.

5.5 Written subject–verb agreement errors: Experiment 2

Experiment 1 constituted an extension to written language of previous experiments examining agreement errors in spoken language. The results of the experiment suggest that agreement errors occur in written language, and that they can be elicited using a similar sentence completion method to that used in the spoken language experiments. Having thus established that the experimental method is successful in eliciting agreement errors, we can now use it to investigate more interesting questions.

5.5.1 Experimental issues

The issues which are of interest here relate to the units which are implicated in functional level processing: which types of linguistic unit display common behaviour, and what characterises them as a group? In particular, is there any convergence between a set of units which pattern in the same way and a class of syntactic constituents which is recognised in linguistic theories? If the distinctions which are proposed by linguistic theories have any psychological reality, then we might expect that units which the theories classify as being related in some way will display common behaviour.

To a certain extent, researchers have prejudged the issue by couching their processing theories in terms of theoretical linguistic distinctions. As we have seen, researchers such as Garrett (1980), Ford (1982), Holmes (1988) and Bock & Cutting (1992) argued on the basis of diverse evidence (such as word exchange errors, pausing data and agreement errors) that functional level processing takes place in clauses. In doing so, they assumed that a class of constituents recognised in theoretical linguistics corresponds to a class of units which is implicated in language production.

One problem with such proposals is that the notion of 'clause' seems to be a theoretical primitive in linguistics. Although every linguistic theory recognises the existence of clauses, they remain undefined. Obviously, without such a definition, a processing theory which makes reference to clauses is largely meaningless. There seems to be agreement that a clause consists minimally of a predicate and its arguments. This is in keeping with the dictionary definition ('A group of words, consisting of a subject and a predicate including a finite verb that does not necessarily constitute a sentence' (Collins English Dictionary, 1986)). However, where

linguists' usage and the dictionary seem to part company is in the finiteness or otherwise of the verb. Although Bock & Cutting (1992) remained agnostic on the issue, both Ford (1982) and Holmes (1988) assumed that finiteness is not a prerequisite for clausehood; this is compatible with usage in theoretical linguistics, where it is common to talk about 'finite clauses' and 'non-finite clauses,' implying that finiteness is not an intrinsic features of the clause.

In what follows, I will therefore assume a definition of a minimal clause as 'a predicate and any obligatory arguments.' This definition does not require all arguments to be overtly realised; for example, subjects of a non-finite clause are often not expressed in English, hence I will assume that *enjoying the film* in *the man enjoying the film* is a clause, despite the absence of an overt subject. It is worth noting that the idea that clauses consist of predicate+argument units converges with Levelt's model of production (Levelt 1989). Levelt proposed that preverbal message planning (in other words the input to functional processing) is specified in terms of propositions, i.e. predicate–argument relations. Hence if clauses do turn out to be the units of functional processing, this could be because the input to functional processing specifies the same type of information, predicate–argument relations, as clauses encode.

The agreement error experiments discussed so far provide experimental evidence that at least finite relative clauses and complement clauses pattern in a way which is consistent with the proposal that functional level planning proceeds in clausal units. Bock & Miller (1991), Bock & Cutting (1992) and Experiment 1 above found evidence that PP modifiers were associated with more agreement errors in the mismatch condition than relative clauses and complement clauses. Bock & Cutting (1992) argued that this was explicable if subject–verb agreement is computed at the level of functional processing and that each clause is processed separately at this level. However, the existing results show only that finite clauses induce similar patterns of agreement errors. If Bock and Cutting are correct in drawing a connection between the occurrence of agreement errors and the clausal status of the modifier which contains the local noun, we might expect that non-finite clausal modifiers would induce a comparable pattern of effects. In other words, we would expect the incidence of errors following non-finite clausal modifiers to pattern with the incidence of errors following relative/complement clauses and not with that following PPs. This does not mean that we would expect to produce identical results for all clausal modifiers; as Bock & Cutting (1992) showed, complement clauses and finite relative clauses produce different overall error rates. Nevertheless, we would expect the general pattern of errors to be a common one.

If we found that non-finite clausal modifiers pattern with finite relative and complement clause modifiers, it would suggest that they form a class with respect to processing. More specifically, it would add to the experimental evidence of Ford (1982) and Holmes (1988) that functional level processing takes place in clausal units regardless of finiteness. The behavioural evidence would also support any linguistic theory which recognises that predicate+argument structures, whether finite or non-finite, form a syntactic class (see for example Lexical-Functional Grammar's concept of a 'clause nucleus' (Bresnan 1982a)). An experiment of this type could therefore cast light upon two proposals: firstly, that clauses (under the definition which I have given) form a unitary syntactic class; and secondly, that this class is implicated in functional level processing. The aim of this experiment was to test these hypotheses.

Predictions

If functional level processing takes place in clausal units, then clausal modifiers (under the definition of clause given above) should induce similar patterns of agreement errors, a pattern which is opposed to that induced by PP modifiers. We would therefore expect to find that non-finite modifiers (*The report to hand to the sly investigators ...*) and participial modifiers (*The report mentioning the sly investigators ...*) will produce similar patterns of agreement errors to relative clause modifiers (*The report that they gave the investigators ...*), despite the difference in finiteness. This pattern should contrast with that found after PP modifiers (*The report about the very sly investigators ...*).

If the results are in accordance with the predictions, it would support the hypothesis that functional level processing acts over 'clausal' units, where clauses are defined as above. It would also have implications for linguistic theories, since it would suggest that clauses form a class with respect to processing. Hence it would support those conceptualist linguistic theories which recognise a class of linguistic entity with equivalent characteristics. This experiment set out to test this hypothesis by comparing the incidence of agreement errors following each of the four modifier types described above.

5.5.2 Methodological issues

There were various methodological issues which had to be taken into account. The first issues related to the materials themselves. The previous experiment used complement clauses, as in Bock & Cutting (1992). However, in this case it proved too difficult to formulate a unified set of materials which involved complement clauses and also permitted infinitival relative and participial modifiers. For this reason, finite relative clauses were used instead, since this permitted the modifiers to be maximally similar across conditions. Previous work by Bock & Miller (1991) and Bock & Cutting (1992) suggests that relative clauses and complement clauses produce qualitatively comparable results, although they never directly compared the two types of clause in a single experiment. In particular, the fact that relative clauses are adjuncts whereas complement clauses are arguments did not appear to result in significant behavioural differences. Secondly, prenominal modifiers were included in addition to the post-nominal modifier. This was because infinitival relative clauses in particular sound slightly unnatural without a prenominal modifier (such as a superlative). This should have had no effect upon the results, since the prenominal modifier was the same across all of the conditions.

The other set of issues related to the design of the experiment. The overall number of errors, even under circumstances specifically designed to elicit them, tends to be very small and this can make it difficult to get reliable effects. It therefore seemed advisable to increase the number of items per condition, to try and reduce the variation within cells. Again, to avoid any strategic effects, a quarter of the items were plural-headed, but this time the number of plural-headed fillers was also increased, to reduce the chance of any lexical priming effects.

5.5.3 Method

Subjects

The subjects consisted of 48 paid undergraduate students from the Universities of Glasgow and Edinburgh.

Materials

The materials for the experiment consisted of 64 sets of materials, consisting of a subject NP that included two nouns, a head noun and a local noun. The local noun was embedded in a PP, finite relative clause, non-finite relative clause or participial phrase that modified the head noun. There were eight versions of each preamble, corresponding to the eight conditions produced by crossing two factors: head–local noun number (match versus mismatch) and modifier type (PP, finite relative clause, non-finite relative clause or participial). These are exemplified below: match/mismatch PP modifier (5.30a & b); match/mismatch finite relative clause (5.30c & d); match/mismatch non-finite relative clause (5.30e & f); match/mismatch participial modifier (5.30g & h).

(5.30) a. The most damning report about the corrupt city councillor ...
b. The most damning report about the corrupt city councillors ...
c. The most damning report that John sent the city councillor ...
d. The most damning report that John sent the city councillors ...
e. The most damning report to send the corrupt city councillor ...
f. The most damning report to send the corrupt city councillors ...
g. The most damning report naming the corrupt city councillor ...
h. The most damning report naming the corrupt city councillors ...

All versions of a preamble had the same head and local nouns, the same prenominal modifier, the same number of syllables and – as far as possible – approximately the same stress pattern and length in terms of number of characters. Forty-eight of the materials had singular head nouns; the remaining sixteen materials had plural head nouns. A complete list of materials is given in Appendix A. An additional 64 filler materials were constructed. These consisted of NPs which consisted of a determiner, a pre-nominal modifier and a head noun. Half of the filler materials had singular heads and half had plural heads.

Two presentation lists were constructed from these materials. Each list contained eight materials of each of the types shown in (5.30a–h). The order of presentation was randomised for each subject. The sentence fragments were then printed out as eight-page booklets.

The instructions on the cover of each booklet explained that we were interested in seeing what sorts of sentences people produce. The instructions asked the subjects to complete the sentence fragments in any way that they liked, as quickly as they could, with the first completion that came to mind. It was stressed that subjects should ensure that their completion formed a grammatical sentence, that they should fill in the sentences in order, and that they should not leave some sentences out and go back to them later.

Procedure

Subjects were each given a booklet to complete and told to hand it back to the experimenter when they had finished. The experimenter answered any questions that the subjects had about the task. Each subject completed the booklet individually in a quiet place. The booklet took about 20 minutes to complete.

Scoring

The completions were assigned to one of four scoring categories. In each case, the first (legible) completion for each sentence fragment was scored. A completion was scored as correct if the verb was inflected correctly for the singular or plural. Completions were scored as agreement errors if they met the criteria for a correct response, but the verb form failed to agree in number with the head noun. Completions were scored as unmarked if the verb was uninflected and hence indistinguishable between singular and plural. Application of these criteria yielded 1949 corrects (63.4% of all responses), 103 (3.4%) agreement errors and 875 unmarked (28.5%) responses. Finally, all completions not fitting these criteria were scored as other (4.7%). These included preambles which were not completed and sentences which were ungrammatical for reasons other than an agreement error.

Design and data analyses

The two independent variables were the type of modifier (PP/finite relative clause/non-finite relative clause/participial phrase) and the number match of the head/local nouns (match versus mismatch). These were crossed to yield eight conditions. Each subject completed 8 preambles in each of the eight conditions and each preamble was completed by 6 subjects in each condition.

The dependent variable in the statistical tests was the number of agreement errors produced in each condition. Analyses of variance were performed on the data, with separate analyses treating subjects and items as random effects.

5.5.4 Results

Examining the results closely, it became clear that there were systematic though unexpected differences in the pattern of errors following singular heads and following plural heads: following singular heads, there were 24 agreement errors, of which 4 occurred in the match condition and 20 in the mismatch condition; following plural heads, there were 79 errors, 51 of which occurred in the match condition and 28 in the mismatch condition. I will therefore present the results for singular and plural heads separately.

Results following singular heads

Tables 5.5 and 5.6 present the results in each scoring category following singular heads as raw totals and proportions respectively (note that the percentages are calculated with respect to singular-headed responses only, not all responses).

Modifier	*Condition*	*Correct*	*Agr error*	*Unmarked*	*Other*
PP	match	204	1	79	4
	mismatch	217	8	63	0
Rel clause	match	193	0	91	4
	mismatch	182	3	99	4
Inf clause	match	212	2	69	5
	mismatch	216	6	64	2
Participial	match	189	1	90	8
	mismatch	189	3	91	5

Table 5.5: Number of responses by scoring category and condition, singular heads only

Modifier	*Condition*	*Correct*	*Agr error*	*Unmarked*	*Other*
PP	match	71%	0.35%	27%	1.4%
	mismatch	75%	2.8%	22%	0.0%
Rel clause	match	67%	0.0%	32%	1.4%
	mismatch	63%	1.0%	34%	1.4%
Inf clause	match	74%	0.69%	24%	1.7%
	mismatch	75%	2.2%	22%	0.7%
Participial	match	66%	0.35%	31%	2.8%
	mismatch	66%	1.0%	32%	1.7%

Table 5.6: % singular head responses by scoring category and condition

Looking at these results, it is clear that relatively few errors were produced following singular-headed preambles: a total of 24 errors, from the overall total of 103 errors. The small number of errors is particularly striking, given that there were three times as many singular-headed items as plural-headed items. Hence, if errors were evenly distributed across singular- and plural-headed items, we would expect errors following singular heads to account for three-quarters of the total number of errors, not one quarter. Expressed as a proportion of all responses following singular-headed items, agreement errors accounted for only 1% of responses.

Overall, the raw figures in Table 5.5 show the pattern of results found in previous experiments: more errors occurred in the mismatch condition than in the match condition following all modifier types, but the difference appears greatest following PP modifiers. Statistical analysis confirmed that more errors occurred following a local noun which mismatched the head noun in number, yielding a main effect of number match ($F_1(1,47) = 12.32$, $p = .001$, $F_2(1,47) = 8.74$, $p = .005$). There was no significant effect of modifier type of the number of errors produced ($F_1(1,47) = 1.66$, $p = .18$, $F_2(1,47) = 1.82$, $p = .15$). There was no interaction between number match and modifier type (all Fs < 1).

Analyses were then carried out comparing each of the clausal modifier types with PP modifiers. A further analysis collapsed the three clausal modifier types into a single 'clausal' condition and contrasted this (i.e. the mean of the three clausal conditions) with PP modifiers.

PPs compared with finite relative clauses
More errors were produced following a local noun which mismatched the head noun in number, giving rise to a main effect of number match ($F_1(1,47) = 8.22$, $p = .006$, $F_2(1,47) = 9.87$, $p = .003$). There was also a hint that more errors occurred following PPs than relative clauses, but there was not a reliable effect of modifier type ($F_1(1,47) = 2.66$, $p = .11$, $F_2(1,47) = 3.13$, $p = .08$). The interaction between number match and modifier type was not significant ($F_1(1,47) = 1.15$, $p = .29$, $F_2(1,47) = 1.34$, $p = .25$).

PPs compared with non-finite relative clauses
The results suggest that errors increased following a local noun which mismatched the head noun in number, yielding a main effect of number match ($F_1(1,47) = 6.13$, $p = .02$, $F_2(1,47) = 8.18$, $p = .006$). No other effects approached significance (all Fs < 1).

PPs compared with participials
The results suggest that more errors were produced in the mismatch condition than in the match condition, resulting in a main effect of number match ($F_1(1,47) = 7.01$, $p = .01$, $F_2(1,47) = 7.01$, $p = .01$). There was no main effect of modifier type ($F_1(1,47) = 1.96$, $p = .18$, $F_2(1,47) = 1.96$, $p = .18$), nor a significant interaction between number match and modifier type ($F_1(1,47) = 1.49$, $p = .23$, $F_2(1,47) = 1.96$, $p = .17$).

PPs compared with clauses
The results suggest that more errors occurred in the mismatch condition than in the match condition, resulting in a main effect of number match, significant by subjects only ($F_1(1,47) = 9.32$, $p = .004$, $F_2(1,47) = .876$, $p = .35$). More errors occurred following PP modifiers than following clausal modifiers, but the main effect of modifier type was significant by items only ($F_1(1,47) = 1.37$, $p = .25$, $F_2(1,47) = 4.11$, $p = .05$). The number match by modifier type interaction did not approach significance ($F_1(1,47) = 1.13$, $p = .30$, $F_2(1,47) = 1.29$, $p = .26$).

Summary
The results following singular heads follow the same pattern as that established in previous experiments, in that – as expected – more errors followed local nouns which mismatched the head noun in number. However, although the raw figures suggest that that there were more errors following PP modifiers in the mismatch condition, the interaction of interest did not achieve significance in any of the analyses.

Results following plural heads

I will now turn to the results for plural-headed subject NPs. Tables 5.7 and 5.8 present the totals and proportions respectively of responses in each scoring category. The percentages are calculated with respect to responses following plural heads only.

Overall, plural-headed items elicited a much higher proportion of errors than singular-headed items, reflected in the substantially higher error rate: 9.4% of all responses following plural-headed items were errors, compared to 1.0% following singular-headed items. However, the responses following plural-headed items differed from those following singular-headed items

Modifier	*Condition*	*Correct*	*Agr error*	*Unmarked*	*Other*
PP	match	59	9	27	1
	mismatch	54	11	30	1
Rel clause	match	42	13	39	2
	mismatch	50	3	42	1
Inf clause	match	59	16	20	21
	mismatch	66	9	20	1
Participial	match	51	13	30	2
	mismatch	66	5	21	9

Table 5.7: Number of responses by scoring category and condition, plural heads only

Modifier	*Condition*	*Correct*	*Agr error*	*Unmarked*	*Other*
PP	match	61%	9.4%	28%	1.0%
	mismatch	56%	11%	31%	1.0%
Rel clause	match	44%	14%	41%	2.1%
	mismatch	52%	3.1%	44%	1.0%
Inf clause	match	61%	17%	21%	22%
	mismatch	69%	9.4%	21%	1.0%
Participial	match	53%	14%	31%	2.1%
	mismatch	69%	5.2%	22%	9.4%

Table 5.8: % plural head responses by scoring category and condition

not only in the overall rate of errors: they also suggest a different pattern of agreement errors. Following plural-headed items, the effect of number match was not the same for all modifier types. Slightly more errors were produced in the mismatch condition following PP modifiers but more errors were consistently produced in the match condition following clausal modifiers.

Statistical analysis confirmed that more errors occurred when the local noun matched the head noun in number than when it mismatched, yielding a main effect of number match ($F_1(1,47) = 7.85$, $p = .007$, $F_2(1,15) = 12.42$, $p = .003$). There was no significant effect of modifier type on the number of errors produced ($F_1(1,47) = .94$, $p = .43$, $F_2(1,15) = 1.62$, $p = .20$), nor was there an interaction between number match and modifier type ($F_1(1,47) = 1.73$, $p = .16$, $F_2(1,15) = .98$, $p = .41$).

PPs compared with finite relative clauses
There was no reliable effect of number match ($F_1(1,47) = 2.19$, $p = .15$, $F_2(1,15) = 3.33$, $p = .09$). Neither was there a main effect of modifier type ($F_1(1,47) = .42$, $p = .52$, $F_2(1,15) = 1.67$, $p = .22$). The raw numbers suggest that more errors were produced in the mismatch condition following PP modifiers and in the match condition following finite relative clause modifiers, but the error by number match interaction was significant by subjects only ($F_1(1,47) = 6.13$, $p = .02$, $F_2(1,15) = 1.85$, $p = .19$).

PPs compared with non-finite relative clauses
The number of errors produced did not differ between the match and mismatch conditions,

hence there was no main effect of number match (all Fs < 1). There was no overall difference in the number of errors produced following each type of modifier, hence no main effect of modifier type (all Fs < 1). Although the raw figures show that the pattern of errors differed following PP modifiers and non-finite relative clauses, the number match by modifier type interaction did not achieve significance ($F_1(1,47) = 2.71$, $p = .11$, $F_2(1,15) = 1.19$, $p = .29$).

PPs compared with participials
There was no difference in the number of errors produced in the match and mismatch conditions, hence there was no main effect of number match ($F_1(1,47) = 1.12$, $p = .29$, $F_2(1,15) = 2.46$, $p = .14$). Modifier type did not affect the number of errors produced (all Fs < 1). The raw figures show that more errors were produced in the mismatch condition following PPs and in the match condition following participials, but the statistical analysis reveals that the number match by modifier type interaction was marginal by subjects only ($F_1(1,47) = 3.78$, $p = .06$, $F_2(1,15) = 1.15$, $p = .30$).

PPs compared with clauses
There was no main effect of number match ($F_1(1,47) = 1.72$, $p = .20$, $F_2(1,15) = 2.86$, $p = .11$), nor was there a main effect of modifier type ($F_1(1,47) = .004$, $p = .95$, $F_2(1,15) = .01$, $p = .92$). However, the number match by modifier type interaction was significant, by subjects only ($F_1(1,47) = 7.78$, $p = .008$, $F_2(1,15) = 1.64$, $p = .22$).

Summary
The results following plural heads reveal a strikingly different pattern to those following singular heads. Plural heads induced substantially more errors than singular heads. These unexpectedly occurred mainly in the match condition. There was some suggestion that clausal modifiers and PP modifiers did not pattern alike, as predicted, but the actual patterns were not as expected. The raw figures show that following clausal modifiers, errors were concentrated in the match condition, whereas PP modifiers induced comparable numbers of errors in the match and mismatch conditions. In the collapsed analysis (clausal modifier versus PP modifier), this yielded a number match by modifier type interaction, significant by subjects only. The individual analyses comparing PP modifiers and each of the clausal modifiers also yielded a significant number match by modifier type interaction for PPs and finite relative clauses, a marginal interaction for PPs and participials, and a weak tendency for PPs and non-finite relative clauses. However, these results were not significant by items, either because of considerable variation between items or because of an insufficient number of items.

5.5.5 Discussion

This experiment was designed to examine the hypothesis that functional processing proceeds in units corresponding to a predicate and its arguments. It was predicted that predicate+argument modifiers would pattern differently from PP modifiers with respect to agreement errors. The results for the collapsed analysis support this prediction. In the individual analyses, PP modifiers and finite relative clause/participial modifiers behaved differently in this respect. The results were less clear following non-finite relative clauses, though they displayed a weak tendency to behave like the other clausal modifiers. The way in which the PP and clausal modifiers differed was not entirely as expected, however.

To summarise, the results revealed two distinct patterns of data. These patterns seemed to be linked to the number of the head noun. Singular head nouns induced very few errors. Most of those errors occurred when the local noun mismatched the head noun in number. However, the type of modifier did not have a reliable effect on the incidence of errors. In comparison, plural head nouns induced a substantial number of errors. Overall, these occurred more frequently when the head and local nouns matched in number. This pattern was modulated by the type of modifier: more errors were produced in the mismatch condition following PP modifiers, but more in the match condition following clausal modifiers (although in the individal analyses, non-finite relative clauses only showed a tendency in this direction and the items analyses were not reliable).

The difference between the results following singular heads and plural heads becomes clearer if we examine the net error rate for each type of modifier. The net error rate (Bock & Miller 1991) corresponds to the number of errors produced in the mismatch condition minus the number of errors produced in the match condition. Bock and Miller suggested that this gives a better estimate of 'true agreement errors, corrected for dialect factors and random mistakes,' (Bock & Miller 1991, p.60). Table 5.9 below presents the net proportion of agreement errors following singular and plural heads.

Modifier	*Sing head*	*Pl head*
PP	2.5%	1.6%
Rel clause	1.0%	-11%
Inf clause	1.5%	-7.6%
Participial	0.65%	-8.8%

Table 5.9: Net error rate following singular/plural heads by modifier type

As the table shows, following singular heads the net error rate is positive across all four modifier types, suggesting that more errors were produced in the mismatch condition. It is also noteable that although the effect is too small to be reliable, the net error rate is largest for PP modifiers, implying that the difference between the match and mismatch conditions was greatest following PPs. Following plural heads, however, the pattern is quite different: the net error rate for the three clausal modifier types is negative, (i.e. more errors were produced in the match condition than in the mismatch condition), whereas the net error rate for PP modifiers remains positive.

The pattern of results is unexpected, and it is unclear how it should be evaluated. In particular, the results of a number of analyses reached significance by subjects only. This raises a question about the reliability of the results. I should make it clear at this point that I do not believe that any strong conclusions can be drawn on the basis of these results. The results indicate that plurality of the head was an important factor and the experiment was simply not designed to investigate this issue. Hence I would suggest that the main value of the experiment lies in highlighting a pattern of data which merits further research. However, there are reasons to believe that the pattern of errors following plural heads at least may be systematic and deserves discussion. Equally, it would be useful to discuss some of the methodological issues which this experiment has raised, since they could be important for future work. In the sections below, then, I will begin by examining some of the factors which may have affected the reliability of the results. I will then discuss some possible interpretations of the data. Finally, I will outline how a future experiment could be designed to investigate these issues more successfully.

Evaluating the reliability of the results

It is obvious that the results are not as clear as we could wish, both for singular heads and plural heads. However, there are a number of reasons why this should be so. In this section I would like to highlight some of the factors which might have affected the reliability of the results. Analyses focusing on errors following singular heads were adversely affected by the fact that the total number of errors was extremely small: 24 errors, accounting for just over 1% of responses. Such a small sample size increases the likelihood of a Type II error. Thus it seems likely that the sample size for errors following singular heads was just too small to produce significant results. This could be avoided in future experiments by increasing the number of subjects and the number of items. In this experiment, the low error rate might be attributable to the educational background of the subjects who participated in the experiment. In the previous experiment, none of the subjects had any post-school educational experience; in the present experiment, all of the subjects had at least one year, and often more, of higher education. It is possible that this was reflected in a greater facility with the written language, resulting in fewer errors. Furthermore, the subjects in the present experiment (unlike those in the previous experiment) were paid, which might have encouraged them to take more care in producing their responses.

The results for plural heads are also less than clear. As Table 5.9 shows, there is a consistent pattern that the clausal modifiers caused more errors in the match condition than in the mismatch condition, contra the results for PP modifiers, but the number match by modifier type interaction was only reliable by subjects in the collapsed analysis and in the individual analyses for finite relative clauses and participials. It could be that different items were not comparable, but this seems unlikely, as the items did not differ from each other in any obvious way. Instead I would suggest that the reason for the unreliability of the items analyses is that the results relate to such a small number of items. When the experiment was designed, it was not anticipated that plurality of the head would turn out to be an important factor and hence this was manipulated as a between-items factor rather than within items. Thus the relevant analyses applied to only sixteen items, i.e. two per cell. This would of course result in a great deal of variance and hence it is not surprising that the items analyses failed to reach significance.

Although we should be wary of placing too much theoretical weight on the results of the present experiment, I think it is reasonable to make the working assumption that the pattern of data revealed in the results are reliable, pending further research. I will now focus on some possible interpretations of it. Since the results for singular- and plural-headed items vary so greatly, it seems sensible to discuss them separately. I will therefore begin by discussing the results for the singular heads only.

Agreement errors following singular heads

The errors for singular heads followed the expected pattern. In keeping with previous work, more errors occurred in the mismatch condition than in the match condition following singular heads. This is consistent with the proposal that verb agreement is computed on the basis of the agreement features carried by the head noun. However, other nouns which are active may interfere with this process, and sometimes a noun other than the head noun erroneously gains control of agreement. If this local noun does not match the head noun in number, the verb agreement which is produced will be incompatible with the number features on the head noun and an agreement error will result. Hence I suggest that the agreement errors following singular heads were caused by incorrect identification of the local noun as the controller of agreement.

The overall pattern of results is compatible with previous findings that the likelihood of this happening may be modulated by the type of modifier which contains the local noun. Although the interaction did not achieve significance in an analysis of variance, Table 5.9 shows that the difference between the match and mismatch conditions was greatest for PP modifiers (2.5%). The clausal modifiers had net error rates of between 0.65% (participial modifiers) and 1.5% (non-finite relative clause modifiers). It would be dangerous to read too much into these results, given the small sample size and absence of significant effects, but if they are reliable, it would suggest that clausal modifiers as a class induce fewer errors than PP modifiers following a singular head. Such a finding would have two implications. Firstly, it would suggest that, as hypothesised, the notion of a clause has some psychological reality, in the sense that predicate+argument units, whether finite or non-finite, form a class with respect to processing. Secondly, it would also be compatible with the hypothesis that these units are implicated in functional level processing, such that verb agreement can be affected by nouns within the same planning unit, or clause, but is partially insulated from nouns in different clauses. Local nouns embedded in PPs form part of the main clause and hence can influence agreement on the main verb; however, local nouns embedded in finite relative clauses – and, it seems, non-finite relative clauses and participials – form separate planning units and so are less able to affect the main verb.

The overall pattern of agreement errors following singular heads, if reliable, is therefore compatible with the pattern found in previous experiments, and hence compatible with the conclusions drawn from those experiments. The pattern of results is also in keeping with the original hypothesis that PP modifiers and predicate+argument modifiers are processed differently.

Agreement errors following plural heads

The results for the plural heads are both clearer and more confusing. On the one hand, they are clearer because the statistical analyses of interest were reliable by subjects (if not by items). On the other hand, they are more confusing because the pattern of results does not fit neatly into any of the current theories, although some of the results are compatible with those from previous experiments, as we will see. There were three main findings for responses following plural heads. Firstly, the error rate was extremely high at 9.4%, nine times higher than the error rate following singular heads. Secondly, more agreement errors occurred when the head noun and the local noun matched in number than when they mismatched. Thirdly, different modifier types caused different numbers of errors in the the match/mismatch conditions: as Table 5.9 shows, more errors were produced in the match condition following the clausal modifiers, resulting in a negative net error rate, whereas slightly more errors were produced in the mismatch condition following PP modifiers. This difference was significant in the collapsed analysis; in the individual analyses, it was significant for finite relative clauses and marginal for participial phrases, whilst the analysis involving non-finite relative clauses showed the same tendency.

How the results compare with previous research

I will begin by discussing the extent to which the results found here are consistent with those from previous research. In the present experiment, slightly more errors were produced following PP modifiers in the mismatch condition than in the match condition, but the difference was very small. This is consistent with the pattern found by Bock & Cutting (1992), who noted that, 'In the [plural-headed mismatch] condition, the number of errors was not much different from conditions in which the head and local noun matched in number,' (Bock & Cutting 1992, p.110). The finding that plural-headed preambles with PP modifiers induced more errors than singular-headed preambles differs from their finding, although Fayol, Largy & Lemaire (1994) found a similar pattern with pre-verbal pronouns in their third experiment. The fact that different experiments have found quite substantial variations in the overall proportion of errors following plural headed PP modifiers suggests that the error rate may be affected by factors other than the syntactic structure of the subject. This in turn suggests that it may not be possible to find a single explanation – or indeed, any overall explanation – for the pattern found here.

Following all three of the modifier types identified as clausal, more errors were produced in the match condition than in the mismatch condition. Surprising though this finding may be, some of the previous work examining agreement errors following clauses has found similar effects. Bock & Cutting (1992) found that the number of agreement errors following finite relative clauses was the same in the match and mismatch conditions in their first experiment, although the overall number of errors elicited following plural heads was substantially lower than following singular heads. It is not possible to draw a direct comparison between the present findings and Bock and Cutting's work because they did not examine errors after plural heads and long clausal modifiers in the same experiment, as here.

Experiment 1 reported above also found more errors in the match condition than the mismatch condition following plural heads (16 errors versus 9 errors respectively). It would be unwise to base too much on this, since the number of items concerned was very small (four), and twelve of the errors were associated with one of those items; in addition, as we have seen, the unequal numbers of singular- and plural-headed preambles in Experiment 1 might have encouraged the production of singular agreement. However, an almost identical pattern of results to those found here, using an identical experimental method, was reported in Branigan, Liversedge & Pickering (1995). In that experiment, we again compared agreement errors following PP and complement clause modifiers, but this time using equal numbers of

singular- and plural-headed items. We found more errors following plural heads than following singular heads (4.1% errors versus 2.1% errors). We also found that PPs and complement clauses patterned differently following plural heads: approximately equal numbers of errors occurred in the match and mismatch conditions with PP modifiers (1.1% and 0.99%), but more errors occurred in the match condition following a complement clause modifier (3.6% versus 2.4%). The convergence of these results with the results of the present experiment adds support to the suggestion that the pattern of data found here is systematic and not coincidental.

Implications for the classification of modifier types

The first and most important implication of these results is that the clausal modifiers are associated with a common pattern of behaviour which contrasts with that associated with PP modifiers. This suggests that the clausal modifiers form a class with respect to processing. The fact that finite relative clause and participial modifiers patterned together suggests that this class is not defined in terms of finiteness. The results for non-finite relative clauses are weaker, but they display the same tendency, and it would probably be unwise to read too much into the differences between the different predicate+argument modifier types, bearing in mind that similar differences have been found between different types of finite clause (Bock & Cutting 1992). It therefore seems likely that clauses, defined minimally as predicate+argument units unspecified for finiteness, form a psychological class. This adds further support to those processing theories which propose the existence of such a class and provides empirical evidence to support linguistic theories which recognise a comparable class of structures. In this sense, the experiment has been successful in investigating the issue which it set out to investigate. However, the results do not allow us to draw any conclusions about the nature of the units involved in functional level processing during production, for reasons which will be discussed below.

Possible explanations for the pattern of results

The pattern of results allows us to suggest that clausal modifiers and PP modifiers form distinct classes, but the explanation for the pattern is not at all obvious. In particular, we wish to know why plural heads in general caused so many errors; and why clausal modifiers following plural heads induced a higher proportion of errors in the match condition, whereas PP modifiers following plural heads caused approximately equal proportions in the match/mismatch conditions. In the following sections, I will explore a tentative line of explanation which is compatible with the data. I would like to suggest that errors following PP modifiers and clausal modifiers may have had the same direct cause, but that this arose for different underlying reasons.

It is not entirely clear why plural heads elicited so many errors. In the previous experiment, where a high proportion of errors was similarly associated with plural heads, I noted that the effect might have arisen in part from the overwhelming proportion of singular-headed items in the experimental session, leading to an expectation for a singular head and a lexical priming effect for the singular form of the verb which might have encouraged subjects to produce singular verb agreement when their attention lapsed. Hence the high proportion of errors following plural heads in the previous experiment could have been linked to the experimental design. However, an explanation of that type seems unlikely here, since a quarter of the experimental materials and half of the filler materials had plural heads.

Let us instead consider an alternative possibility: that plural heads might quite generally be associated with a higher proportion of errors, but for reasons other than interference from a local noun. Bock & Cutting (1992) suggested on the basis of their experimental findings that the singular verb form is the default. In other words, the singular verb form is always produced unless there is a reason to override it in favour of the plural. If they are correct, then failure to compute subject–verb agreement for *any* reason should result in singular verb agreement by default. Clearly, following a plural head such default agreement would result in an agreement error. I suggest that in this experiment, plural-headed items sometimes caused a failure to assign *any* noun as the controller of the verb, resulting in default assignment of singular agreement and hence an agreement error. This contrasts with the agreement errors following singular heads, which seem to be caused by incorrectly assigning a local noun as controller of agreement.

In the following section, I will discuss possible reasons why plural-headed items caused a failure to identify a controller of agreement; I will suggest that both PP modifiers and clausal modifiers induced default agreement, resulting in an agreement error, but for different reasons.

Cognitive overload

A failure to identify any noun as controller of the verb could have two causes: lapses in attention and/or cognitive overload. Fayol *et al*'s (1994) work highlighted the importance of working memory load in the production of agreement errors. I suggest that in this experiment, processing overload sometimes occurred, causing the production of default singular agreement. Following singular heads, production of default agreement would be indistinguishable from production of correct agreement, but following plural heads it caused agreement errors, resulting in a higher proportion of agreement errors following plural heads.

The direct cause of the high proportion of agreement errors might therefore be attributed to cognitive overload; but it leaves open the question of what exactly caused the overload in the first place. The pattern of data and findings from previous experiments suggest that the cause was not the same for preambles involving PP modifiers and those involving clausal modifiers: with PP modifiers, overload occurred irrespective of the number of the head and local noun; with clausal modifiers, however, overload was concentrated on cases where the head and local nouns matched in number. The following sections examine the specific causes of cognitive overload with each type of modifier in more detail.

Cognitive overload following PP modifiers

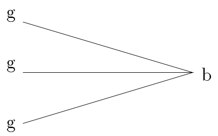
Bock & Cutting (1992) showed that modifier length affects the incidence of agreement errors following PP modifiers: significantly more errors occurred following long PP modifiers than following short PP modifiers. They argued that since PP modifiers are processed as part of the same planning unit as the matrix clause, long PP modifiers increase the size of that planning unit and hence place more strain on the processor. As a result, long PP modifiers such as the ones employed in this experiment may cause cognitive overload during production. Such

an approach would explain why there was little difference between the match and mismatch conditions following plural heads: if agreement errors occur following PP modifiers because of cognitive overload, which results in production of (default) singular agreement, and cognitive overload arises as a result of long modifiers, the plurality of the local noun is immaterial. It appears, then, as if the PP modifiers increased production complexity and caused cognitive overload during production of the sentence completion.

Cognitive overload following clausal modifiers

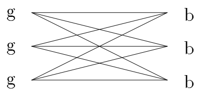
It is not clear that clausal modifiers are subject to the same constraints. Although Bock & Cutting (1992) found a significant effect of length following PP modifiers, they did not find a significant effect of length following clausal modifiers: comparable numbers of errors occurred following both short and long clausal modifiers. Bock and Cutting suggested that this was because clausal modifiers form a separate planning unit from the main clause and hence variations in their length do not affect the complexity of the planning unit where agreement of the main verb is computed. However, Bock and Cutting did find that long clausal modifiers caused more repetition errors, from which they concluded that clausal modifier preambles presented subjects with more difficulty than PP modifier preambles during comprehension. This makes intuitive sense, since clausal modifiers encode more information than PP modifiers (i.e. entire propositions), and would be consistent with experimental evidence that clauses are important units in comprehension (see for example Caplan (1972)). If correct, it suggests that whereas cognitive overload was centred on production processes in the case of PP modifiers, it occurred during comprehension of the preamble in the case of clausal modifiers.

There is still one aspect of the results which remains to be explained: the asymmetry between the match and mismatch conditions following clausal modifiers. That is, why were *more* errors produced in the match condition than the mismatch condition ? In the context of the approach outlined here, this reduces to the question of why clausal modifiers with a plural head and a plural local noun should be more likely to cause cognitive overload in comprehension than clausal modifiers with a plural head and a singular local noun. There is no obvious answer to this question but one possibility which seems plausible is that the difference arises at the level of semantic processing. In order to produce a coherent completion, subjects had to read the preamble and comprehend it, which in turn involved semantically interpreting it. The essential difference between plural-headed clausal modifiers in the match and mismatch conditions in this respect lies in the complexity of the semantic interpretation. In the mismatch condition, the local noun is singular, hence a straightforward many-to-one relationship need be established. For example, a preamble such as *The games that they taught the boy ...* requires the reader to establish a mental model where a relationship exists between a single entity (*the boy*) and each of the entities in the set denoted by *games*. (Note that preambles involving singular heads will be similarly straightforward, since they require either a comparable one-to-many relationship or an even less complex one-to-one relationship). This can be represented as in (5.31) below, using the representational system developed by Fodor (1982), where the lines represent relationships between games (each of which is represented by a g) and the boy (represented by the b).

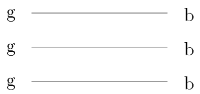


(5.31)

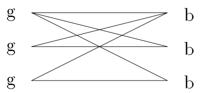
In the match condition, however, the interpretation is considerably more complex. It requires the reader to establish a many-to-many relation between the entities denoted by the head and those denoted by the local noun. Moreover, the exact nature of this relation may be ambiguous. For example, consider the preamble *The games that they taught the boys ....* This requires the reader to establish a mental model involving more than one boy and more than one game. It is unclear whether every entity in one set is linked to every entity in the other set (i.e. that every game was taught to every boy) (5.32), or whether every entity in one set is associated with a (different) single entity in the other set (i.e. that each boy learnt a different game) (5.33), or something in between (5.34).



(5.32)



(5.33)



(5.34)

It seems plausible that establishing such a model is considerably more difficult than establishing one where there is a straightforward many-to-one mapping (see Fodor (1982) for discussion of how such mappings might be established and represented). I therefore suggest that the asymmetry between the match and mismatch conditions for clausal modifiers might arise from the differences in their semantic content. In the match condition, subjects must establish a more complex mental model of the relations between entities, resulting in a higher cognitive load. This makes plural-headed preambles with clausal modifiers in the match condition more likely to cause cognitive overload, which in turn causes the production of the default singular verb agreement and a resulting agreement error.

Cognitive overload – summary

To summarise, then, I suggest that in some circumstances subjects may suffer from cognitive overload. When this occurs, they will tend to produce the default agreement, which (in English

at least) is the singular verb form. Following a singular head, this agreement is appropriate and it is not possible to detect any error. Following a plural head, however, production of the default agreement results in an agreement error. However, I suggest that the causes of cognitive overload are different for PP modifiers and clausal modifiers. PP modifiers form single planning units with the main clause, hence long modifiers will increase the complexity of the planning unit and may cause overload during production. The number of the local noun plays no part in determining this complexity, hence there are approximately equal number of errors in the match and mismatch conditions.

Clausal modifiers form separate planning units from the main clause, and so do not increase production complexity; however, perhaps because they express propositions, they may cause difficulty during initial comprehension of the preamble. This is exacerbated when the head and local nouns are both plural, forcing a many-to-many interpretation (the precise form of which is ambiguous). Hence clausal modifiers may induce cognitive overload during comprehension, concentrated on the match condition. Unfortunately, the experimental method used here did not require subjects to reproduce the preamble and so it is not possible to investigate whether there were any differences in reproduction of the preamble between PP and clausal modifiers. However, if the approach outlined here is correct, we would expect to find substantially more clausal preambles reproduced incorrectly than PP preambles.

Plausibility

Finally, plausibility may also have had some effect on the production of agreement errors. The preambles were not pre-tested for plausibility and hence we cannot be sure that the singular-headed items and plural-headed items were equally plausible as NPs. If they were not, then this could have affected subjects' responses. In some cases, subjects might have misread the preambles and produced endings which were correct for the preamble which they thought they had read but incorrect with respect to the printed preamble. It seems feasible that such errors would be particularly likely to occur where the head was implausible in one number but plausible in the other. If plural heads are generally less plausible with such modifiers than singular heads, subjects might be more likely to misread or misinterpret plural-headed preambles and hence produce more errors of this type following them. It is not clear that this could explain the asymmetry found between the match and mismatch conditions following clausal modifiers, but it might have contributed towards the high proportion of errors for plural heads. This is again speculative; further research would be needed to decide firstly, whether plural-headed preambles are more likely to be implausible than singular-headed preambles with PP modifiers; and secondly, whether this has any bearing on the production of agreement errors.

Implications for further research

The pattern of results found here suggests that there are differences in the way in which predicate+argument modifiers and PP modifiers are processed, but there are a number of methodological issues which must be addressed in future work before any firmer conclusions can be drawn. The first and most important of these issues is that the number of the head noun turned out to be critical. This was unanticipated and as a result it was not manipulated as a within-items variable. Any future work using the same method would have to take this into consideration and include head noun number as a factor. Secondly, the small number of agreement errors that were found following singular heads caused some concern with respect to the representativeness of the sample. Future experiments would benefit from using greater numbers of items and testing more subjects to ensure an adequate number of data points. Thirdly, in order to investigate whether the difference found in this experiment between clausal and PP preambles lies at the level of comprehension versus production, it might be advisable to ask subjects not simply to complete the preambles but also to reproduce them. However, this would have the disadvantage of making the experimental task less natural and more attention-demanding. Finally, plausibility may have an important effect upon the production of agreement errors. This possible confound could be avoided by pre-testing the materials to ensure that they are equally plausible in all conditions.

5.5.6 Summary to Experiment 2

As predicted, the present experiment found that subject NPs involving post-nominal PP modifiers caused different patterns of agreement errors from subject NPs involving post-nominal predicate+argument modifiers. However, the pattern of agreement errors was unexpected. The number of the head noun unexpectedly turned out to be a crucial factor. Agreement errors were more frequent following singular heads when the local noun and the head noun mismatched in number. Following plural heads, the pattern was quite different. The error rate was higher overall but more errors occurred in the match condition following clausal modifiers.

It was suggested that errors following singular heads arose when the local noun was incorrectly designated as the controller of verb agreement, but that errors following plural heads occurred when subjects failed to designate any noun as controller of agreement, resulting in production of default (singular) verb agreement. I suggested that this failure was caused by cognitive overload. PPs might be more likely to cause cognitive overload during production because they increase the complexity of the planning unit; this would be unaffected by local noun number. However, the overload effect for clauses might be concentrated on comprehension, because clauses comprise fundamental units in comprehension; in particular, overload might be concentrated on cases where the head and local noun were both plural, requiring the construction of a complex semantic interpretation.

These results are compatible with a processor which treats certain predicate+argument units in one way and PPs in another. Although we cannot be sure that all predicate+argument units are treated alike, since there was not a significant interaction between PPs and non-finite relative clauses (though there was a trend), the fact that participials and finite relative clauses patterned alike suggests that the relevant class of units is not defined in terms of finiteness. This would be consistent both with previous experimental work (such as that of Ford & Holmes (1978), Ford (1982), Holmes (1988)) and with linguistic theories which recognise a class of structures with the same properties. However, in the light of the above discussion, we cannot be sure whether the errors arose from differences in the way in which the two classes of modifier were processed during comprehension or during production. Hence we cannot draw any inferences from these results that clauses are implicated in production as the units

of functional level processing. Future work could address the problem by asking subjects to reproduce the preambles and analysing the incidence of preamble repetition errors in addition to agreement errors, following Vigliocco, Butterworth & Semenza (1995).

A further issue of interest is whether argument and adjunct PPs display similar behaviour. Both Bock and her colleagues' work (Bock & Miller 1991; Bock & Cutting 1992) and the work presented here suggest that clauses which are arguments of the head noun (complement clauses) and those which are adjuncts of the head noun (relative clauses) induce qualitatively comparable patterns of errors. It would be interesting to see whether the same is true of argument and adjunct PPs; as yet, there has been no systematic study of this issue.

5.6 Summary

In this chapter, I have examined subject–verb agreement errors. I argued that the incidence of agreement errors could in principle be informative about representational issues and presented two experiments which carried out preliminary explorations of this hypothesis. The preliminary findings presented here suggest that modifiers of different types cause different patterns of agreement errors. More specifically, predicate+argument units behave differently from PPs, apparently regardless of finiteness. It is not clear what causes the differential pattern of errors found here, nor whether the effects occur during comprehension, production or both, but I have suggested some possible lines of enquiry for further research.

Chapter 6

Syntactic priming in language production

6.1 Introduction

In the previous chapter I examined how patterns of agreement errors could cast some light upon representational issues. This chapter is also concerned with representation. I will begin by discussing some of the problems which make empirical studies of representation difficult, and then present a phenomenon, priming, which seems to allow the study of representation without these problems. Next I discuss possible corpus evidence and existing experimental evidence for syntactic priming in language production. The main part of this chapter presents the results of two experiments which use syntactic priming as a tool to study syntactic structure in written language production. I will argue that these experiments provide evidence that language production involves the creation of syntactic structure and that they can be informative about syntactic representation.

6.2 The difficulties of studying representation

As I discussed in Chapter 2, the issue of how syntactic structure is mentally represented is a crucial issue for conceptualist linguistic theories and theories of language processing, but one which has tended to be neglected. The difficulty lies in identifying experimental methods which can be used to examine the mental representation of syntactic structure. Traditionally, the experimental emphasis has been on exploring processing, because it is relatively straightforward – at least in comprehension – to find evidence for differences in processing. The problem is that while processing differences may be evidence for representational differences and hence provide indirect evidence about representation, they are not necessarily evidence for differences in *syntactic* representation, nor are they necessarily informative about the form which those representational differences take. Production and comprehension pose different problems in this regard, as the following sections aim to show.

6.2.1 Problems posed by comprehension

In comprehension, the linguistic input to the comprehender can be tightly controlled by the experimenter, allowing each stimulus to be controlled for semantic and lexical content, and for its syntactic characteristics to be manipulated in a systematic manner. In this way the experimenter can ensure as far as possible that differences in processing between two sentences do not arise from – for example – semantic influences but are instead attributable to differences in syntactic structure. Unfortunately, processing differences which result from a distinction in syntactic structure are not in themselves informative about how that distinction might be represented. As an example, let us consider recent work on unbounded dependency constructions in language comprehension. In theories such as GB, unbounded dependency constructions involve an 'empty category' in a canonical position which is associated with an overt element in a non-canonical position. Empty categories are constituents which appear in the syntax but have no lexical or phonological content. In a sentence such as (6.1), for example, GB analyses postulate an empty category (represented here as *ec*) following the verb *give* and coindexed with the overt constituent *What*.

(6.1) What$_i$ did John give the girl ec_i ?

Other linguistic theories such as HPSG (Pollard & Sag 1994, Chapter 9) eschew empty categories, capturing the linguistic relations in unbounded dependency constructions by other means, such as lexical rules.

The existence or non-existence of empty categories is a fundamental point of disagreement between competing theories, and one on which experimental studies might be expected to cast some light. There have been a number of studies of unbounded dependency constructions (see Fodor (1989) for detailed discussion), most of which assumed the existence of empty categories. However, Pickering & Barry (1991) suggested that there is intuitive evidence that the dependency is formed *before* the location of the putative empty category is reached and hence that empty categories cannot be represented in the grammar; Traxler and Pickering (in press) subsequently provided experimental evidence that subjects formed the appropriate dependency as soon as they encountered the verb (*give* in (6.1) above). However, as Gibson & Hickok (1993) argued, these results are also compatible with a grammar which does contain empty categories, by showing that if the processor works partially top-down, it could postulate an empty category before reaching its location.

Hence the processing evidence is compatible with (at least) two different representation–process pairs, one which does not have representations of empty categories and employs a strictly bottom-up processor, and one which includes empty categories and employs a partially top-down processor. Experimental evidence of this type cannot distinguish between alternative theories of representation, since alternative process–representation pairs could always result in the same behaviour.

6.2.2 Problems posed by production

In production, the situation is slightly different, in that the result of processing – a string of words – is in the public domain and hence open to inspection. However, the representation–

process pair indeterminacy still exists, since the *representation* of that string is not in the public domain. Furthermore, production experiments pose particular problems with respect to investigating syntactic structure because the input to processing cannot be controlled to the same extent as in comprehension experiments. It has proved difficult to find experimental manipulations which can systematically elicit particular structures without involving an unnatural task or without alternatively laying themselves open to non-syntactic influences. In particular, it is difficult to separate form from meaning, in other words to exclude semantic or discourse influences.

A good example to illustrate this is the case of the full/zero relative clauses discussed in Chapter 4. I suggested there that the differences in distribution between full relative clauses and zero relative clauses might reflect differences in their underlying representations: the simpler structure associated with the latter might facilitate its production early in the matrix clause compared to the former. However, there are other non-processing factors which could also give rise to the same distributional effects. Zero and full relative clauses may fulfill different discourse functions; the difference in distribution could therefore reflect a difference in – for example – information structure. Certainly, zero relative clauses in the corpus discussed in Chapter 4 seemed to be used in some cases to refer back to entities which were originally introduced with a full relative clause. Given the tendency in English for 'old' information to appear early in the sentence and 'new' information to appear later (Clark & Haviland 1977), at least some of the disparity in distribution could be accounted for in discourse terms: full relative clauses usually present new information and hence appear later, whereas zero relative clauses present old information and hence tend to appear earlier. Equally, the differences could stem from differences in the communicative intention and thus reflect semantic differences between the propositions expressed by zero relative clauses and those expressed by full relative clauses.

In production, then, it is difficult to distinguish between processing differences which are based upon syntactic differences between structures and those which are based on differences at other levels of structure.

6.2.3 Summary

To sum up, it seems that one reason why empirical studies of the mental representation of syntactic structure have been so sparse is that there simply have not been techniques which can be used to tap into it. However, there is no a priori reason why it should not be studied, provided the right experimental tools can be found. In the remainder of this chapter and in the following chapter, I will discuss a technique which I believe allows us to tap into representation.

6.3 Priming effects in language processing

It has long been recognised that the way in which people react to stimuli can be affected by the features of previous stimuli which they have encountered. A well-known example of this tendency is set effects in problem-solving, where subjects settle upon a particular solution for a set of problems and continue to use this, even when there are alternative – simpler – solutions (Luchins (1942), cited in Bock (1986b)).

Similar repetition effects have been identified in language processing. For example, Neisser (1954) found a facilitation effect in a word recognition task if subjects had previously been exposed to the target word. Meyer & Schvaneveldt (1971) found a similar facilitation effect when subjects were exposed to semantically related words: reaction times in a lexical decision task were faster when subjects had just seen a word which was semantically related to the target word than when they had seen an unrelated word. For example, reaction times were faster for the target *doctor* when it followed *nurse* than when it followed *bread.* Furthermore, whereas the set effects noted above seem to be (possibly conscious) strategies which are formulated to deal with an immediate problem, the effects in language processing are apparently automatic: facilitation occurs between semantically related words even when exposure to the first word is so brief that the subject is unaware of having seen it (Fowler, Wolford, Slade & Tassinary 1981).

These language processing phenomena have been termed 'priming effects'. I will define priming as the phenomenon whereby processing of one stimulus at a particular level of processing affects the processing of a subsequent, related stimulus at that level of processing. In comprehension, it can act by speeding responses to, or improving comprehension of, a stimulus; in production, it can make a speaker more likely to produce, or increase his/her fluency in producing, a word or structure. Note that priming as I use it here has a very specific meaning: although some cases of parallelism (of words or structures) may originate from priming, not all cases of parallelism effects are priming effects at a particular level. For example, a speaker may deliberately choose to repeat a word for rhetorical effect. This would not be considered an instance of lexical priming.

6.3.1 The theoretical implications of priming

Priming phenomena are particularly important because they offer us a way of tapping into representation. The crucial part of the definition above states that priming occurs between two stimuli which have related representations. Let us examine how priming is hypothesised to work, taking lexical priming as an example. Priming is usually explained in terms of activation levels: when the first stimulus is encountered, the representations which are associated with it – in the case of lexical priming, lexical entries – become activated. They retain some activation even after responding to the stimulus. Thus when the next stimulus is encountered, the representations associated with the first stimulus still retain residual activation.

If the second stimulus is sufficiently like the first stimulus (for example, it is identical or bears a close semantic relationship), then some (or all) of the representations which it activates will be the same as those activated by the first stimulus. Since those representations will already have residual activation from the first stimulus, this means that less activation is required for them to reach the criterion level for recognition/access. From this it follows that reaction times will be shorter for primed words than for unprimed words. It is important to note that the prime and target stimuli *must* be related in order for priming to take place: if they are not, then the representations which the first stimulus activates will not be the same as those associated with the second stimulus and hence there will be no facilitation effect. Note that this facilitation effect is often a relative notion, i.e. priming affects relative activation with respect to a baseline.[1]

Thus priming offers us a way of tapping into mental representation: if one stimulus primes another, then at some level of structure they must have related representations. As a corollary of this, priming of language stimuli is also informative about the processing of language. Priming can only occur if the language processor is sensitive to the dimension along which the two stimuli are related. For example, the fact that priming takes place between semantically related words implies not only that the words have representations which are related along the semantic dimension, but also that the processing system accesses semantic information.

If we now abstract away from the specific example of lexical priming, we can draw a more general conclusion about the implications of priming effects. Specifically, if facilitation effects occur between two stimuli when one aspect of language is kept constant and all other factors are varied, it suggests that the cognitive system is sensitive to that aspect and that it assigns the two stimuli related representations with respect to that aspect.

The implications for studying syntactic structure

The significance of this for studying syntactic structure is obvious. Because priming effects are informative about representation at a given level of structure, priming allows us to separate form from content, in other words to investigate syntactic structure whilst excluding any lexical or semantic influences. Most fundamentally, if we found repetition effects when prime and target sentences have only their syntactic structure in common, this must mean that the processor is sensitive to (and hence represents) syntactic information, independent of semantic or lexical information. In other words, evidence of syntactic priming effects would be evidence that syntactic structure is in some way psychologically 'real'. In addition, priming could in principle be informative about the how syntactic structure is represented. By systematically manipulating which syntactic features the prime and the target have in common, it would be possible to determine which features are intrinsic to that level of representation. If some dimension of structure is intrinsic to the representations over which priming takes place, priming should not occur if prime and target differ along that dimension, since the processor will no longer treat them as being related. For example, if thematic information is an intrinsic part of the representations which are primed, we would not expect priming to occur between two sentences which differ in this crucial respect. If priming does occur in these conditions, it suggests that the processor is sensitive to some common dimension between prime and target but that thematic information is not relevant to that dimension.

Summary

To summarise, priming effects can be informative about both representation and processing, since they rely upon the processor recognising that two stimuli are related. Syntactic priming effects could therefore be informative about syntactic representation and syntactic processing. Such effects could manifest themselves in many ways. In comprehension, we might find that

[1] Inhibitory priming effects are also found, where the effect of priming is to depress the relative activation of the primed stimulus. For example, phonological priming seems to be an inhibitory effect, such that the primed word becomes relatively less accessible than a control word (see for example Bock (1987a)). I will return to the issue of inhibitory priming in Chapter 7.

comprehension of a sentence with a particular syntactic structure would be faster following comprehension of another sentence with a related structure. In production, we might expect that speakers would tend to repeatedly produce a particular syntactic structure across consecutive sentences.

6.3.2 Syntactic parallelism in spontaneous discourse

Evidence for syntactic parallelism in discourse

There is substantial evidence that syntactic parallelism effects occur in natural discourse. Schenkein (1980) noted that the participants in a surreptitiously recorded dialogue had a tendency to repeat particular types of structure, which he called 'action sequences'. These sequences included both discourse-level structures, such as particular types of discourse move (e.g. request, assertion, justification) and syntactic structures. An example from his corpus is given below in (6.2).

(6.2) A: But you can go to sleep tonight.
B: How am I going to sleep tonight ?

The same observation was made by Tannen (1984, 1989) in analyses of dinner table and other informal conversations. Tannen noted syntactic repetition as an instance of an overall tendency towards repetition in discourse, which was also manifested at several other levels (e.g. the lexical and phonological levels). Weiner & Labov (1983) found the same tendency in interviews, but centred on a particular syntactic structure. In an analysis of the incidence of passive structures in the interviews, they found that the best predictor of where a passive structure would be produced was where the speaker had previously produced another passive structure in the previous five clauses.

The parallel structure effect was also examined in Dutch by Levelt & Kelter (1982), who termed it the 'correspondence effect'. Levelt and Kelter focused upon question-answering sequences and in particular questions of the forms *To whom did Paul show the violin* and *Whom did Paul show the violin?*, i.e. questions involving either a preposed PP or a preposed NP. Both questions allow (among other possible responses) a response containing a PP (*To John*) or an NP (*John*). Levelt and Kelter examined the effect under both laboratory and non-laboratory conditions. In the laboratory conditions, subjects were shown pictures and asked questions about actions depicted in the pictures. In the non-laboratory conditions, Dutch shopkeepers were phoned and asked (in Dutch) either *What time do you close?* or *At what time do you close?*. In both cases, they found a significant correspondence between the form of the question and the form of the answer: PP responses were produced more frequently as answers to PP-preposed questions and NP responses as answers to NP-preposed questions. However, the effect either diminished or disappeared if additional material was presented to the listener following the question (for example, *What time do you close, because I'll have to come in specially*). Levelt and Kelter concluded that the correspondence effect was partly lexical in nature, stemming from repetition of a particular preposition, but that it also reflected the retention in working memory of recent speech. They suggested that such a strategy would aid the production and comprehension of surface anaphora, and might also contribute to fluency.

Possible explanations for parallelism effects in discourse

Evidently, there is ample evidence that some sort of syntactic parallelism effect can be found in discourse, but it is not clear what the source of the effect is, nor whether it can be taken as evidence about syntactic representation. As I noted in section 6.3.1 above, parallelism effects are informative only if it is clear that they reflect the facilitation of the processes or representations associated with the level of structure under investigation. Hence in the cases above, it would only be possible to conclude that there is evidence of a syntactic priming effect which is informative about syntactic representation if it could be shown that there are no other factors which could cause such parallelism.

In fact, there are several reasons why such effects might be found. Sociolinguistic influences might explain some of the cases of parallel syntactic structure noted above. The first of these is the fact that certain registers of language are associated with particular structures; for example, formal registers are characterised by a high incidence of passive structures. Hence one possible explantion for Weiner and Labov's (1983) findings is that the clusters of passive sentences reflect shifts of register within the interview.

Secondly, researchers have noted a general 'tendency for a speaker to adapt his speech style according to the characteristics of the receiver' (Giles & Powesland 1975, p.153) which is motivated by considerations relating to the social relationship between the speaker and the hearer (Giles & Powesland 1975; Le Page & Tabouret-Keller 1985). This adaptation may be towards the receiver's speech style ('convergence', in Giles and Powesland's terms) or away from it ('divergence') and seems to be motivated by a desire to identify oneself as part of a particular social group. Such 'accommodation', as Giles and Powesland term it, takes place at several linguistic levels, including the syntactic level. Thus a speaker who wishes to identify himself/herself as part of the same social group as the receiver will tend to parallel the receiver's speech, including the syntactic structures used in his/her utterances. It seems likely that any such tendency would be magnified in question-answer sequences, where the speaker's utterance is directly linked to that of the receiver. Another factor which could affect syntactic structure is discourse content; persistence of a discourse topic may also lead to persistence of syntactic structure, either for rhetorical purposes (Tannen 1989) or simply because similar communicative intentions (in elaborating on a topic, for example) might trigger the same syntactic forms.

In addition to such high-level factors, there are also language-internal influences which could be at work in the research discussed above. The most obvious of these is lexical priming. At least some of the parallel structure effects could be attributed to the ease of retrieving from the mental lexicon a word which has already been used. In Schenkein's (1980) example above (6.2), for example, the overlap in lexical content between each speaker is very marked. The same factor could explain Weiner and Labov's (1983) findings (repetition of the auxiliary *have* or *got* and the preposition *by*) and Levelt and Kelter's (1982) findings, as Levelt and Kelter themselves suggested. Similarly, prosodic priming might occur. This could favour the production of successive sentences with the same prosodic contour, which in turn would favour sentences with the same syntactic structure.

Hence although there is evidence of structural parallelism in natural discourse, there are a

number of non-syntactic factors which could either cause or be confounded with it. As a result, the evidence from discourse is not necessarily evidence of syntactic priming. Nevertheless, it is possible that at least a part of the parallelism effect found in discourse has its basis in purely syntactic factors, in other words that syntactic priming effects do occur. A way to demonstrate this would be to show that the tendency still holds when other possibly influential factors are excluded. Estival (1985) took this approach in examining a small corpus of interviews for passive structures. Like Weiner and Labov (1983), she found that passives tended to occur in clusters. Estival then analysed the occurrence of passive structures with respect to factors such as discourse-motivated repetition and lexical repetition; she found that even when these factors were taken into account, there was still a significant syntactic parallelism effect. From this she concluded that there is a syntactic priming effect in natural discourse. However, Estival took only a limited number of factors into account and it is impossible to be sure that all possibly influential factors were excluded. For this reason, it would be preferable to use experimental methods to study whether syntactic priming effects can be found.

Summary

There is evidence that syntactic parallelism effects occur in discourse, but these effects have many possible sources. The strongest conclusion that can be drawn from the discourse evidence is that it *suggests* the existence of a level of constituent structure processing in language production. We cannot conclude from it that syntactic priming effects do occur and hence we cannot draw any conclusions about the nature of the syntactic representations which are implicated in language production unless we can exclude these other factors from consideration. In other words, an experimental technique for eliciting syntactic priming effects is required.

6.3.3 Experimental findings of syntactic priming in language production

In a series of papers, Bock and her colleagues (Bock 1986, 1989; Bock and Loebell 1990; Bock, Loebell and Morey 1992) developed an experimental procedure which elicited syntactic repetition effects whilst excluding discourse, conceptual, semantic and lexical influences. I will review their work in the following sections.

Bock (1986b)

Bock (1986b) used a picture description task to elicit speech, under the guise of a memory test. Subjects were asked to study a set of pictures and sentences so that they would be able to recognise them later. They were then shown a series of pictures and sentences, some of which had been in the original study set. They were asked to state whether or not each stimulus had been in the original study set. In addition, they were asked to repeat each sentence and describe each picture before making the recognition judgement; they were told that this was to ensure that they had understood the sentences/pictures.

Embedded within the series of sentences and pictures were a number of priming trials. The trials consisted of a priming sentence followed by a completely unrelated target picture. Each target picture was designed so that it could be described in two ways. The two alternations which Bock investigated were active/passive sentences (6.3) and prepositional/double object sentences (6.4). Bock examined whether the form of the priming sentence which the subjects heard and repeated influenced the type of picture description which they subsequently produced. The question was whether hearing and repeating a sentence like (6.3a) would make subjects more likely to produce an active description for a subsequent picture depicting a transitive action, and whether hearing and repeating a sentence like (6.3b) would make them more likely to produce a passive description. Similarly, when faced with a picture of a ditransitive action, would subjects produce a prepositional object description more often after a prepositional object prime (6.4a) and a double object description more often after a double object prime (6.4b)?

(6.3) a. One of the fans punched a referee.
b. The referee was punched by one of the fans.

(6.4) a. A rock star sold some cocaine to an undercover agent.
b. A rock star sold an undercover agent some cocaine.

Bock found significant repetition effects: the form of the priming sentence reliably affected the form of the target description. After a priming sentence of a particular type, subjects were more likely to describe an immediately subsequent picture using the same type of structure. This tendency held even when the conceptual content of prime and target varied: passive sentences with inanimate agents (6.5a) primed passive sentences with animate agents (6.5b):

(6.5) a. Spring vacation was ruined by a blizzard.
b. The ball is kicked by the boy.

Because the priming sentence and the picture had no semantic content in common, these effects could not be attributed to the repetition of open-class words or to semantic factors. Nor could there be any effect of discourse, since subjects were repeating isolated sentences and describing isolated pictures. Equally, since there was no obvious link between the sentences and pictures – the recognition task required subjects to treat each picture or sentence as a separate trial – there was no reason for subjects to maintain the priming sentence in their memory, excluding possible episodic trace effects. Hence the repetition effects must have had another cause. Bock suggested that they resulted from the facilitation of the procedures associated with creating syntactic structure, in other words that they were evidence of syntactic priming.

Bock (1989)

In her subsequent experiments, Bock investigated the phenomenon further, ruling out alternative explanations and narrowing down the possible locus of the effect. The experiments reported in Bock (1989) were designed to exclude any remaining lexical influences. The materials in Bock's (1986b) experiments were designed so that there was no open class overlap between prime and target, but it is possible that the priming effects reflected closed class lexical priming between the preposition (*to* or *for*) in the prepositional object sentences or the preposition *by* in the passive sentences, although this seems unlikely (strong priming effects

were also found for active sentences and double object sentences where there was no closed class word overlap). To test this possibility, Bock compared whether prepositional object primes which contained *for* (6.6a) were as successful as those containing *to* (6.6b) in eliciting prepositional object target descriptions containing *to* (6.7). Any lexical priming effect should manifest itself as significantly more prepositional object descriptions following (6.6b) than following (6.6a).

(6.6) a. The secretary is baking a cake for her boss.
b. The secretary is taking a cake to her boss.
c. The secretary is taking her boss a cake.

(6.7) The girl is handing a paintbrush to the man.

In fact, both types of prepositional object sentence were equally successful in eliciting prepositional object descriptions for a subsequent picture, compared with the double object control (6.6c). Although there were lexical priming effects, these manifested themselves only as a trend towards increased use of *to* and *for* in descriptions involving other types of structure, such as infinitival and complement descriptions – the identity of the preposition had no effect upon the incidence of syntactic repetition, suggesting that the priming effect reflected more abstract similarities between the priming and target sentences. Again, Bock suggested that the most plausible candidate for these similarities was the procedures which construct syntactic structure. She further proposed that these procedures could be associated with the elements of phrase structure grammars.[2]

Bock and Loebell (1990)

This hypothesis was tested more fully in a subsequent set of experiments. The first experiments investigated whether priming effects would occur when the priming sentence had the same phrase structure as the target sentence, but involved different thematic roles. For example, would sentences like (6.8a) below, where the NP in the final PP bears a Goal role, prime the production of (6.8d), where the final NP bears a Beneficiary role?

More tellingly, given that in some accounts of thematic relations, both *the church* in (6.8a) and *the man* in (6.8d) would bear the same thematic role (Goal), Bock and Loebell also examined whether priming occurred between sentences like (6.9a) where the final NP bears a Location role, and (6.9d), where it bears an Agent role. The thematic-mismatch condition was compared with a condition where the roles in prime and target matched ((6.8b) and (6.9b)), and a control condition ((6.8c) and (6.9c)).

(6.8) a. The wealthy widow drove her Mercedes to the church.
b. The wealthy widow gave her Mercedes to the church.
c. The wealthy widow gave the church her Mercedes.
d. The girl handed her paintbrush to the man.

[2]Bock also used these results to argue against Garrett's (1980) closed class immanence hypothesis, as described in Chapter 3.

(6.9) a. The 747 was landing by the control tower.

b. The 747 was landed by the control tower.

c. The control tower landed the 747.

d. The boy was stung by the bee.

A significant priming effect was found following both (6.8a) and (6.9a), despite the differences in the thematic roles in the prime and target sentences, compared to the control conditions ((6.8c) and (6.9c)). In fact, the thematic role dimension had no effect: priming sentences which involved different thematic roles to those in the target picture were as effective in eliciting priming effects as sentences which involved the same thematic roles.

In their final experiment, Bock and Loebell examined whether the priming effect could be caused by phonological or metrical correspondence between the prime and target. To test this, they compared sentences which had the same metrical structure and phonologically identical closed class words in the same linear positions, but which differed in their phrase structure, as in (6.10) below. The question was whether both sentences would prime the production of prepositional object sentences, such as (6.11).

(6.10) a. Susan brought a book to Stella.

b. Susan bought a book to study.

(6.11) The girl gave a paintbrush to the man.

They found that despite the superficial similarity between the two sentences, priming only occurred following (6.10a), in other words, where the priming sentence and the target sentence shared their phrase structure. From this they concluded that the constituent structure of the prime had a reliable effect on the realisation of the description, but that metrical structure and the linear position of closed class elements in the prime had no detectable effect. Note however that these results are not in themselves evidence that priming requires the repetition of phrase structure, since the primes differ in two respects, phrase structure and categorial structure. In addition to the experimental manipulation, whereby *to Stella* is the daughter of the VP whereas *to study* is a modifier of *book*, the two constituents also differ in their category: *to Stella* is a PP, whereas *to study* is an infinitival clause.

Bock, Loebell and Morey (1992)

Bock, Loebell & Morey (1992) used the same technique to investigate grammatical function assignment and constituent structure creation in spoken language production. In particular, they investigated whether there is a direct mapping between the grammatical functions which are assigned during functional-level processing and the subsequent constituent structure. If this is correct, then whatever is assigned the subject function during functional processing will also appear as the subject in the final constituent structure. The alternative to this, mediated mapping, assumes that the relations which are originally assigned may be altered during constituent structure generation, so that the entity which is initially assigned the subject function may not appear as the subject in the final utterance.

Bock *et al* suggested that the distinction between the direct and mediated mapping approaches has analogues in linguistic theory. For example, in Government-Binding theory (Chomsky 1981, 1982, 1986) there are two levels of constituent structure, D-structure and S-structure, and relations defined at D-structure may be altered at S-structure. In a passive sentence, for example, the patient is assigned the object function at D-structure but then becomes the subject at S-structure via a movement operation. Under this assumption, the object of an active sentence and the subject of a passive sentence will share their initial functional assignment, although their S-structure functions differ.

In other theories (such as LFG (Kaplan & Bresnan 1982), HPSG (Pollard and Sag 1987, 1994)) and GPSG (Gazdar, Pullum, Klein & Sag 1985)), surface structure representations are derived directly. These approaches capture the relationship between active and passive sentences as a relationship between rules in the grammar, not as alternative S-structure realisations of a common D-structure. Hence an NP assigned the subject function during functional processing will be associated directly with the surface structure subject position. According to this approach, the subject of an active sentence and the subject of a passive sentence share their functional assignment.

Bock *et al* suggested that in addition to, and distinct from, a priming effect based on constituent structure, there would also be an effect based upon grammatical function assignment which would manifest itself as a tendency for entities with similar conceptual features (such as animacy) to be assigned the same function across consecutive sentences. For example, if the prime contained an inanimate subject, then there would be a tendency for the inanimate entity in the target to be assigned a function which would allow it to be realised as the subject too.

Bock *et al* argued that the mediated and direct mapping approaches make different predictions in this respect concerning active and passive sentences. The mediated mapping approach suggests that in active primes with animate objects (6.12b below) and passive primes with animate subjects (6.12c), the underlying object is animate; hence both should prime active descriptions of pictures depicting inanimate agents and animate patients, because this allows the animate entity to be realised as an object once more. According to the direct mapping approach, however, active and passive primes with animate surface structure objects (6.12b and 6.12d) result from assigning the object function to the animate entity and so it is these two structures which should elicit more active target descriptions.

In their experiment, Bock *et al* therefore manipulated two variables: the syntactic form of the priming sentence and the animacy of the arguments in the priming sentence. Each prime appeared in four forms: an active structure with an animate subject and inanimate object (6.12a); an active structure with an inanimate subject and animate object (6.12b); a passive structure with an animate subject and inanimate object (6.12c); and a passive structure with an inanimate subject and an animate object (6.12d). The following picture always involved an animate patient and an inanimate agent, permitting an active or passive description such as (6.13).

(6.12) a. Five people carried the boat.
b. The boat carried five people.
c. Five people were carried by the boat.
d. The boat was carried by five people.

(6.13) a. The alarm clock awakened the boy.
b. The boy was woken by the alarm clock.

Bock *et al* found evidence which supported the direct mapping approach: primes with inanimate surface subject arguments elicited more target descriptions with inanimate surface subject arguments than primes with animate surface subject arguments. They additionally found a distinct constituent structure priming effect: active primes were more likely than passive primes to be followed by active descriptions. They concluded that language production involves two distinct types of process, those which bind arguments to syntactic functions and appear to be sensitive to conceptual features, and those which construct constituent structures and are sensitive to syntactic features. Their results argue against relation-changing operations during language production. Hence while the data fits well with linguistic theories in which relation-changing operations play no part, such as LFG, HPSG and GPSG, Bock *et al's* findings are difficult to reconcile with linguistic theories which do assume relation-changing operations, such as GB. As such, they may be interpreted as evidence that the syntactic representations proposed in such theories do not correspond to the syntactic representations which are implicated during language processing.

Summary

In the experiments described above, Bock and her colleagues systematically varied lexical, semantic, thematic and metrical factors; they found that a structural repetition effect reliably occurred whenever the phrase structure of the prime matched that of the intended target. When the phrase structure differed, however, no repetition effect was found. I argued above that we could only be sure that structural repetition effects were evidence of syntactic priming if they were found when all other factors were varied and only the syntactic structure of prime and target were kept constant. These findings show exactly that. Hence Bock *et al*'s results are strong evidence for syntactic priming effects in speech production.

These results imply the existence of a level of processing in speech production which is syntactic in nature; at this level, the processor is not sensitive to semantic/conceptual or phonological information, hence the absence of conceptual and phonological/metrical effects. The experiments therefore suggest that syntactic structure is in some sense psychologically real in language production. They also support the modular architecture outlined in Chapter 3, where syntactic processing proceeds without bottom-up or top-down interference.

The effects seem to take place at the constituent structure level. Bock, Loebell and Morey's (1992) experiment found differential effects of functional assignments and constituent structure on the realisation of target descriptions. The experiment demonstrated that it was possible to prime a functional level process (functional assignment), but that its effects were quite distinct from the structural priming under discussion here. It therefore seems safe to conclude that

the priming effect found in all of the experiments discussed above is located at the level of constituent structure processing.

These experiments also provide evidence about the type of structures which are implicated at this level of processing in spoken language production. Here the relevance of these experiments to linguistic theory becomes clearer. Taken together, they suggest that the structures are not specified for semantic content (neither conceptual features such as animacy, nor features determined by lexical context, such as thematic roles); nor for lexical content (including closed-class words); nor for phonological content. Rather, they are at the very least specified for grammatical category and for hierarchical configuration.

However, these experiments raise a number of questions which as yet remain unanswered. These questions fall into two categories. The first set of issues relates to the nature of syntactic priming, such as the circumstances under which it occurs, whether priming effects are restricted to spoken language production, and what the mechanisms are by which priming occurs. The second set of issues is concerned with the inferences which we can draw about syntactic representation from evidence of syntactic priming. That is, between which types of sentence can syntactic priming effects be found, and what does this tell us about the nature of syntactic representation? In the remainder of this chapter and in the following chapters, I will explore some of these issues in more detail.

6.4 Priming in written production: Experiment 1

6.4.1 Experimental issues

The first question to be answered concerns the extent to which Bock and her colleagues' results are restricted to spoken language production. It is noticeable that all of the evidence adduced so far in support of syntactic priming has related to spoken language production. Before drawing any strong conclusions about the significance of the results described above for language production in general, we would want to show that comparable effects can also be found in written production. If language production involves a single system for both the written and spoken modalities, then it should be possible to prime the syntactic structure of sentences which people produce in written language in the same way that their spoken productions can be primed.

The experiment described here tested this using a written sentence completion task. This required subjects to use their knowledge of language and their production system to produce grammatical completions for a set of sentence beginnings. The rationale is the same as in the spoken experiments described above: the use of one particular structure in one sentence should predispose its use in a subsequent sentence. Hence, if syntactic priming effects occur, we would expect to find that subjects will produce a higher proportion of sentences with the same structure as the preceding sentence than with an alternative structure. For example, we would expect that after completing a sentence fragment like (6.14a) as (6.14b), people would be more likely to complete a fragment like (6.15a) as (6.15b) than as (6.15c).

(6.14) a. The girl gave the book ...
b. The girl gave the book to the teacher.

(6.15) a. The politician showed ...

b. The politician showed the report to the interviewer.

c. The politician showed the interviewer the report.

Using a sentence completion task as the experimental method offered an advantage over the method used in Bock and her colleagues' experiments, where subjects listened to and repeated the prime sentence. Bock and her colleagues assumed that in order to repeat the sentence correctly, subject had to use the same procedures which are involved in creating a novel sentence. Without this assumption, there would be no way in which repeating the prime could involve the same procedures as producing a picture description and hence no way in which priming could occur (under their hypothesis that priming arises from the repeated use of particular procedures). Potter & Lombardi (1990) found experimental evidence which is consistent with this. They suggested that when subjects recall a sentence, they are regenerating it from a conceptual structure and a set of activated lexical entries. Repetition may appear verbatim because all of the relevant words are already active and so are likely to be chosen to express the conceptual content of the sentence. Potter and Lombardi showed that when subjects were prompted with a (quasi-)synonym of one of the words in the sentence, they often produced the synonym instead of the original word when they recalled the sentence; for example, if they were prompted with *palace* and one of the words in the sentence was *castle*, they often recalled the sentence with *palace* in place of the original *castle*. Potter and Lombardi argued that this suggests recall is not based upon remembering the form of the sentence but instead involves regenerating it.

Using a sentence completion method obviates the need to make any such assumption, since subjects have to create (rather than just repeat) a completion in the prime position, just as they will subsequently create a completion in the target sentence. It was also hoped that forcing them to create a response in the priming position might strengthen any priming effect. Another step which was taken to strengthen the priming effect was to use two primes before every target, in place of the single prime used in Bock and her colleagues' experiments. It was hoped that repeated use of the same structure would cause a stronger effect.

One disadvantage of requiring subjects to produce the primes rather than merely repeating them is that it is impossible to ensure that they will produce primes which have the desired structure. That is, just as they can complete the target sentences with structures other than the structures of experimental interest (here prepositional/double object structures), so they can complete the primes using alternative structures. In this experiment, the problem was to a large extent circumvented, though not entirely excluded, by using verbs which most commonly appear in the types of structure under study here.

A decision was made to focus on one of the same construction pairs as those used in Bock and her colleagues' experiments, in order to make the experiment as comparable as possible with the experiments studying spoken production. The particular construction pair which was chosen was the double/prepositional object alternation, by which certain verbs (such as *give*) can take either two NP complements or an NP complement and a PP complement, as in (6.16) below:

(6.16) a. Tom gave Ben a pen.

b. Tom gave a pen to Ben.

The prepositional/double object pair was chosen over the other pair of structures (actives/passives) which Bock and her colleagues had also examined because using the former pair of structures simplified the experiment and the conclusions which can be drawn from it in three ways. Firstly, on practical grounds, it is straightforward to provide subjects with sentence preambles which will encourage them to produce prepositional or double object sentences but will not bias them either way, as in (6.15a); however, it is not obvious what sort of sentence preamble could be presented to subjects which would encourage them (in an unbiased way) to produce either a passive sentence or an active sentence. Secondly, the two forms as exemplified in (6.16) appear to be equivalent in their focus, semantic content and register, unlike active/passive sentences.[3] These differences between actives and passives could simply confuse the issue, or possibly even explain any syntactic parallelism effects.

Thirdly, the active/passive sentences add unnecessary complexity with respect to the level at which priming occurs. Since syntactic relations are involved at both the functional level and constituent level of processing, the priming effect could in theory occur at either level. Active/passive sentences allow no way of distinguishing between the two since the two structures differ from each other not only at the constituent structure level, but also at the functional level, under the assumption – borne out by Bock, Loebell and Morey's (1992) experiment – that there is a direct mapping to surface grammatical relations. For example, in (6.17a) below, *Simon* is the subject and *Andrew* is the object, whereas in (6.17b), *Andrew* is the subject and *Simon* is the oblique object. Thus priming from (6.17b) to (6.18) could be a consequence of constituent structure repetition or functional structure repetition. Hence any comparison of active and passive sentences could be explained in terms of functional processing.

(6.17) a. Simon chased Andrew.

b. Andrew was chased by Simon.

(6.18) Fred was seen by Helen.

However, any priming effects found with prepositional/double objects would presumably reflect differences at the constituent level. There is no compelling evidence that prepositional/double object sentences are distinguished at the functional level; I suggest that in both (6.19a) and (6.19b), *the book* is the object and *Tania* is the oblique object. Although this cannot be proved for English, supporting evidence can be found in a related language where the same alternation is found. In German, the case-marking makes it possible to differentiate between direct objects (which receive accusative case) and oblique objects (which receive dative case). As (6.20) shows, the patient of the action receives accusative case in both the prepositional object (6.20a) and double object (6.20b) sentences, while the beneficiary receives dative case.

(6.19) a. Alun gave the book to Tania.

b. Alun gave Tania the book.

[3] Although it is unlikely that register differences would occur within a list.

(6.20) a. Peter brachte das Buch zu dem Jungen.
Peter brought $\textit{the}_{nom/acc}$ *book to* $\textit{the}_{dat}$ *boy*
'Peter brought the book to the boy.'

b. Peter brachte dem Jungen das Buch.
Peter brought the_{dat} boy $\text{the}_{nom/acc}$ book
'Peter brought the boy the book.'

Assuming that case marking reflects functional level assignments, this suggests that the only difference between the two sentences is in their constituent structure. In that case, any priming effect involving prepositional/double objects can only be explained if the effect centres upon the constituent structure level rather than the functional level.

In summary, it was anticipated that the syntactic structure of the sentence completion which subjects produced for a fragment would influence the syntactic structure of a subsequent fragment, even though the fragments were lexically and semantically unrelated.

6.4.2 Method

Subjects

The subjects consisted of 64 unpaid undergraduate students from the University of Glasgow.

Materials

The materials for the experiment consisted of 12 sets of priming materials, each comprising three sentence fragments. The first two fragments in each set were primes; the third fragment was the target. In each case, the two primes consisted of a subject NP and a distransitive verb followed by an NP. The target consisted of a subject NP and a ditransitive verb only. The three verbs employed in each set were always different, and a wide range of ditransitive verbs were employed.

Two alternative versions of each set of materials were constructed; examples are given in (6.21) and (6.22) below. In both versions, the target was exactly the same (*The head waiter gave ...* in the example below). However, the prime fragments differed: both versions involved the same subject NP and the same verb, but differed in the NP which followed the verb.

(6.21) The messenger handed the unsigned note ...
The senior lecturer loaned the main textbook ...
The head waiter gave ...

(6.22) The messenger handed the countess ...
The senior lecturer loaned the visiting professor ...
The head waiter gave ...

In one version (6.21), the materials were constructed such that the NP following the verb in each prime made a plausible patient of the action denoted by the verb but an implausible beneficiary. This meant that although it was possible to complete the prime as a double object sentence, any such completion would be implausible (e.g. *! The senior lecturer loaned the main*

textbook a pen).[4] The aim of this was to encourage subjects to complete these fragments as prepositional object sentences.

In the other version (6.22), the NP following the verb in the primes was a plausible beneficiary but an implausible patient. Here, a prepositional object completion would be implausible (e.g. *! The senior lecturer loaned the visiting professor to the student*) and hence it was hoped that subjects would complete these primes as double object sentences.

The intention was that subjects would produce equal numbers of prepositional and double object completions; and that they would produce either two prepositional object sentences or two double object sentences in a row. Because the third fragment consisted of just a subject NP and a verb, it could always be completed as either structure. A full list of materials is provided in Appendix B.

An additional 72 filler materials were constructed. Twenty-four of these consisted of fragments of varied types, including both bare NPs and NPs followed by transitive verbs (e.g. *The rock star photographed ...*); 24 were complex NP materials (e.g. *The notice that Nick had cancelled the meeting ...*);[5] and 24 were relative clause fragments (e.g. *The sentry who was woken by ...*).

Two presentation lists were constructed from these materials. Each list contained six materials (= 18 fragments) of the type shown in (6.21) and six materials of the type shown in (6.22), giving a total of 12 priming trials, interspersed with the 72 fillers. The order of presentation was randomised for each subject with the constraint that at least three filler sentences intervened between each priming trial (this constraint was relaxed where necessary for the last two items). The sentence fragments were then printed out as eight-page booklets.

The instructions on the cover of each booklet explained that we were interested in seeing what sorts of sentences people produce. The instructions asked the subjects to complete the sentence fragments in any way that they liked, as quickly as they could, with the first completion that came to mind. It was stressed that subjects should ensure that their completion formed a grammatical sentence, that they should fill in the sentences in order, and that they should not leave some sentences out and go back to them later.

Procedure

Subjects were each given a booklet to complete and told to hand it back to the experimenter when they had finished. The experimenter answered any questions that the subjects had about the task. The experiment took place during an undergraduate practical class. The booklet took about 20 minutes to complete.

Scoring

For each fragment, the first legible response made by the subject was scored as a prepositional object sentence, a double object sentence or other. The scoring criteria were essentially the same as those used by Bock and Loebell (1990).

[4] I use *!* here to mark pragmatically anomalous sentences.
[5] These formed the first agreement error experiment presented in Chapter 5.

In prime position, a sentence was scored as a prepositional object sentence if the completion contained a beneficiary NP which was the object of the preposition *to*. A sentence was scored as a double object sentence if the completion contained a patient/theme NP.

In target position, a sentence was scored as a prepositional object sentence if the first NP following the verb was the patient/theme, followed by the beneficiary as the object of the preposition *to*. To be scored as a double object sentence, the verb had to be followed by two NPs; the first NP following the verb had to be the beneficiary and the second NP had to be the patient/theme. To be scored in either category, a description had to have a grammatical alternative in the other category where the positions of patient/theme and beneficiary were reversed (this was to ensure that each prepositional object completion allowed a control form and vice versa).

In both positions, 'other' responses were those which did not meet the scoring criteria. These were sentences which were completed with other structures, such as simple transitive sentences etc.

Design and data analyses

There was one independent variable, prime sentence type (prepositional object versus double object). This yielded two conditions. Each subject completed 12 experimental materials, 6 in each condition. Each material was presented to 64 subjects, 32 in each condition.

As I have already noted, the nature of the task made it impossible to ensure that all potential priming trials were actually completed as priming trials, i.e. completed as either a prepositional object structure or a double object structure. All priming fragments which were completed as alternative structures were excluded from the analyses. I provide exact figures for the number of successful priming trials in the results section below.

Three types of analysis were carried out. The first I will term the 'single prime' case. In this analysis, I considered the responses where *at least* the immediately preceding fragment was completed as a prepositional or double object prime. The dependent variables in this analysis were the numbers of prepositional and double object targets produced following prepositional object prime completions, expressed as a proportion of *all* the responses which were produced after a prepositional object prime, and the number of prepositional/double object targets produced after a double object prime, expressed as a proportion of all the responses produced after a double object prime.

The rationale for calculating the dependent variables was as follows. By hypothesis, production of a prepositional object completion in prime position should predispose production of a prepositional object completion in target position, and similarly a double object response in priming position should encourage the production of a double object target. However, we cannot simply compare the number of prepositional object targets following prepositional object primes with those following double object primes, since there might not be equal numbers of primes completed as prepositional objects and double objects. For example, it might be the case that more fragments are completed as prepositional objects in prime position than double objects. Hence the target responses must be expressed as a proportion of the responses following each type of prime.

The second type of analysis was the double prime case. This considered responses following

completion of both of the prime fragments as prepositional objects or completion of both of the prime fragments as double objects. The dependent variables were the number of prepositional and double object targets produced after prepositional object primes as a proportion of the total number of responses produced after prepositional object primes, and the number of prepositional/double object targets produced after double object primes, as a proportion of all responses produced after double object primes.

A third analysis was carried out on a subset of the double prime responses. Bock and Loebell (1990) reported that although they found reliable syntactic priming effects for active/passive sentences and prepositional/double object sentences in spoken language, the prime and target sentences often differed in their fine-grained structure, for example in the addition or omission of adjectives, auxiliary verbs and adverbs. Bock and Loebell did not provide any statistical analyses for this aspect of their data. However, their comments suggest that priming may not rely upon prime and target having globally identical syntactic structures, but instead may occur when *part* of the syntactic structure of the prime sentence and the target sentence is shared.

If that is the case, we should still find a priming effect when prime and target differ in their detailed syntactic structures. To test this, the third analysis examined only those double prime responses where the internal structure of at least one of the object NPs in the target sentence differed from the internal structure of the corresponding object NP in at least one of the primes. In other words, this analysis excluded all double prime responses where both of the primes and the target had identical syntactic structures with respect to the internal structure of the object NPs. I will refer to this as the 'double prime (different NP structure)' case.

Analyses of variance were carried out on the data, with separate analyses treating subjects and items as random effects.

6.4.3 Results

Results following single primes

The results are presented in two parts, starting with the single prime case. Because we could not control the form of a subject's response in the priming fragments, not all of the 'priming' fragments were actually completed in the intended manner, as a prepositional or double object structure; these trials must be excluded from consideration. However, the amount of data excluded in this way is relatively small: out of a possible total of 768 priming trials, the prime immediately preceding the target was completed as either a prepositional or double object sentence in 654 trials (85%). In the following analyses, I will only be concerned with this subset of trials.

Out of the 654 priming trials, 348 (53%) priming sentences were completed as a double object and 306 (47%) as a prepositional object prime. There were 470 (72%) successful priming trials, i.e. trials where both the prime *and* the target were completed as a prepositional/double object sentence, and 184 (28%) trials where the target response did not fall into either category. An equal proportion of the target responses were completed as prepositional/double object sentences in each condition: 72% following double object primes and 72% following prepositional object primes. Hence the priming manipulation did not affect the overall proportion of prepositional/double object completions. However, as the tables below show, it did affect the *relative* proportions of prepositional and double object target responses.

In Table 6.1 below, the percentages of each type of response following each type of prime are presented.

	PObj Prime	*DObj Prime*
PObj target	158 (52%)	116 (33%)
DObj target	62 (20%)	134 (39%)
Other response	86 (28%)	98 (28%)

Table 6.1: Responses following single PObj or DObj prime

As Table 6.1 shows, the type of completion which subjects produced for a priming fragment affected the type of completion which they produced for a target fragment. Following a prepositional object prime, the target fragment was completed as a prepositional object sentence 52% of the time, compared to only 33% of the time following a double object sentence. Hence prepositional primes increased the number of prepositional object responses by 19%, relative to their frequency following double object primes. Similarly, double object targets were produced 19% more frequently following double object primes than following prepositional object primes (39% following double object primes compared to 20% following prepositional object primes). Overall, subjects completed the target sentence with the same structure as that of the priming sentence 45% of the time and with the alternative structure 27% of the time.

An analysis of variance confirmed that subjects were more likely to produce the structure used in the previous fragment than the other structure ($F_1(1,63) = 41.58$, $p = .0001$; $F_2(1,11) = 22.55$, $p = .006$). Planned means comparisons confirmed that there were priming effects for both types of construction. Prepositional objects were produced more frequently following a prepositional object prime than following a double object prime ($F_1(1,63) = 19.87$, $p = .0001$, $F_2(1,11) = 10.43$, $p = .008$) and double object sentences were produced more frequently following a double object prime than following a prepositional object prime ($F_1(1,63) = 21.73$, $p = .0001$, $F_2(1,11) = 12.15$, $p = .005$). There was also a suggestion of a main effect of target sentence type but this was only significant by subjects ($F_1(1,63) = 7.92$, $p = .007$; $F_2(1,11) = 1.19$, $p = .30$). No other effects approached significance (all Fs < 1).

Results following double primes

I will now turn to the double prime case, where *both* of the fragments in priming position were completed as double object sentences or as prepositional object sentences. In this case, both of the primes preceding the target were completed as either a prepositional or double object sentence in 546 trials (71%). Again, in the following analyses, I will only consider this subset of trials.

There were 398 successful priming trials where both of the primes and the target were completed as a prepositional/double object sentences: 225 (57%) followed a double object prime and 173 (43%) followed a prepositional object prime. Comparable proportions of target

responses were completed as double/prepositional object sentences in each condition: 72% of responses following double object primes and 75% of responses following prepositional object primes. Table 6.2 below presents the numbers of each type of response produced following each type of prime.

	PObj Prime	*DObj Prime*
PObj target	124 (54%)	103 (33%)
DObj target	49 (21%)	122 (39%)
Other response	56 (25%)	89 (28%)

Table 6.2: Responses following double PObj or DObj prime

As the tables show, prepositional object targets occurred 21% more frequently following prepositional object primes than after double object primes (54% versus 33% respectively). Double object primes increased the frequency of double object responses by 18% relative to their frequency following prepositional object primes (39% versus 21%). Overall, the structure of the target matched that of the priming sentence 45% of the time; the alternative structure to that of the priming sentence was produced only 28% of the time.

An analysis of variance confirmed that subjects were more likely to complete the target fragment using the same structure as that of the primes ($F_1(1,63) = 29.90$, $p = .0001$; $F_2(1,11) = 25.65$, $p \leq .0004$). Planned means comparisons were used to determine whether the priming effect occurred for both types of structure. More prepositional object targets were produced following two prepositional object primes ($F_1(1,63) = 17.34$, $p = .0001$; $F_2(1,11) = 14.78$, $p = .003$) and more double object targets were produced following two double object primes ($F_1(1,63) = 12.74$, p .0007; $F_2(1,11) = 11.00$, $p = .007$). There was also a suggestion of a main effect of target sentence type but this was significant by subjects only ($F_1(1,63) = 9.15$, $p = .004$; $F_2(1,11) = 1.69$, $p = .22$). No other effects approached significance (all Fs < 1).

Results following double primes (different NP structures)

In this analysis, double prime responses where the internal structure of at least one of the object NPs in the target sentence differed from the internal structure of the corresponding object NP in at least one of the primes were considered. There were 375 (49%) trials which fulfilled these criteria: 209 (56%) followed double object primes and 166 (44%) followed prepositional object primes. Table 6.3 below presents the numbers of each type of response produced following each type of prime.

	PObj Prime	*DObj Prime*
PObj target	119 (52%)	98 (31%)
DObj target	47 (20%)	111 (35%)
Other response	64 (28%)	107 (34%)

Table 6.3: Responses following double PObj or DObj prime (different object NP structure)

Prepositional object targets occurred 21% more frequently following prepositional object primes than after double object primes (52% versus 31% respectively), and double object primes increased the frequency of double object responses by 15% relative to their frequency following prepositional object primes (35% versus 20%). Overall, the structure of the target matched that of the priming sentence 42% of the time; the alternative structure to that of the priming sentence was produced only 27% of the time.

An analysis of variance confirmed that subjects were more likely to complete the target fragment using the same structure as that of the primes ($F_1(1,63) = 32.50$, $p = .0001$; $F_2(1,11) = 27.85$, $p = .0003$). Planned means comparisons were used to determine whether the priming effect occurred for both types of structure. More prepositional object targets were produced following two prepositional object primes ($F_1(1,63) = 22.52$, $p = .0001$; $F_2(1,11) = 18.41$, $p = .001$) and more double object targets were produced following two double object primes ($F_1(1,63) = 11.00$, $p = .002$; $F_2(1,11) = 10.07$, $p = .009$). There was also a suggestion of a main effect of target sentence type but this was significant by subjects only ($F_1(1,63) = 9.38$, $p = .003$; $F_2(1,11) = 1.96$, $p = .19$). No other effects approached significance (all $Fs < 1$).

6.4.4 Discussion

The results suggest strongly that syntactic priming effects are found in written language production: subjects tended to complete sentences using the same syntactic structure as a previous sentence completion. This effect manifested itself as changes in the proportions of prepositional and double object sentence completions as a function of the syntactic structure which was used to complete a previous fragment. It does not seem to be attributable to factors such as discourse coherence, semantic similarity or lexical overlap between the sentences. The evidence also suggests that the effect was not restricted to sentences with globally identical syntactic structures: a reliable priming effect was found even when the prime(s) and target differed in their fine-grained structure.

Excluding other influences

Discourse factors can of course be dismissed immediately: the experimental task required subjects to complete a series of unconnected randomised sentence fragments and there was no evidence in the completions which subjects produced that they were forming any connections between consecutive sentences. Hence there was no sense in which they formed a discourse and so no way in which discourse relations could affect the completions which the subjects produced. In any case, it is not clear that prepositional object sentences and double object sentences encode different discourse relations. Nor is there is any evidence that the priming manipulation affected the conceptual content of the target responses in any way: approximately the same proportion of target responses (72–75%) were prepositional/double object sentences in both priming conditions. Hence the priming manipulation did not seem to affect the content which was expressed, only the way in which that content was expressed, i.e. the relative proportions of each structure within those responses. Furthermore, the prepositional and double object structures examined in this experiment have equivalent semantic content. Hence even if there were any conceptual relationship between prime and target, it could not explain the systematic differences in the syntactic structure of the target sentence.

Lexical influences can also be excluded. The only way in which lexical factors could directly affect which structure was produced in target position would be if the effect centred upon repetition of the preposition *to*. If we followed Levelt & Kelter (1982) in attributing the effect to repetition of the preposition, we would expect to find priming effects only following a prepositional object prime, and no effects following a double object prime, since the preposition only occurs in the former case. However, this is not what we find. As the results show, there is a reliable priming effect for double object sentences.

Finally, given the nature of the task, it is unlikely that the effects were caused by subjects maintaining the form of a previous sentence (or episodic trace) in their memory: as far as subjects were aware, they were merely completing unconnected sentence fragments as quickly as possible and there was no reason to believe that they should try to remember what they had previously written. In any case, if the effects resulted from a memory trace for the priming sentence, we would presumably only expect to find priming effects between sentences which had globally identical structures.

It seems safe to conclude that the syntactic repetition effect was caused by similarities between the sentences which occurred at a more abstract level, namely at the level of syntactic structure. The results are consistent with those found by Bock (1986b) and we can draw some of the same conclusions from them as those which were drawn by Bock.

At which level of processing is priming occurring?

The results suggest that in written language production there is a stage of processing which is concerned with essentially syntactic information and at which lexical/semantic information is unspecified or invisible. As in Bock's experiments, I suggest that this level corresponds to the constituent structure level, since the two alternatives appear to involve the same functional assignments and differ only in their constituent structures. This experiment therefore adds weight to the existing evidence that syntactic structure is processed autonomously in language production.

What is being primed?

The results are consistent with an explanation based upon activation levels, where residual activation from the priming stimulus affects realisation of the subsequent target completion. However, this raises the question of exactly what it is that is being activated in production. Clearly, it must be something which is syntactic in nature.

Bock (1986b) suggested that the appropriate entities are the *procedures* which are responsible for creating the constituent structure. She noted, 'Because they appear to involve abstract procedures or operations over representations rather than connections between them, the interpretation of the priming patterns observed in [the syntactic priming] experiments is somewhat different from that of other effects commonly found in the cognitive literature' (Bock 1986b, p.379).[6] On this account, priming effects for double object sentences would arise from the

[6] Bock assumed here that lexical priming effects arise from alterations in the activation of *connections* between lexical representations; however, some accounts of lexical priming assume that priming affects the activation levels of the *representations* themselves – see for example Morton (1969).

raised activation of the procedures which map from functional structures to double object constituent structures.

An alternative possibility which is equally consistent with the data, however, is that the syntactic priming patterns are actually qualitatively comparable with lexical priming patterns and reflect the activation of *representations*, not procedures. The obvious candidates for these representations are the statements of the competence grammar, in other words the knowledge of language which underlies both production and comprehension. On this account, priming for double object structures would arise because the knowledge statement which licenses double object structures (and which is implicated in both the comprehension and production of double object structures) would have higher activation.

There is no way of distinguishing between the two alternatives at present, since the current data is compatible with both approaches. For the present, then, I will leave the question open, but I will return to it in Chapter 8.

How can syntactic structure be characterised?

Assuming, then, that the priming effects reflect the activation of some aspect of the language processor (whether dynamic processes or knowledge statements) which relates directly to syntactic structure, there remains the issue of how to characterise it. There are two separate strands to this question. The first concerns its vocabulary, in other words the nature of the elements which are specified there. The second issue concerns its content, or the way in which those elements are specified. I will treat each issue in turn.

The vocabulary of syntactic structure

Clearly, whatever it is that is being primed must be something which is abstracted away from specific lexical items, since the effects occurred between sentences which involved different verbs. For example, production of a double object sentence involving *post* primed production of a double object sentence involving *show*. The obvious explanation is that priming affects the activation of something which is specified over classes of words, not individual words, i.e. something akin to grammatical rules. (Note that in keeping with the discussion above, I leave it as an open question whether 'rule' should be taken to refer to a procedure whereby constituents are created, or to knowledge that specifies possible relationships between constituents. In the following discussion and in the following chapters, my use of 'rule' should be taken to include *both* possibilities, unless otherwise stated). The results therefore suggest that however syntactic structure is mentally represented, it must contain abstract specifications which are distinguishable from the properties of individual lexical items. That is, the grammar is more than a repository of words and their associated properties; it must contain information which is specified over abstract classes.

This is an important finding, because it constrains the class of psychologically plausible models of syntactic structure. For example, it would exclude any theory in which every lexical item was individually specified for its syntactic privileges and there were no statements of generalisations holding over classes of items. I will exemplify this by looking at one existing linguistic theory. HPSG (Pollard and Sag 1987, 1994) is a lexicalist theory, in that rules are pared down to a minimum; instead, information about the relevant combinatorial possibilities

(among other things) for a word is encoded into its lexical entry, or 'sign'. The grammar itself contains only a few generalised schemata which capture possible immediate dominance relations between signs. Each schema covers an entire class of possible relations, for example all head–complement structures. Thus *all* heads, of whatever category, are subject to this schema. If this were all that was specified in the grammar, then the theory would not be able to account for the priming effects found in this experiment. More specifically, there would be no way in which *The butler handed the countess the note* could prime *The teacher showed the children the storybook* because there would be nowhere in the grammar where a connection would be drawn between the fact that both *hand* and *show* may appear with two NP complements.[7]

By the same token these results exclude any processing theory which encodes syntactic structure in terms of distinct lexical entries. To take an example, MacDonald, Pearlmutter & Seidenberg (1994) proposed a model of language processing in which each lexical entry is linked to its possible argument frames, e.g. *eat* is linked to an intransitive argument frame and a transitive argument frame. If these argument frames are shared between multiple entries, such that *give* and *show* have connections to the same argument frames, then the model is compatible with the priming effects found here, since previous accessing of the double object argument frame to complete a sentence containing 'give' will raise its activation and make it easier to access to complete a sentence with *show*. If however each argument frame is specified separately for each verb, then there is again no way in which priming effects can transfer from one verb to another.

Hence the priming data shows that syntactic information must be specified in a form which applies not just to a single item, but to categories of items with related syntactic properties. In other words, these results suggest that syntactic information is mentally represented in terms of abstract schemata. Any linguistic theory which claims psychological plausibility must capture such relationships in some way. In many linguistic theories this is achieved through phrase structure rules, but the same information can be captured through other means. For example, in the version of HPSG presented in Pollard & Sag (1987) there is a system of lexical types which subsumes individual lexical items with common properties under a single abstract sign (in this case, 'ditransitive verb'). Each verb which is thus subsumed inherits its syntactic privileges from this sign. The sign thus specifies combinatorial possiblities for a whole class of verbs in the same way that a phrase structure rule does.[8] The priming results reported here are compatible with both approaches, but in what follows I will discuss the issues in terms of rules rather than signs.

To summarise, priming seems to arise from the activation of something akin to syntactic rules, whether the representations themselves or procedures directly associated with them, which are specified in terms of abstract categories. When one of these rules is applied during the production of a sentence, its activation may be raised such that it is more accessible for application during the production of a subsequent sentence.

[7] I will show below that HPSG is in fact compatible with priming effects.

[8] More recent versions of HPSG have explored the concept of multiple inheritance, by which a lexical item inherits properties from a range of sources rather than from a single abstract sign. This is still compatible with the findings reported here, since lexical items with common properties (such as ditransitive verbs) inherit the same properties from the same sources.

The content of syntactic rules
The evidence from priming suggests that the vocabulary of syntactic representation is abstract categories and that relationships between these categories are captured in terms of something akin to rules. As yet, however, I have not considered the content of these rules, or how they associate categories.

One way to answer this question is by considering the extent to which prime and target must be related for priming to occur. That is, does priming only occur between sentences which have identical syntactic structures or can it occur between sentences which share only some elements of structure, and if the latter, which elements? This question has a direct bearing on the inferences which we can draw about the content of syntactic rules. I have argued that priming effects arise from the activation of a syntactic rule above its usual resting level and that they occur between two sentences which both employ this rule during production. If two sentences only have one particular part of syntactic structure in common (for example, the structure of the subject NP), then there is only one rule which is common to the production of both sentences. Hence if priming occurs between two sentences which share only one particular part of syntactic structure, that substructure must be represented in a rule, since that is the only rule which both sentences have in common.

If priming only occurred between sentences which had identical syntactic structures, the conclusions which we could draw would be limited. It could mean that syntactic rules specify small pieces of structure but that priming requires the repetition of many such rules, to form the same global structure. Under this approach, priming would arise from the repeated use of a number of rules which together form a sentence. However, the evidence would be equally compatible with the hypothesis that a syntactic rule specifies an entire sentence and that priming reflects the activation of this single overarching rule. For example, it could be that there is a rule corresponding to the entire structure of a double object sentence such as *John gave the tall girl the book*, including specifications that the subject is a proper noun and that the indirect object NP includes an adjective. Such a notion is highly implausible, to say the least, but it would be a possible interpretation of the data.

If on the other hand priming occurs when only some of the structure of prime and target is shared, then it suggests that rules specify smaller spans of structure, at most those elements of structure which are common to prime and target. The experiment presented here provides evidence that priming effects are not restricted to sentences with identical syntactic structures. The prepositional/double object alternation was reliable as a function of the type of prime but crucially was not dependent upon the prime(s) and target having identical structures: a significant priming effect was found even when we only considered responses where the internal structure of the object NPs differed between primes and target. Hence we can conclude that syntactic rules specify smaller parts of structure than an entire sentence and that syntactic priming in production does not require all of the same rules to be employed in prime and target.

Furthermore, there is a convergence between the rules for which we find evidence in priming and those which are typically proposed in linguistic theories. In most linguistic theories, rules specify local relations between a mother node and its daughter nodes; they do not make any reference to the internal structure of the daughters or the larger context in which the mother node appears. In this experiment, assuming a simple phrase structure grammar, the relevant local tree consists of the VP node, its daughter V node and the complements of the V, either two NPs or an NP and a PP, corresponding to the phrase structure rules VP $\rightarrow$ V NP NP and VP $\rightarrow$ V NP PP.[9] Since rules are blind to the internal structure of constituents, the structure of the rest of the sentence could vary greatly between prime and target. These theories would therefore predict that only a local tree in the prime and the target need match, assuming that priming only requires repetition of a single rule. The data from this experiment is compatible with this: priming occurred at the level of the local tree expanding the VP, but differences below this substructure, in the internal structure of the object NPs, seemed unimportant. Bock and Loebell's (1990) comments that their primes and targets often differed with respect to the addition or omission of auxiliary verbs suggests that the same might be true with respect to the structure of the $\bar{\mathrm{I}}$ containing the VP, though we cannot draw any strong conclusions about this. Thus there seems to be a convergence between the theoretical assumption that rules are defined in terms of local trees and the actual behaviour of the language processor.

The priming data therefore suggests not only that language production involves rules which are specified in terms of syntactic categories, but that these rules, like context-free phrase structure rules, specify strictly local relationships. Hence there is a convergence between the constructs of linguistic theories and the structures for which we find evidence in syntactic priming experiments.

6.4.5 Summary to Experiment 1

This experiment demonstrates that syntactic priming effects can be found in written language and are not restricted to spoken language production. It suggests that language production involves a level of processing which is concerned with syntactic information but not semantic or lexical information. This information seems to be represented in terms of abstract schemata or rules. I argue that these rules specify local substructures and that they encode the same type of information, such as major category information, as the phrase structure rules of linguistic theory. Priming arises from the activation of one or more of these rules. Although it is possible that priming effects are stronger the more structure the prime and target have in common, the results of this experiment suggest that priming can occur through the repeated use of a single rule.

6.5 Priming in written production: Experiment 2

We have seen that priming effects are found in language production between sentences which involve the same overall VP structure. It was hypothesised that language production involves the application of syntactic rules which specify relationships between categories in terms of local relations between a mother node and its daughters, irrespective of the internal structure of those daughters or the syntactic context in which the substructure occurs. Priming occurs through the repeated application of one of these rules. The approach taken here predicts that priming effects will be found even when prime and target differ substantially in their overall

[9] I am assuming a ternary-branching structure for the VP here, as discussed in Pollard & Sag (1987).

syntactic structures, as long as they both involve a particular local substructure. The application of a rule at any point in the overall structure should make its subsequent reapplication easier, leading to priming effects. (One implication of this is that priming should not only be possible at the level of VP structure, as here, but also at the NP level, PP level etc, as Bock & Loebell (1990) conjectured, though I will not pursue the topic further here).

Although there is support for this hypothesis from the previous experiment and the experiments reported by Bock and her colleagues, there has as yet been no systematic test of it. The experiment reported here was designed to do this, by examining whether priming occurs when prime and target share a local substructure but otherwise differ greatly in their syntactic structures. The experiment used the same sentence completion method as the previous experiment and examined the same structures, prepositional and double object structures, since they had been shown to be amenable to priming. As before, the aim of the experiment was to see whether the proportion of prepositional and double object completions for a sentence fragment like *The boy gave ...* varied according to the structure of a previous completion. This time, however, the priming structure did not appear in the same syntactic context in the prime as in the target.

In half of the primes, the priming structure formed the matrix VP, but the internal structure of the NP following the verb was manipulated, as in (6.23a). In the other half, the priming structure appeared embedded within an NP in a simple transitive sentence, as in (6.23b).

(6.23) a. The teacher gave the book that frightened the child ...
b. The teacher frightened the child that gave the book ...

Following both types of prime, the target fragment consisted of a subject NP and a ditransitive verb, as in the first experiment.

According to the theory of priming which was outlined above, both types of prime should be effective in eliciting priming effects, since both involve application of the rule VP $\rightarrow$ V NP NP. If, on the other hand, the internal structure of the prime is important, then we would expect to find priming effects only with the second type of prime.[10] However, if the context in which the priming structure appears is important, then only the first type of prime will be effective, since in the second case the prime appears embedded in an NP rather than as the matrix VP.

6.5.1 Method

Subjects

The subjects were 48 unpaid undergraduate students from the University of York.

[10] This prediction only holds under the assumption that subjects will not produce target responses which involve complex NP direct objects, in other words produce target responses which have the same global structure as the prime sentence. Previous experience had shown that subjects rarely produce complex NPs in their target responses; in fact, there were no cases in this experiment where subjects produced target responses where the first NP following the verb was a complex NP as in the prime sentence.

Materials

The materials for the experiment consisted of 24 sets of priming materials, each comprising two fragments. The first fragment in each set was a prime; the second fragment was the target. There were four conditions: matrix prepositional object prime; matrix double object prime; embedded prepositional object prime; and embedded double object prime.

Four alternative versions of each set of materials were constructed, one for each condition; examples are given below. In two of the versions, the prime consisted of a subject NP followed by a ditransitive verb and an object NP which contained a simple transitive relative clause. The NP was chosen to be either a good patient/theme (6.24a), favouring a prepositional object completion, or a good beneficiary (6.25a), favouring a double object completion. In the other two versions, the prime consisted of a subject NP followed by a simple transitive verb and an object NP which contained a ditransitive verb and object NP. The object NP in the relative clause was again either a good patient/theme (6.26a) or a good beneficiary (6.27a). The subject NP, the simple transitive verb and the ditransitive verb were the same in each condition.

The target was identical in all four versions. It consisted of a subject NP followed by a ditransitive verb (the (b) fragment in the examples below).

(6.24) a. The teacher gave the book that frightened the child ...
b. The barrister showed ...

(6.25) a. The teacher gave the youth that frightened the child ...
b. The barrister showed ...

(6.26) a. The teacher frightened the child that gave the book ...
b. The barrister showed ...

(6.27) a. The teacher frightened the child that gave the youth ...
b. The barrister showed ...

The verbs which were used in the materials were those which had elicited the most prepositional/double object completions in the previous experiment.

It was anticipated that the completions which subject produced would be matrix clause prepositional or double object completions for versions (6.24) and (6.25) and embedded clause prepositional or double object completions for versions (6.26) and (6.27). A complete list of materials is provided in Appendix B.

In addition, 48 filler fragments were constructed. The fillers were designed to resemble the experimental materials but did not contain any ditransitive verbs. They were of varying types; all involved a subject NP and a verb; some also involved an object NP. Some of the fillers included NPs which contained relative clauses.

Four presentation lists were constructed from these materials. Each list contained six materials (= 12 fragments) in each condition, i.e. six materials of the type shown in (6.24), six of the type shown in (6.25), six of the type shown in (6.26) and six of the type shown in (6.27). This gave a total of 24 priming trials (= 48 fragments) interspersed with 48 fillers. The order of presentation was randomised for each subject, with the constraint that each priming trial had to be separated from each other trial by at least one filler sentence. The fragments were then printed out as six page booklets.

The instructions told subjects that we were interested in the types of sentences which people produce and asked them to complete the sentences as quickly as they could, with the first completion that they thought of. They were told to complete the sentences in order and not to leave any out.

Procedure

The experiment took place in an undergraduate class. Subjects were given a booklet and told to hand it back to the experimenter when they had finished. The experimenter answered any questions which they had. The booklet took about 15 minutes to complete.

Scoring

The criteria were the same as those used in the previous experiment. Application of these criteria yielded 917 responses (87%) where the priming sentence was completed with a prepositional object or double object structure; of these, 21% occurred in the High-prepositional object condition; 27% in the High-double object condition; 24% in the Low-prepositional object condition; and 28% in the Low-double object condition.

Design and data analyses

The two independent variables in this experiment were prime sentence type (prepositional object versus double object) and prime site (matrix clause versus embedded clause). Crossing these two factors yielded four conditions. Each subject completed 24 experimental materials, 6 in each condition. Each material was presented to 48 subjects, 12 in each condition. The dependent variables were the proportions of prepositional and double object completions produced by each subject in each cell of the design. Separate analyses were carried out treating subjects and items as random variables.

6.5.2 Results

Here, I am only concerned with the 917 trials where the prime was successfully completed as either a prepositional object or a double object sentence. Of these, there were 553 (60%) successful priming trials, where both the prime and the target were completed as prepositional or double object structures, and 364 trials (40%) where the target was completed with an alternative structure.

Table 6.4 presents the overall totals and percentages of target responses in each condition.

The results suggest that prepositional object sentences were produced more often than double object sentences in all four conditions. The syntactic structure of the previous sentence had no discernible impact upon the proportions of each construction which were produced for the target sentence. The analyses of variance confirm this picture. There was a main effect of target construction type ($F_1(1,47) = 7.23$, $p = .01$, $F_2(1,23) = 5.68$, $p = .03$). There was also

	Matrix PObj Prime	*Matrix DObj Prime*	*Embed PObj Prime*	*Embed DObj Prime*
PObj target	70 (37%)	95 (38%)	87 (39%)	86 (34%)
DObj target	41 (22%)	61 (24%)	57 (26%)	56 (21%)
Other response	78 (41%)	95 (38%)	77 (35%)	114 (45%)

Table 6.4: Responses following Matrix/Embedded PObj/DObj primes

a suggestion of an interaction between prime sentence type and prime site, but this was only significant by subjects ($F_1(1,47) = 5.49$, $p = .02$, $F_2(1,23) = 2.01$, $p = .17$). No other effects reached significance (all $Fs < 1$). In particular, the interaction between prime sentence type and target sentence type was not significant.

6.5.3 Discussion

The results show no evidence of priming: subjects were no more likely to produce a prepositional object sentence following production of a previous sentence which contained a prepositional object structure, or a double object sentence following production of a sentence containing a double object structure. Hence we cannot conclude on the basis of these results that rules specify local trees and that priming occurs whenever a single rule is repeatedly applied. Given the robustness of the priming effects in the previous experiment, the complete absence of any such effects here is somewhat surprising. I will consider two possible explanations.

Prime and target were not related in the necessary manner

One possibility is that the experimental hypothesis was, quite simply, wrong: priming only occurs between structures which are related on a more global level of structure. In both of the cases here, the prime contained a complex NP immediately following the verb whereas the target did not (subjects did not produce complex NPs in this position in their responses). An explanation of this type would have to be based on the assumption that priming did not take place in these cases because the prime and target were not sufficiently related structurally and so the same representations were not activated in each case.

If that is correct, then it suggests that syntactic representations are defined over much larger structures than I originally suggested; they cannot simply be defined over local trees. But that then raises the question of exactly which domains syntactic representations are specified over: how precisely must prime and target be related in order for the same representations to be activated? The problem with this account is that any attempt to resolve the issue only explains a subset of the results, unless additional assumptions are made. The relevant domain cannot be the global structure of prime and target, i.e. it cannot be the case that they have identical structures at all levels, because as already noted, priming occurred in Experiment 1 above even when the prime and the target differed in their fine-grained structures. Hence the domain must be smaller than the entire sentence.

One could perhaps explain the absence of any effects in the conditions where the critical VP was embedded within an NP (e.g. *The teacher frightened the child that gave the book* ... by hypothesising that priming can only take place from main clauses to main clauses (or perhaps more generally, between clauses in a similar syntactic context – which takes us back to the problem of defining a syntactic context). But this does not explain the absence of effects where the critical VP occurred in the main clause. Nor can the absence of effects in those cases be explained by postulating that the fine-grained structure of just the critical VP must be identical: priming occurred in Experiment 1 above when the internal structure of exactly the same constituent as that at issue here (the NP following the verb) varied. Any such explanation would therefore have to state that *some* internal differences were permitted (e.g. the presence/absence of an adjectival phrase) but not others (e.g. the presence/absence of a relative clause). This seems an unattractive route to follow.

Insufficient activation of the relevant rule

However, there is a simpler explanation. This explanation assumes that the prime and the target were related to each other in the relevant way and did activate the same representations, but that this activation was not sufficient to cause priming effects. It therefore attributes the absence of priming effects to processing factors and not to representational differences. There are several reasons why activation might have been insufficient to cause priming.

Interference from competing rules

The crucial observation here is that the cases where priming was found in Experiment 1 above despite differences in fine-grained structure and the current experiment involve distinct types of structural variation. In Experiment 1, the variation generally involved the addition or omission of adjectives and adverbs. In this case, however, the variation always involved relative clauses. Hence in the current experiment, the priming sentence involved expansions of *two* VPs, the matrix VP and the embedded VP, whereas in the previous experiments, the prime involved the expansion of only *one* VP, namely the matrix VP.

In my discussion of priming so far, I have suggested that priming raises the activation of one rule. However, I have not addressed the question of whether priming is simply a repetition effect, such that repeated use of a rule makes it easier to apply subsequently, or whether it is a competitive effect, where priming would raise the *relative* activation of a rule with respect to a competitor. The existing evidence is compatible with either possibility, since priming has been measured in terms of the probability of producing one structure rather than another. However, if priming is a competitive effect, as Bock (1986b) suggested, it seems plausible that the expansion of one rule will not only raise its activation but also suppress the activation of other, related rules. Hence the activation of one VP rule might suppress that of another VP rule. In this way, the presence of another VP in the priming sentence might interfere with any priming effects by inhibiting to some extent the activation of the appropriate rule (VP $\rightarrow$ V NP NP or VP $\rightarrow$ V NP PP) which we are trying to prime.[11]

There is some evidence that this may be the correct explanation. Compared to the previous experiment, the materials in this experiment were better designed to elicit more completions involving prepositional and double object structures, and fewer completions involving other structures; in particular, the target fragments contained verbs which Experiment 1 had shown to be particularly frequently completed as prepositional/double object structures. In prime

[11] I will return to the question of competition in some detail in the next chapter.

position, approximately the same proportion of prime fragments were completed as either prepositional or double object sentences in this experiment as in the previous experiment (87% here compared with 85% in the previous experiment). However, in target position, substantially *fewer* fragments were completed as double or prepositional object constructions in target sentence position, with a corresponding rise in the number of alternative completions (40% alternative completions following successful prime completions, compared to 28% in the previous experiment). This is consistent with the suggestion that the appropriate rules were less highly activated in target position in this experiment compared with the previous experiment.

If this explanation is correct, then the absence of priming effects here derives from the experimental method which was used and is not a reflection of any underlying representational factors. In other words, it may well be the case that – as hypothesised – syntactic structure is defined over local trees, but that priming effects do not occur when the immediate syntactic context involves the activation of competing rules. Certainly, this approach would explain why priming effects are found with regard to other variations in structure.

Weak activation following a single prime

In addition, priming may have been weaker in this experiment because subjects only filled in a single prime fragment before completing the target. In the previous experiment, statistical analysis showed that priming occurred when the immediately previous fragment was completed as a prepositional or double object, but this analysis included the cases where *both* of the preceding primes were completed in this way. In fact, in most cases (83%) where the immediately preceding prime was completed as a prepositional/double object, the first prime was also completed in the same way.[12] Hence we cannot be sure that the priming effect in written language is robust enough to appear after a single prime, as in this experiment. The combination of weak activation following a single prime and inhibition from a competing rule could substantially reduce any priming effect.

Inter-trial interference

There is also the possibility of inhibitory activation because of interference between trials. In the previous experiment, there were at least three filler sentences between each priming trial; in this experiment, for reasons having to do with the situation in which the experiment was conducted, there was only one. It is therefore possible that residual activation from the previous trial could affect a subsequent trial (see Bock (1989) for evidence of this in a spoken production priming experiment). It is not clear how much stress should be laid on this as a source of explanation: one would expect it to result in more 'noise' in the results, not the absence of priming effects altogether. Nevertheless, it could be a contributory factor.

The duration of priming effects

The approach explored here raises further issues for future investigation, such as the duration of priming effects. The results reported by Weiner & Labov (1983) and Bock (1989) suggest that

[12] The fact that both primes tended to be completed in the same way is compatible with a priming effect from the first prime to the second prime.

the priming effect may be of a fairly substantial duration in some cases. However, Levelt and Kelter (1982) found evidence that the immediate syntactic context can suppress the priming effect. Levelt and Kelter found that when the priming structure was followed by a causal clause (for example, the priming structure *At what time do you close ...* was followed by the causal *... because I'll have to come in specially*), there was no priming effect. The findings of the present experiment are in keeping with this. It is possible that the activation of a structure does not have a simple linear decay function, such that the longer the time since its initial activation, the weaker its residual activation. Instead, the *context* in which it is activated may affect its decay in some way, with competing structures in the same utterance having a greater effect than those in other utterances (perhaps because they are in direct competition). This could explain why different experiments have provided different evidence in this respect. In both Levelt and Kelter's experiment and the present experiment, the priming structure was presented as part of the same sentence as the (putative) competing structure, whereas in Bock's experiment the priming structure and potentially competing structures were presented separately. (There is insufficient detail to draw any conclusions from Weiner and Labov's results). In the absence of any further evidence, we cannot draw any conclusions about this.

6.5.4 Summary to Experiment 2

This experiment failed to find any evidence of priming effects between sentences where the prime involved a relative clause and the target did not. I suggest that this could be attributed to the fact that the priming sentence involved the activation of two VP rules, one associated with a prepositional or double object structure and one associated with a different structure (e.g. a simple transitive structure), and that the two rules were in competition. This affected the activation of the rule being primed and hence suppressed any priming effect. Such an explanation is compatible with the finding that priming effects occur between sentences which differ in their fine-grained structure in other ways, although it may well be the case that the priming effect is stronger the more aspects of structure (both at the syntactic level and at other levels, such as prosodic or metrical structure) the prime and target have in common.

6.6 Summary

In this chapter I have examined how syntactic priming can be used as a tool to investigate syntactic representation, allowing syntactic factors to be manipulated independently of semantic factors. If priming effects are found between sentences which have only one dimension of structure in common, it suggests that the processor is sensitive to that dimension and that it treats the sentences as being related along it. Syntactic priming effects provide evidence that language production involves a stage of processing which is concerned with syntactic structure and can give insights into how that structure is represented. After discussing previous work on syntactic priming effects in spoken language production, I presented the results of two experiments which examine such effects in written language production.

I showed that in written language, production of a sentence with a particular structure can increase the likelihood of producing a subsequent sentence with the same structure, even

when the two sentences have no common lexical or semantic content. I suggested that this occurs because repeated application of a rule associated with syntactic structure raises its activation and makes it easier to reapply subsequently. The results suggest that these rules are characterised in terms of abstract categories which subsume individual lexical items. The fact that priming effects occur even when the prime and target sentences differ with respect to their fine-grained structure suggests not only that priming may arise from the repeated application of a single rule, but also that these rules specify local relationships. However, priming effects may not occur if the prime and target differ greatly in their overall structure, perhaps because of inhibition from other rules.

Chapter 7

Syntactic priming in language comprehension

7.1 Introduction

In the previous chapter, I showed that there is considerable evidence for the existence of syntactic priming effects in both spoken and written language production. This chapter examines whether similar effects can be found in language comprehension. That is, can the syntactic structure of a previous sentence affect the way in which a subsequent sentence is comprehended? Evidence of syntactic priming in comprehension would be strong evidence that comprehension involves the computation of syntactic structure. It could also provide evidence about the specific characteristics of this syntactic structure. I will begin by presenting the existing evidence for syntactic priming in comprehension and discussing the possible implications of any such effects, in particular how they might cast light upon some of the questions raised in the previous chapter. The main part of this chapter presents the results of a series of studies which explore syntactic priming in comprehension. I will argue that syntactic priming effects are found in comprehension and that they are compatible with those which are found in production.

7.2 Evidence for syntactic priming in comprehension

Intuitively, the way in which we comprehend sentences can be affected by previous sentences which we have encountered. This feeling is familiar to anyone who has read a theoretical linguistics paper or a psycholinguistic report: overexposure to 'marginal' sentences or garden path sentences rapidly leads to a loss of one's normal intuitions, so that by the fifth complex NP constraint violation or reduced relative clause, one has difficulty in making judgements about relative grammaticality/processing difficulty any more. Matthews (1979) claimed that judgements of the grammaticality of a sentence like (7.1) varied according to the structure of preceding sentences. If (7.1) was judged after previously judging a sentence like (7.2), it was more likely to be judged grammatical than if it preceded (7.2).

(7.1) The canoe floated down the river sank.

(7.2) The man that was thrown down the stairs died.

If a grammaticality judgement for a sentence can in part reflect the difficulty of parsing it, these results could be interpreted as evidence of a syntactic priming effect: comprehending a previous sentence with a related structure apparently facilitated the subsequent processing of a sentence with a structure which is usually difficult to process.[1]

Thus, it seems to be the case that, as in language production, the syntactic structure of previous sentences can affect the processing of subsequent sentences during comprehension. So far, however, there has been little experimental research relating to this question.

Mehler and Carey (1967)

Mehler & Carey (1967) presented subjects with eleven sentences masked by white noise and asked them to write down that they thought they had heard. They investigated two types of structure, copular object sentences (7.3a) and progressive transitive sentences (7.3b). Although the two sentence types are superficially similar, they have different syntactic structures under standard linguistic analyses. Mehler and Carey gave subjects ten sentences of one type followed by a sentence of the other type. Thus subjects would hear ten sentences like (7.3a) followed by (7.3b), or ten sentences like (7.3b) followed by (7.3a).

(7.3) a. They are conflicting desires.
b. They are forecasting cyclones.

They found that subjects were worse at comprehending the target sentence in each case when it was preceded by sentences of the other type than when it was preceded by sentences of the same type. From this, they concluded that comprehension of a sentence could be disrupted by the prior presentation of several sentences which were superficially similar but actually had different syntactic structures.

They also compared 'control' (7.4a) and 'raising' (7.4b) sentences using the same method.

(7.4) a. They are reluctant to consent.
b. They are troublesome to employ.

In these cases, there was no evidence of any effect of the preceding sentences on comprehension of the eleventh sentence. Overall their results suggest that the structure of previously encountered sentences can affect comprehension of a subsequent stimulus, but that the conditions under which it ocurs may be limited to certain types of sentence. In other words, there may be a syntactic priming effect in comprehension, but one which is restricted to certain sentence types only. Note however that in both of their studies they only employed one target sentence of each type. Hence there is no way of knowing whether their effects are limited to

[1] Matthews' example is particularly interesting because the prime and target sentence involve related but not apparently identical structures. This could mean either that the two sentences do share a common structure, as some linguistic theories suggest, or alternatively that priming can take place between syntactically related structures (where what is denoted by 'syntactically related' remains to be defined) as well as between identical structures. I will not pursue the point here, but it is an issue which deserves further research.

those particular sentences or whether they are representative of a more general priming effect. The same criticism holds of Mehler and Carey (1968) and Carey, Mehler and Bever (1970), reported below.

Mehler and Carey (1968)

Mehler & Carey (1968) presented subjects with a series of pictures and asked them to judge whether a sentence correctly described a picture. The sentences had the copular object and progressive transitive structures exemplified in (7.3) above. Subjects were presented with five sentences of one type followed by a sixth sentence which was either of the same type or of the other type. Mehler and Carey found that when the sentence correctly described the picture, subjects responded faster to the sixth sentence if it had the same structure as the preceding five sentences. However, no effect was found when the sentence did not correctly describe the picture. Mehler and Carey concluded that there was a facilitation effect, but that making judgements of falsity is sufficiently difficult that it obscures any priming effects.

Carey, Mehler and Bever (1970)

Carey, Mehler & Bever (1970) used the same task as Mehler and Carey (1968). The five priming sentences were again either copular object sentences or progressive transitive sentences. However, the sixth sentence in each case was globally ambiguous and could be analysed as either structure, as in *They are lecturing doctors*, where *lecturing doctors* could be an NP (the copular object reading) or a VP (the progressive transitive reading). The picture which was presented to subjects with the target sentence appeared in one of four conditions: compatible with one reading; compatible with the other reading; compatible with both readings; compatible with neither reading. In addition to deciding whether or not the target sentence was compatible with the picture, subjects were also asked to provide a paraphrase of the sentence. This allowed Carey *et al* to determine which reading of the target sentence subjects had obtained (although note that it is an off-line task which only gives information about the ultimate reading which subjects obtained).

Carey *et al* found that there was no difference between response latencies for pictures which were compatible with the primed reading and pictures which were compatible with *both* readings. If however the picture was compatible with the unprimed reading, subjects' responses were significantly slowed. In addition, significantly more subjects reported obtaining the primed reading than the unprimed reading in the paraphrase task. Carey *et al* concluded that 'Syntactic expectation can influence the processing of ambiguous sentences such that the ambiguity is not perceived and that reaction time is no different from an equivalent unambiguous sentence,' (Carey, Mehler & Bever 1970, p.254).

Dooling (1974)

Dooling (1974) argued that Mehler and Carey's (1967) results might have resulted from prosodic similarity rather than a syntactic relationship between sentences. Using the same technique as Mehler and Carey, he examined the effect of varying the prosodic structure of the

target sentence in addition to varying the syntactic structure. There were four conditions, such that the target sentence had either the same syntactic and prosodic structure as the priming set, or the same syntactic structure but a different prosodic structure, or a different syntactic structure and a different prosodic structure (this comprised two conditions, because Dooling examined two different types of sentence). For example, following a priming set composed of sentences such as *they are handsome lions*, subjects would hear either *They are combat soldiers* (same syntactic and prosodic structures), or *They are big elephants* (same syntactic structure but different prosodic structure), or *They are tricky to measure* (different syntactic and prosodic structures), or finally *They are terrible to hear* (different syntactic and prosodic structures).

Dooling found a significant effect of prosodic structure: subjects were better at understanding the target when it had the same prosodic structure as the priming set, but he did not find a significant effect of syntactic structure. Dooling argued that the particular effects found by Mehler and Carey (1967) could be explained in terms of prosodic similarity. However, he did not rule out the possibility of syntactic priming. It should be noted that Dooling's experiment did not include a condition where the target sentence had the same prosodic structure as the priming set but a different syntactic structure (such as *They are making pancakes*), which would show whether prosodic structure alone could have a facilitatory effect. Hence Dooling's results suggests that a prosodic priming effect may occur under some circumstances, but do not disprove the existence of a syntactic priming effect.

Frazier, Taft, Clifton, Roeper and Ehrlich (1984)

Frazier, Taft, Clifton, Roeper & Ehrlich (1984) reported a self-paced reading experiment in which subjects read sentences consisting of two clausal conjuncts which were coordinated with *and*. In half of the trials, the conjuncts were similar at a syntactic or semantic level of analysis; in the other half, they differed. Frazier *et al* studied five pairs of constructions in a single study: active/passive sentences (7.5); minimally-/non-minimally attached sentences (7.6); non-shifted/shifted heavy NP sentences (7.7); agentive subject/theme subject sentences (7.8); and animate/inanimate object/theme sentences (7.9). The difference between the (a) sentence and the (b) sentence in (7.5)–(7.7) was designed to lie at the level of syntactic structure; in (7.8), it was designed to lie at the level of thematic structure. The sentences in (7.9) were included to act as controls for the thematic role manipulation in (7.8), to ensure that any difference in the comprehension of the (a) and (b) versions was really at the level of thematic structure and not confounded with animacy.

(7.5) a. The tall gangster hit John.
b. John was hit by the tall gangster.

(7.6) a. Jim believed all Tom's stories.
b. Jim believed all Tom's stories were literally true.

(7.7) a. Mary wrote a long note about her predicament to her mother.
b. Mary wrote to her mother a long note about her predicament.

(7.8) a. Jack rolled down the hill.

b. The rock rolled down the hill.

(7.9) a. John telephoned the library.

b. John telephoned the doctor.

For each pair of constructions (a) and (b), there were four conditions in a crossed design: (a) followed by (a); (a) followed by (b); (b) followed by (a); and (b) followed by (b). For example, subjects might see an active sentence in the first presentation, followed by *and* and a passive sentence in the second presentation:

(7.10) The tall gangster hit John / and Sam was hit by the short thug.

Frazier *et al* predicted that, for the structures in (7.5)–(7.7), reading times would be faster for the second conjunct when its syntactic structure mirrored that of the first conjunct. Their results seem to support this: overall, reading times were significantly faster following a conjunct with a parallel structure. When individual contrasts were carried out, Frazier *et al* found significant priming effects for agentive/theme subject sentences, animate/inanimate subject/theme sentences, active sentences, non-minimally attached sentences and shifted Heavy NP sentences. Hence their results appear to show priming effects which were based on syntactic structure. Frazier *et al* suggested a number of possible explanations for their results, including the possibility that coordinate structures elicit a specialised parsing process which is based on the assumption of parallel structure.

However, there are some difficulties in interpreting their results. Firstly, the sentences were not controlled for overall conjunct length, word length, fine-grained constituent structure and metrical structure. In some cases, the first and second conjuncts varied greatly in these respects, all of which could influence reading times. In addition, the conjuncts were not controlled for lexical and semantic similarities. In many cases, the second conjunct in the parallel structure conditions contained many of the same open class lexical items as the first conjunct, raising the possibility that apparent structural priming effects were confounded by lexical priming. Similarly, the semantic relatedness of the events described in the first and second conjuncts in many of the materials could also have contributed to reduced reading times. This is a particular issue, since Frazier *et al* also seemed to find some evidence of parallelism effects based upon semantic structure with sentences like those in (7.8) and (7.9) above. Hence, reduced reading times for the second conjunct in (7.11) below could result not only from structural parallelism (as claimed), but also from lexical or semantic parallelism, or a combination of the three.

(7.11) Jim believed all Tom's stories and Sue believed all Jim's stories.

Hence it is not clear that these results can be taken as evidence of syntactic priming in comprehension. Even if the possible explanations mentioned above could be excluded, the results still leave a number of questions unanswered. For example, it is not entirely clear whether priming effects can be found with all types of construction. Note that Frazier *et al* found priming effects for the preferred structure only in one case (actives) and the dispreferred

structure only in two other cases (non-minimally attached sentences and shifted heavy NP sentences).

Furthermore, nearly all of the materials in their experiment involved the repetition of the same verb in both conjuncts. This is important, because it places restrictions on any conclusions which we might draw from Frazier *et al*'s results concerning the nature of syntactic representation. Specifically, any priming effects found under these conditions would not allow us to conclude that comprehension involves rules (whether processes or knowledge statements) which are lexically non-specific, i.e. make reference only to abstract categories. This is because the effects could be attributable to the facilitation/inhibition of syntactic privileges associated with a specific lexical item. For example, a facilitation effect for the second conjunct in (7.11) above could occur because comprehension of the first conjunct raises the activation of one rule associated uniquely with the verb *believe* (corresponding to the NP complement structure) over another rule associated uniquely with *believe* (corresponding to the S complement structure). Unless it can be shown that priming transfers from one lexical item to another (e.g. from a minimally-attached sentence involving *believe* to a minimally-attached sentence involving *know*), we cannot be sure that priming is tapping into an abstract (i.e. lexically non-specific) level of syntactic structure.

Cuetos, Mitchell and Corley (to appear)

The experiments described above are explicitly concerned with the effects of immediately preceding sentences on a subsequent sentence, in other words with priming as a short term effect. However, priming could also have longer term effects. Cuetos, Mitchell and Corley (to appear) reported an experiment in which Spanish children were exposed over a period of two weeks to sixty stories containing either relative clauses which were attached to the embedded NP in a complex NP construction, or alternatively relative clauses which were attached to the Head NP. Cuetos *et al* found that when the children were tested two weeks later, their attachment preferences for ambiguous complex NP constructions were reliably affected by the type of story which they had heard. Children who had heard stories containing low-attached relative clauses were more likely to interpret the relative clause in the ambiguous construction as being low-attached, whereas children who had been exposed to high-attached relative clauses in the stories tended to interpret the relative clause as being high-attached. Cuetos *et al* claimed that these effects reflect 'tuning', by which preferences for resolving syntactic ambiguities can be affected by previous experience. This could be a long term correlate of the syntactic priming effects discussed here, where repeated previous experience could result in long term alterations in the base activation of the rule corresponding to one alternative.

7.2.1 Summary

The work described here suggests that in some cases the syntactic structure of preceding sentences can affect the way in which a subsequent sentence is comprehended. In other words, there is evidence which is compatible with the existence of syntactic priming effects in comprehension. However, there has not been any systematic exploration of these effects and given the various problems with the previous work in this area, which I have noted above, it would clearly be premature to conclude that syntactic priming effects occur in comprehension.

7.3 Experimental issues

If syntactic priming could be shown to occur in comprehension, it would have important implications relating both to issues of syntactic representation in language processing and to issues of the processes involved in language comprehension. The experiments to be presented below were designed to address some of these issues, which can be captured under two main questions: does syntactic priming occur in comprehension, and if so, how is it effected?

7.3.1 Does priming occur in comprehension ?

The first issue which must be addressed is whether priming effects occur in comprehension, or whether they are limited to language production. As I argued in the previous chapter, the existence of priming effects associated with a particular aspect of language (such as lexical or syntactic structure) is evidence that this particular aspect is relevant to the language processor and hence that it must be represented in some way. That is, the operation of the processor can only be affected by the fact that two consecutive sentences have the same syntactic structure if the processor is sensitive to syntactic structure. Thus the most obvious implication of syntactic priming effects in comprehension would be that syntactic structure is computed at some level of processing in comprehension. They would hence provide empirical support for the widely held view that syntactic processing is an important part of comprehension.

By manipulating the precise syntactic characteristics which the prime and the target share in common, it would then be possible to examine which aspects of syntactic structure are relevant at this particular level of processing in comprehension. For example, if it could be shown that priming takes place between sentences which share their phrase structure configuration but differ in thematic structure, it would suggest that there is a level of representation at which the information sources are separated. Hence in addition to showing that syntactic structure is computed during comprehension, priming effects in comprehension would also be informative about which types of information are accessed separately by the processor.

However, the possibility of priming in comprehension also has implications for our conception of the relationship between syntactic representation and the processes of production and comprehension. I have argued that priming effects are informative about the way in which syntactic structure is represented, since for the cognitive processor to treat two stimuli in the same way, it must assign them related representations. Thus far, however, we only have evidence from language production and hence we can only draw inferences about syntactic representation in production. If we wish to draw any conclusions about syntactic representation in general and in particular if we wish to make the claim that there is a single system of syntactic representation which is common to both production and comprehension, i.e. that they make reference to the same underlying grammar, it is obviously highly desirable to show that the effects can be generalised. If the effect was limited to a single modality (production), it would considerably weaken the plausibility of the claim, although it would not necessarily

force us to relinquish it, as I will now argue.

Thus far it has been left open whether priming affects the activation of statements which encode knowledge of language, or whether it instead affects the activation of processes which are associated with syntactic structure, as Bock (1986b) suggested. If priming affects processes, then we would not necessarily expect to find priming occurring in both production and comprehension, since it is possible that the processes of production are amenable to priming whereas those of comprehension are not. Hence we could maintain the claim that there is a single representational system for syntactic structure even in the absence of priming effects in comprehension, if we assume that priming is based upon processes.

However, if priming affects statements in the knowledge base, then we might expect to find priming occurring in comprehension, if comprehension makes reference to the same underlying grammar as production. Note that this is *not* to claim that evidence of priming in comprehension is necessarily evidence that priming taps into knowledge of language itself; it is entirely possible that priming could occur in both comprehension and production based on the facilitation/inhibition of processes. But if priming does not occur in comprehension, this might be taken as an argument against an account of priming based on activation of knowledge which is common to production and comprehension.

In addition to such considerations about the nature of syntactic representation, priming in comprehension could also provide valuable evidence about a factor which could affect comprehension in addition to the wide range of factors which have already been identified, such as lexical and syntactic preferences (Frazier & Rayner 1982; MacDonald, Pearlmutter & Seidenberg 1994) and discourse context (Crain & Steedman 1985). As such, it could give us insights into the specific mechanisms of parsing. For example, any evidence that priming can alter the initial choice of analysis which the processor makes at a point of ambiguity might suggest that the processor is not restricted in the initial choices which it makes. This might be problematic for those theories which suggest that the initial choice of analysis is always fixed, such as Frazier's (1979) Garden Path theory.

7.3.2 How could priming be effected in comprehension ?

The second issue which the previous chapter raised, and on which comprehension data might be expected to throw some light, is the mechanism by which priming is effected. In the previous chapter, we saw that in production, completing a prime sentence as a double object structure can make a subject more likely to complete a subsequent sentence as a double object structure. I suggested that this occurred because the prime sentence raised the activation of rule implicated in producing double object structures. However, there are two ways in which this could occur. Priming could simply affect the base activation of a rule such that it is subsequently easier to access and apply. In that case, priming would be a simple repetition effect. Alternatively, priming could act by altering the *relative* activation of a rule so that it becomes more highly activated relative to other rules. In the production experiments reported in the previous chapter, subjects always had a choice between completing the target sentence as a double object or a prepositional object sentence. The effect of priming could be to influence which was chosen. In that case, priming would be primarily a competitive effect.

In order to show that priming is largely a competitive effect, we would have to show that priming effects occur when the processor has to choose between more than one syntactic alternative, and that they do not occur – or occur to a considerably lesser degree – when there is only one possible syntactic structure. Studying priming effects in language production alone cannot help us decide this, because language production inherently involves choice: for any given message, there is always more than one possible syntactic realisation between which the processor must choose.

If we assume that any priming effects in production and in comprehension are effected in the same ways, then studying priming effects in comprehension could resolve this issue because comprehension does not inherently involve competition between syntactic alternatives. For example, the fragment *The boy was jogging ...* can only be assigned one syntactic structure, hence there is no point at which the processor has to make a choice about which syntactic rule to apply. It is only in sentences with local ambiguities, where there is more than one possible analysis, that such a choice need be made. In principle, evidence about syntactic priming effects in comprehension could therefore allow us to distinguish between the two alternatives.

Priming as a simple repetition effect

If priming is a simple repetition effect, it would predict that priming effects should be found with all types of structure in comprehension. Priming would simply raise the activation of the rule associated with the relevant syntactic structure in the first sentence and so make it easier to apply in a subsequent sentence. This could manifest itself as reduced reading times for primed sentences than for unprimed sentences. Although the effect should therefore be quite general in nature, it might be stronger for constructions that are rarer or harder to process and hence – presumably – have a lower base activation. Common constructions might be subject to 'ceiling' effects, whereby the base activation is sufficiently high that priming has no discernible effect. (I will return to the question of ceiling effects later in this chapter).

Priming as a competitive effect

The second alternative, priming as a competitive effect, would predict priming effects only in sentences which involve syntactic ambiguity. It is noticeable that in the existing evidence reviewed above, most of the structures which were examined involved local (or global) ambiguities.

If priming is associated with ambiguity, then the occurrence of priming will be linked to garden path effects, where the processor (assuming a serial or ranked parallel approach) selects one analysis to pursue and must then reanalyse when the initial parse turns out to be incorrect (Bever 1970). Under a competitive priming account, then, the active/passive sentences and prepositional/double object sentences studied by Bock (1986) and in Experiment 1 in the previous chapter would not elicit priming effects, since neither type of structure involves structural ambiguity.[2]

[2] It could be argued that prepositional/double object sentences involve some ambiguity, since the NP immediately following the verb can be interpreted as either the beneficiary or the patient. However, both cases result in the same phrase structure, with the NP attached directly to the VP (I am assuming a ternary-branching account of ditransitive verb VPs here, in line with Pollard and Sag (1987)). Hence any difference is interpretive rather than phrase-structural. Furthermore, the correct interpretation is usually resolvable immediately on semantic/pragmatic grounds, for example *the book* in *give the book* must be a patient and not a beneficiary.

In a competitive account, priming could affect processing in two ways. In one case, priming would increase the activation level of the rule associated with the primed structure relative to that associated with the unprimed structure. Under normal circumstances, the resting activation level for the rule associated with the preferred reading is higher than that for the dispreferred reading, but priming the dispreferred reading could raise its activation level such that it becomes a good competitor for application. Here priming would tend to be centred on the dispreferred analysis but it could also have some effect upon the preferred analysis. This account fits well with models of language comprehension which are based upon constraint-satisfaction (Taraban & McClelland, 1988; Trueswell, Tanenhaus & Garnsey, 1994; Spivey-Knowlton, Trueswell & Tanenhaus, 1993; MacDonald, Pearlmutter & Seidenberg, 1994). In this case, priming can – in principle – affect the initial choice of analysis which the processor makes, although that will not necessarily be the case. For example, a single priming sentence may be inadequate to raise the activation of a particularly poor competitor sufficiently that it becomes the processor's first choice, but exposure to a series of primes (as in Mehler and Carey's (1967) experiment) might achieve this.

Alternatively, it could be that the initial choice of the processor can never be altered or in any way affected by priming. Such a position follows from theories of processing where the initial analysis is assigned on the basis of immutable strategies, such as Minimal Attachment and Late Closure (Frazier, 1979; Frazier and Rayner, 1982). Since the processor will always choose the same analysis, priming will be unable to affect the preferred analysis. Instead, priming would only be able to affect the process of reanalysis, by raising the activation level of rule associated with the dispreferred reading such that its ultimate choice would be facilitated.

Even if priming is a purely competitive effect, there are still further distinctions which might prove to be relevant. In particular, there might be a distinction between sentences which involve a strong garden path and those which involve a weak garden path. In a strong garden path sentence, the dispreferred analysis is difficult to reach. That is, recovery from misanalysis requires much greater effort. Intuitively, a strong garden path is found in (7.12) below when it is presented in isolation:

(7.12) The actress sent the flowers was very pleased.

In a weak garden path, such as (7.13), the dispreferred analysis can be reached without difficulty and the sentence is intuitively unproblematic to process. Nevertheless, there is considerable evidence that sentences like (7.13) do cause some processing difficulty (see for example Frazier& Rayner, 1982; Rayner & Frazier, 1987; Trueswell, Tanenhaus & Kello, 1993; though c.f. Kennedy, Murray, Jennings & Reid, 1989).

(7.13) The father decided the punishment for stealing was too severe.

Pritchett (1992) and Gorrell (1995) argued that this intuitive difference between strong and weak garden paths actually corresponds to a fundamental difference in the way in which the processor conducts reanalysis, with strong garden paths requiring major reanalysis of the existing parse. Alternatively, the difference between strong and weak garden paths could simply be one of degree. In strong garden paths, the resting activation of the dispreferred analysis might be substantially lower than that of the preferred analysis, whereas in weak garden paths the dispreferred analysis might have only a slightly lower activation. Whichever approach we take, it seems plausible that the strong/weak garden path distinction might prove to be relevant for priming. It could be that priming only occurs in strong garden path sentences, or that it is weaker with weak garden paths.

If priming is found only with locally ambiguous structures, as the competitive account predicts, this would seem to exclude an account of priming in comprehension based on episodic traces, since there would be no reason to assume that an episodic trace account should be restricted to sentences involving local ambiguities. Finally, it should be noted that *both* simple repetition and competitive priming might occur. For example, simple repetition might only produce weak priming effects relative to competitive priming.

7.3.3 Summary

There are a number of ways in which syntactic priming effects could occur in comprehension. Any such effects would be informative about both the mental representation of syntactic structure and the processes which underlie sentence comprehension. In the remainder of this chapter, I would like to present a number of experiments which have explored some of these issues in more detail. These are presented in three sections. The first two sections present two studies of six and three experiments respectively, which aim to establish the existence of syntactic priming effects in comprehension. The third section presents a further experiment which explores the effect of one particular aspect of structure, thematic structure, in syntactic priming.

7.4 Study 1 (Experiments 1–6)

The most important issue to be addressed was whether syntactic priming effects occur in comprehension when other possibly influential factors are excluded. The existence of such effects could not be taken for granted, making it desirable to test a wide range of structures. The second main issue of interest was whether priming is based on repetition, competition or a combination of both. In order to explore this further, both unambiguous sentences and locally ambiguous sentences were tested.

In the category of unambiguous sentences, the obvious structures to test were those which have been previously used in production priming, i.e. active/passive sentences and prepositional/double object sentences, since this allows a direct comparison to be drawn between priming in production and priming in comprehension. A third pair of unambiguous structures, subject/object relative clauses, were also chosen. They were particularly well-suited to the experiment because they are identical in everything except the order of the verb and an NP and hence can be extremely well controlled. Furthermore, it has been shown that subject relative clauses are significantly easier to process than object relative clauses (Wanner & Maratsos, 1978; Pickering & Shillcock, 1992) and I have already suggested that if priming is a simple repetition effect, it might be stronger (hence easier to detect) with structures that are harder

to process, in this case object relative clauses.

The ambiguous sentence types which were chosen were those which have been studied extensively in the sentence comprehension literature. Both strong garden path constructions, such as complement/relative clause ambiguities, and weak garden paths, such as high/low attached PPs, were included; the full range of constructions is discussed and exemplified below.

The experimental method which was used was whole-sentence self-paced reading, where subjects read a prime sentence followed by a target sentence. Whole-sentence self-paced reading cannot identify when any priming effect comes to bear during comprehension, but it gives subjects a natural task to carry out (reading a whole sentence) and at this point the issue of interest is whether priming effects occur at all, not their time course. If priming in comprehension raises the activation of a syntactic rule, as I have hypothesised for production, it should manifest itself as a reduction in reading time for a sentence in the primed condition compared with the unprimed condition. That is, we would expect to find that subjects will read a sentence more quickly if they have just read another sentence with the same syntactic structure, even if the two sentences vary greatly in their lexical and semantic content, than if they have just read a sentence with a different structure.

7.4.1 Method

Subjects

The subjects were 28 paid volunteers recruited from a summer school held at the University of Glasgow.

Materials

Six pairs of constructions were tested. Examples of each pair are given below. The constructions were: active/passive sentences (7.14); prepositional/double object sentences (7.15); subject/object relative clauses (7.16); high/low attached prepositional phrases (7.17); subordinate transitive/intransitive clauses (7.18); and complement/relative clauses (7.19).

(7.14) a. The motorbike injured the walker.
b. The walker was injured by the motorbike.

(7.15) a. The hurdler gave the whistle to the judges.
b. The hurdler gave the judges the whistle.

(7.16) a. The badminton player that assaulted the inspector jogs by the river.
b. The badminton player that the inspector assaulted jogs by the river.

(7.17) a. The thief opened the safe with the key today.
b. The thief opened the safe with the lock today.

(7.18) a. While the woman was eating the creamy soup the pudding went cold.
b. While the woman was eating the creamy soup went cold.

(7.19) a. The caretaker reminds the porter that the sleepy boss annoyed the old architect.

b. The caretaker reminds the porter that the sleepy boss annoyed about the alarm.

I will term the first sentence type in each pair (i.e. the (a) examples) type A and the second sentence type (i.e. the (b) examples) type B.

For each pair of structures, 32 sets of materials were constructed. Each consisted of two sentences, a prime sentence and a target sentence. In the complement/relative sentences, the two sentences were separated by a full stop. In all other construction types, half of the materials consisted of two sentences separated by a full stop, and half consisted of two sentences separated by the conjunction *and*.

The materials were controlled in a number of ways designed to rule out other explanations for any priming effects. All of the materials were controlled so that the prime sentence and the target sentence differed substantially in their lexial and semantic content: there was no open-class lexical overlap between the two sentences and they described unrelated events. The NPs in the prime sentence and the target sentence were matched for animacy wherever possible. The materials were controlled for word length. The subject/object relative clause, high/low PP attachment and complement/relative clause materials were matched as much as possible for the number of syllables and metrical structure.

There were four conditions, in a crossed design (A prime–A target; A prime–B target; B prime–A target; B prime–B target). Four versions of each material were constructed, one for each condition, as demonstrated below using active/passive sentences as exemplars:

(7.20) a. The potter shaped the jug and the runner won the race.

b. The potter shaped the jug and the race was won by the runner.

c. The jug was shaped by the potter and the runner won the race.

d. The jug was shaped by the potter and the race was won by the runner.

In addition, 64 filler materials were constructed, consisting of two sentences separated by full stops. Simple yes-no questions were constructed for a quarter of the experimental and filler materials. Half of the questions pertained to the first sentence in each material and half to the second sentence. They were also balanced so that the correct answer was 'yes' for half of the questions and 'no' for half of the questions. The questions were designed to encourage subjects to read the sentences properly.

Four presentation lists of 256 materials were constructed. A pseudo-random ordering of the materials was generated individually for each subject, such that materials of any particular construction type were separated by at least four other materials. This was to reduce any possibility of priming effects occurring between previous materials and the target sentence.

Procedure

Subjects were run individually using an Apple Macintosh computer with a colour screen. Reaction times were measured using a button box. Subjects were told that their task was to read sentences on a screen at their own pace and to answer the questions which followed some of the trials as quickly and as accurately as possible. Before each trial, an asterisk appeared

as a prompt. Pressing a button caused the first sentence to be displayed on the screen. When they had read this, a second press removed the first sentence and replaced it with the second sentence. A third press removed the second sentence and displayed either a yes–no question relating to one of the sentence or the words 'No question'. Another button press completed the trial and revealed the asterisk prompt for the next trial. It was stressed that subjects should read at a rapid but comfortable pace. Each session lasted approximately 35 minutes, with a two minute break half-way through.

Before the experimental materials were presented, there were eight practice trials to familiarise subjects with the procedure. These materials also consisted of two sentences separated by *and* or a full stop, and sometimes followed by a question. The practice trials involved a variety of construction types unrelated to those used in the actual experiment. The first two trials of the experimental session were also practice trials.

Design and data analyses

There were two independent variables, prime sentence type and target sentence type. These were crossed to yield four conditions. Each subject saw 32 materials of each construction pair, 8 in each condition. Each material was presented to 28 subjects, 7 in each condition.

Analyses of variance were carried out on the data, with separate analyses treating subjects and items as random effects. The dependent variable was the time taken to read the target sentence in each condition. Means comparisons were also carried out to examine whether priming effects occurred with both types of construction in each construction pair.

7.4.2 Results

Approximately 0.5% of the data was removed as a result of equipment failure. These errors were due to problems with the button box employed. In addition, all responses under 400 ms and over 20000 ms were removed automatically (approximately 3% of the data), and then data points more than 2.5 standard deviations from the mean for a subject were replaced with the cut-off value (approximately 2% of the data).

Table 7.1 below presents the data for all six construction types, and reports the time spent reading the context sentence and the target sentence.

In the following sections, I will present the results for each construction pair separately.

Active/Passive Sentences

In prime sentence position, there was a main effect of construction type: actives were read faster than passives (F_1 (1,27) = 29.4, $p = .0001$; F_2 (1,31) = 23.4, $p = .0001$). This was also the case in the target sentence position (F_1 (1,27) = 18.0, $p = .0002$; F_2 (1,31) = 12.8, $p = .001$). No other effects approached significance (all Fs < 1). Hence there was no sign of an effect at the target sentence position which would indicate a facilitation effect based on prime sentence structure.

Prepositional/Double Object Sentences

No effects approached significance in either context or target sentence position (all Fs < 1).

	Prime sentence	*Target sentence*
Active–Active	2190	2041
Active–Passive	2133	2317
Passive–Active	2568	2073
Passive–Passive	2550	2258
Prep Obj–Prep Obj	3012	2537
Double Obj–Prep Obj	2985	2604
Prep Obj–Double Obj	2936	2625
Double Obj –Double Obj	2978	2605
Subject Rel–Subject Rel	4664	3373
Subject Rel–Object Rel	4757	3779
Object Rel–Subject Rel	5096	3661
Object Rel–Object Rel	5374	3822
Trans Subord–Trans Subord	5243	3897
Trans Subord–Intrans Subord	4965	4031
Intrans Subord–Trans Subord	4600	4336
Intrans Subord–Intrans Subord	5052	3722
High PP–High PP	3922	3162
High PP–Low PP	3994	3588
Low PP–High PP	4375	3183
Low PP–Low PP	4369	3876
Complement–Complement	6674	4751
Complement–Relative	6298	6095
Relative–Complement	8303	5087
Relative–Relative	8454	4895

Table 7.1: Reading Times (ms) for Prime and Target Sentences

Subject/Object Relative Sentences

In prime sentence position, there was a main effect of construction type: subject relatives were read faster than object relatives (F_1 (1,27) = 13.2, p = .001; F_2 (1,31) = 12.9, p = .001). Subject relatives were also read faster than object relatives in target position (F_1 (1,27) = 9.58, p = .005; F_2 (1,31) = 5.21, p = .03). No other effects approached significance. In particular, at target position, the interaction of interest between prime sentence type and target sentence type was not significant (F_1 (1,27) = 1.98, p = .17; F_2 (1,31) = 2.30, p = .14).

High/Low Attached PP sentences

In prime sentence position, high attachment sentences were read faster than low attachment sentences. (F_1 (1,27) = 6.85, p = .01; F_2 (1,31) = 4.96, p = .03). This also held in target sentence position. (F_1 (1,27) = 14.6, p = .0007; F_2 (1,31) = 18.7, p = .0001). No other effects approached significance (all Fs < 1).

Transitive/Intransitive Sentences

In prime sentence position, there was a strong suggestion that intransitive sentences were read faster than transitive sentences.[3] This was significant by subjects and marginal by items. (F_1 (1,27) = 5.69, p = .02; F_2 (1,31) = 3.51, p = .07). In addition, there was a suggestion of a spurious interaction between the constructions in the prime and (as yet unseen) target sentences. This was significant by subjects only (F_1 (1,27) = 7.32, p = .01; F_2 (1,31) = 2.55, p = .12).

In target sentence position, the predicted interaction between prime and target sentence type was strongly significant (F_1 (1,27) = 6.38, p = .02; F_2 (1,31) = 13.1, p = .001). In other words, subjects read a transitive or intransitive sentence faster if they had just read another sentence with the same construction type than if they had just read a sentence with the other construction type. In addition, there was a suggestion than intransitive sentences were read faster than transitive sentences (F_1 (1,27) = 5.34, p = .03; F_2 (1,31) = 2.79, p = .10).

Means comparisons were carried out to examine whether the effect occurred for both types of sentence. Transitive targets were read faster after transitive contexts than after intransitive contexts (F_1 (1,27) = 4.40, p = .05; F_2 (1,31) = 7.98, p = .008). There was a suggestion that intransitive targets were read faster after intransitive contexts than after transitive contexts, significant by items only (F_1 (1,27) = 2.17, p = .15; F_2 (1,31) = 5.22, p = .03).

Complement/Relative Sentences

In prime sentence position, there was a main effect of sentence type: complement clause sentences were read faster than relative clause sentences (F_1 (1,27) = 22.9, p = .0001; F_2 (1,31) = 26.7, p = .0001). No other effects approached significance.

In target sentence position, complement clause sentences were read faster than relative clause sentences (F_1 (1,27) = 9.22, p = .005; F_2 (1,31) = 8.38, p = .007). There was a strong

[3] This might seem surprising, since the intransitive structure is actually the dispreferred (garden path) structure; we might therefore expect reading time to be longer for intransitives than for transitives rather than the converse. However, it is simply the result of a length confound: the intransitive sentences contained one NP fewer than the transitive sentences. The same holds for the intransitive/transitive sentences in target position.

suggestion that a sentence which had been preceded by a complement clause sentence was read faster than one which had been preceded by a relative clause sentence (F_1 (1,27) = 8.73, p = .006; F_2 (1,31) = 3.31, p = .08). The predicted interaction between prime and target sentence type was strongly significant (F_1 (1,27) = 15.6, p = .0005; F_2 (1,31) = 12.0, p = .002). In other words, subjects read a complement clause or relative clause sentence faster if they had just read another sentence with the same construction type than if they had just read a sentence with the other construction type.

Again, means comparisons were used to test whether the effect occurred for both sentence types. Relative clause targets were read faster after relative clause primes (F_1 (1,27) = 19.1, p = .0002; F_2 (1,31) = 14.3, p = .0007). However, there was no indication that complement clause targets were read faster after complement clause primes than after relative clause primes (F_1 (1,27) = 1.49, p = .23; F_2 (1,31) = 1.24, p = .27).

7.4.3 Summary

These six construction types clearly divided into two groups. There were clear facilitation effects due to repetition of structure with the complement/relative sentences and the transitive/intransitive sentences. These results suggest that syntactic priming does occur in comprehension and more specifically that it is found with these construction types.

However, there were no comparable facilitation effects with four other pairs of constructions. Note in particular that no priming effect was found in comprehension with prepositional/double objects, despite the occurrence of priming with these structures in production. Nor was priming found with the active/passive sentences, the subject/object relative sentences and the high/low attached PP sentences. We cannot therefore conclude that priming occurs in comprehension with these construction types. The full implications of these results will be discussed below with the results of the second study.

7.5 Study 2 (Experiments 7-9)

The results of Study 1 suggest that syntactic priming occurs in comprehension. However, priming effects were only found with certain types of sentence. The aim of this study was to examine in more detail the constructions with which priming occurs. It used the same task and the same design as Study 1 but employed two new construction pairs as well as repeating one of the experiments in Study 1.

7.5.1 Method

Subjects

The subjects were 36 paid volunteers recruited from the student communities of the Universities of Edinburgh and Glasgow.

Materials

Three pairs of constructions were tested: active/passive sentences (again) (7.21)[4]; NP object/S complement ambiguities (7.22); and main clause/reduced relative ambiguities (7.23).

(7.21) a. The potter shaped the jug.
b. The jug was shaped by the potter.

(7.22) a. The baker explained the rules about parking to the apprentice.
b. The baker explained the rules about parking were too restrictive.

(7.23) a. The artist sent the letter to the teacher.
b. The artist sent the letter drew the teacher.

For each pair of structures, 32 sets of materials were constructed. Each consisted of a prime sentence and a target sentence, half separated by a full stop and half by the conjunction *and*. The materials were designed so that there was no semantic or open-class lexical overlap between the prime and target sentence. The object/complement ambiguity sentences and the main clause/reduced relative clause sentences were matched as far as possible for metrical structure, number of syllables and word length. The active/passive sentences were controlled as in Study 1.

As before, four versions of each material were prepared, in a crossed design (A prime–A target; A prime–B target; B prime–A target; B prime–B target). In addition, 64 filler materials were produced, comprising two further experiments (one is reported as Experiment 10 below; the other is not reported here). Sixteen materials in each set were separated by *and*, the remaining sixteen by a full stop. Simple yes–no questions were produced for 12 materials in each set. As before, half referred to the first sentence and half to the second sentence, and were equally split between 'yes' and 'no' answers.

Four presentation lists of 162 materials were constructed. A pseudo-random ordering of the materials was generated individually for each subject such that materials of any particular construction type were separated by at least three other materials.

Procedure

The procedure in Study 2 was identical to that in Study 1, except that subjects were given two 45 second breaks during the experimental session. The session took about 25-30 minutes.

Design and data analyses

There were two independent variables, prime sentence type and target sentence type. These were crossed to yield four conditions. Each subject saw 32 materials for each construction pair, 8 in each condition. Each material was presented to 36 subjects, 9 in each condition.

Analyses of variance were carried out, with separate analyses treating subjects and items as random effects. The dependent variable was the time spent reading the target sentence in each condition. Means comparisons were also carried out to determine whether priming effects occurred for both types of sentence in each pair.

[4] The same materials were used as in Study 1.

7.5.2 Results

All trials which included a response under 400 ms (including some button box errors), or over 20000 ms were removed automatically. These criteria removed 2.89% and 0.19% of the data respectively. In addition, data points more than 2.5 standard deviations from the mean calculated for each trial position (prime, target or question position) for each subject were replaced with the cut-off value for that subject. In all, this accounted for 2.47% of the data. Analysis of subjects' responses to the questions revealed that they responded correctly on average to 84% of questions.

Table 7.2 below presents reading times for the three construction types in the prime and target sentences.

	Prime sentence	*Target sentence*
Active–Active	2076	1841
Active–Passive	1995	2177
Passive–Active	2293	1873
Passive–Passive	2351	2086
Object–Object	3715	3201
Object–Complement	3893	3358
Complement–Object	3841	3118
Complement–Complement	3841	3365
Main–Main	2952	2644
Main–Reduced Rel	2896	3913
Reduced Rel–Main	4646	2861
Reduced Rel–Reduced Rel	4307	3650

Table 7.2: Reading Times (ms) for Prime and Target Sentences

Active/Passive Sentences

In prime sentence position, there was a main effect of structure type: active sentences were read faster than passive sentences (F_1 (1,35) = 15.7, p = .0003; F_2 (1,31) = 23.4, p = .0001). This also held for the target sentence position (F_1 (1,35) = 46.2, p = .0001; F_2 (1,31) = 10.8, p = .003). The interaction of interest was marginally significant by subjects but not by items (F_1 (1,35) = 4.04, p = .052; F_2 (1,31) = 1.71, p = .20).

NP complement/S complement

There was no main effect of sentence type in prime sentence position (Fs < 1). In target sentence position, there was a main effect of sentence type: NP complement sentences were read faster than S complement sentences, according to the subjects analysis (F_1 (1,35) = 8.96, p = .005; F_2 (1,31) = 1.75, p = .20). The interaction of interest was not significant (Fs < 1).

Main clause/Reduced relative clause sentences

In prime position, there was a main effect of sentence type: main clause sentences were read faster than reduced relative clause sentences (F_1 (1,35) = 89.8, p = .0001; F_2 (1,31) = 117, p

= .0001). This main effect was also found in target sentence position (F_1 (1,35) = 96.3, p = .0001; F_2 (1,31) = 81.7, p = .0001). The interaction of interest was strongly significant (F_1 (1,35) = 18.4, p = .0001; F_2 (1,31) = 8.91, p = .006).

Planned means comparisons were used to determine whether the effect occurred for both sentence types. Reduced relative targets were read faster following a reduced relative prime (F_1 (1,35) = 11.0, p = .002; F_2 (1,31) = 6.57, p = .02). With main clause targets, the facilitation was significant by subjects but not by items (F_1 (1,35) = 7.53, p = .01; F_2 (1,31) = 2.75, p = .11).

7.5.3 Summary

The main clause/reduced relative ambiguities displayed reliable priming effects. However, no priming effects were found with the object/complement ambiguities. The active/passive experiment showed a weak suggestion of a priming effect.

7.6 Discussion

These experiments demonstrate that syntactic priming effects do occur in language comprehension, in line with the findings of Mehler & Carey (1967) and Frazier *et al* (1984). That is, the comprehension of a sentence with a particular syntactic structure can be facilitated by the prior comprehension of a sentence with the same syntactic structure. We found strong and reliable priming effects with the complement/relative clause ambiguities (7.24), the transitive/intransitive sentences (7.25) and the main clause/reduced relative ambiguities (7.26):

(7.24) a. The caretaker reminds the porter that the sleepy boss annoyed the old architect.

b. The caretaker reminds the porter that the sleepy boss annoyed about the alarm.

(7.25) a. While the woman was eating the creamy soup the pudding went cold.

b. While the woman was eating the creamy soup went cold.

(7.26) a. The artist sent the picture to the teacher.

b. The artist sent the picture drew the teacher.

Other explanations for these effects can be ruled out: primes and targets were controlled for lexical and semantic similarity, and the complement/relative clause materials and the main clause/reduced relative clause materials were matched for number of syllables and metrical structure. The pattern of results also argues against an explanation based on the continuing activation of a representation or episodic trace for the entire preceding sentence, since priming was only found with ambiguous structures. Furthermore, the effects were not dependent on the prime and the target being conjoined, since the complement/relative clause experiment showed strong priming effects even though the prime and target were separated by a full stop. Hence syntactic priming is not dependent on specialised parsing strategies associated with coordinated structures, as suggested by Frazier, Taft, Clifton, Roeper & Ehrlich (1984).

7.6.1 Priming and rules

The minimal conclusion which can be drawn from these experiments is that syntactic priming effects are not restricted to language production, but also occur in comprehension. Hence the processor must be sensitive to the syntactic structure of the input during comprehension. This syntactic structure cannot be represented in terms of specific lexical items: priming occurred between sentences which were lexically distinct. When the processor encountered *The artist sent the picture drew the teacher* and then encountered *The builder brought the whisky thanked the workmate*, it can only have treated them in the same way (and hence produced priming effects) if its decisions about how to analyse the input were based upon abstract, lexically non-specific relations. Hence during comprehension, the processor must be making reference to information which is not lexically specific, but rather defined over classes of lexical items, for example verbs which are optionally transitive or intransitive. This suggests that, as in production, comprehension involves abstract characterisations, or rules, specifying possible relations between categories. I propose that, as in production, syntactic priming effects in comprehension result from the activation of syntactic rules associated with particular analyses. When the processor encounters an ambiguous string, it has a choice of analyses to follow, corresponding to a choice in which rule to apply. If a rule has been applied previously, it will have increased activation and hence will be easier to apply again.

7.6.2 Priming as a competitive effect

The results also provide some insight into the mechanism of priming. Priming effects were only found in these experiments with locally ambiguous sentences where one continuation produces a strong garden path effect. Of course, we cannot conclude on the basis of null results that priming does not occur with unambiguous sentences or with weak garden path sentences. One reason why priming effects manifested themselves only with strong garden path sentences might be that in these cases the disparity in the availability of the two analyses made any effects sufficiently strong to be detectable by whole-sentence self-paced reading. Whole-sentence self-paced reading is not a particularly sensitive technique and it is possible that priming effects would be detected in the weak garden path sentences or possibly even the unambiguous sentences using a more sensitive technique such as eye-tracking. We must therefore leave open the possibility of a simple repetition priming effect. However, the robustness of the priming effects that were found here with the strong garden path sentences strongly suggests that a major element of priming is competitive.

The competitive element to priming is particularly clear if we compare the results of priming double/prepositional object sentences in production and in comprehension. In production, there is a strong priming effect: double object completions elicit more double object completions and similarly prepositional object completions elicit more prepositional object completions. By contrast, no priming effect was found for the same structures in comprehension. In the former case, the prepositional and double object rules are competing with each other for application, because both are equally applicable to a particular functional structure. In the latter case, there is no such competition: the first NP is analysed as the sister of the verb, an analysis which is compatible with both rules, and the final constituent is an NP, in which case

the relevant rule is the double object rule, or it is a PP, in which case the relevant rule is the prepositional object rule.

Thus a major component of the priming effect seems to be dependent on the existence of alternative syntactic analyses between which the processor must choose. The effect of priming seems to be to affect the way in which a choice is made. As in production, I suggest that priming does this by affecting the relative activation of the syntactic rules associated with the alternative analyses. Processing the prime sentence raises the activation of the rule associated with that structure relative to its competitor and hence makes it more accessible subsequently.

In all of the experiments discussed here, both the prime and the target involved the same competition between alternative structures. However, if priming reflects increased activation of a rule following its previous application, we would expect to find priming whenever the relevant rule had previously been applied, even if its previous application did not involve a competition. Hence the proposal which I am developing here would predict that there would be a priming effect for *The artist sent the picture drew the teacher* after *The girl shown the dog kissed the boy*, even though the latter sentence is unambiguous and hence does not involve a competition. Of course, we might expect to find greater priming effects when the prime involves the same competition as the target, since in that case the relevant rule might have to be more highly activated to beat the competition, presumably resulting in higher residual activation and so a stronger priming effect. However, I suggest that previous use, even in an unambiguous sentence, of the relevant rule will be a necessary and sufficient condition for priming to occur.[5]

In addition to these two main conclusions concerning the use of rules and the effect of competition, however, the experimental results also raise some issues which I will discuss in the following sections. These relate to the content of the rules, whether priming is facilitatory or inhibitory, and whether priming can affect the preferred analysis.

7.6.3 The content of syntactic rules

I have argued that priming effects arise when a syntactic choice point is repeatedly encountered. In the previous chapter I suggested that the choice point in production arises during the mapping from functional to constituent structure, and that it involves a choice between individual phrase structure rules, for example between alternative expansions of a VP. Experiment 1 in the previous chapter showed that priming takes place even if the prime and the target differ in their fine-grained structure, as long as they share the critical local structure which corresponds to a single rule.

In comprehension, the choice point arises when the processor has alternative ways of analysing the input. The question arises of whether this choice also corresponds to a choice in rules which correspond to local trees. As in production, it should be possible to draw some conclusions about the domain of the rules by examining the extent to which prime and target must be related. If prime and target need only be alike with respect to a local substructure, we could conclude that the rules which the processor uses in comprehension are specified over

[5] I would argue that the same is true of priming in production: previous use of a forcibly prepositional object verb like *donate* would result in priming of a prepositional object structure with a verb like *give*, even though the prime sentence would not involve a competition between the prepositional and double object structures.

local trees. If they need be alike over larger spans of structure, it could be that the processor is making reference to rules which are specified over larger domains, or alternatively that priming in comprehension requires the repetition of many rules.

It is not possible to draw any firm conclusions on the basis of this data, since care was taken to ensure that prime and target were as alike as possible, but I will discuss some possibilities which are compatible with the experimental results, using transitive/intransitive subordinate clause constructions, as in (7.27), as an example. In these structures, there is a point of ambiguity where an NP can be attached as the object of the subordinate verb or as the subject of the main clause. Since the sentences only differ in this regard, the application of the rule corresponding to one analysis rather than the other must be causal in priming.

(7.27) a. While Mary was knitting the socks got wet.

b. While Mary was knitting the jumper the socks got wet.

If priming reflects the reactivation of a single rule, and those rules specify local trees, then the choice is between the rules corresponding to VP $\rightarrow$ V NP and VP $\rightarrow$ V. The substructure corresponding to this rule is the only aspect of syntactic structure which is relevant. On this model, priming would occur as long as both the prime and the target contain a local substructure to which the same rule applies; in other respects, they could differ markedly. As long as the prime involved the application of either the intransitive or the transitive rule, then, it would not matter whether – for instance – the prime was in a main clause and the target was in an embedded clause, or indeed whether the internal structure of the ambiguous NPs differed in each case. If this turned out to be the case, then it would suggest that the rules which are implicated in comprehension are strictly local. This is the position for which I have argued in production, and I think it is plausible that the same applies to comprehension. Note that under this approach, repetition of a local substructure is a necessary and sufficient condition for priming to occur but the effect might be stronger if the rules which are applied immediately before the point of ambiguity are the same in prime and target.

However, it could be that the repetition of structure over a larger domain could be relevant to syntactic priming. At one extreme, priming might only occur if the prime and target sentences are identical in structure. In that case, as I discussed for production, it could be either that rules are specified over larger domains than local substructures, or that every rule which is involved in parsing the entire sentence is the same and is applied in the same order. This would of course require the application of indefinitely many rules to be remembered.

A more restrictive non-local account would be that the only relevant aspect of syntactic structure is the nodes on the right edge of the tree and their daughters, i.e. the nodes created by the application of the rules associated with forming the right edge of the tree, since these are the active nodes during comprehension in the sense that they present potential attachment sites for new material. On this account, priming occurs in the transitive/intransitive subordinate clause experiment because the prime and the target share the representation $_{\bar{S}}$[CONJ $_{S}$[NP $_{VP}$[V]]] in the intransitive cases and $_{\bar{S}}$[CONJ $_{S}$[NP$_{VP}$[V NP]]] in the transitive cases. Reduced priming might still occur if there were differences in the right edge when this was some distance from the point of ambiguity but the whole right edge would be relevant in principle. However,

other nodes in the tree would not be relevant so that, for example, the internal structure of the subject NP would be irrelevant.

A possible problem with any account is that different tree structures might involve the application of the same rules in the same order. Although this does not apply to the cases of priming studied here, it might apply to the structures studied in Cuetos *et al* (to appear). In ambiguous structures like *the daughter of the colonel who had a limp*, both the low- and the high-attached analyses require the application of the same rule which associates an $\bar{N}$ with a relative clause. The difference between the two analyses lies in the syntactic context in which the $\bar{N}$ appears. Hence if 'tuning' did turn out to be a form of syntactic priming, priming would have to be sensitive to aspects of global tree geometry, since both alternatives apparently involve the application of the same rules in the same order. Here priming would not affect the choice of rule, but which node to apply the rule to. This might be realised by coindexation of the categories specified in a rule with the nodes in the existing tree.

We cannot distinguish between these possibilities on the basis of the existing evidence, but they raise interesting questions for future research. In particular, we might wish to examine whether short-term priming effects of the sort studied in the present experiment can also be found for the structures with which Cuetos *et al* found their 'tuning' effects. In the absence of any further data, I suggest that the simplest assumption is that priming in both production and comprehension occurs when a single rule is repeatedly applied.

7.6.4 Does priming involve facilitation or inhibition ?

On the basis of these results, it is not possible to draw any conclusions concerning whether priming works by facilitation, inhibition, or a mixture of the two. That is, the relevant rule might be a better competitor because its previous use has raised its activation, or because its previous use has depressed its competitor's activation, or because its previous use has both raised its activation and depressed its competitor's activation. In the experiments reported here, both facilitation and inhibition accounts would predict reduced reading times in the primed condition compared to the unprimed condition. This is because of the crossed design: a sentence of a particular type is always preceded by a sentence with a competing structure or with the same structure. Hence the structure of the prime sentence will always compete with or support that of the target sentence. As a result, it is impossible to tell whether the observed differences in reading times between the primed and the unprimed conditions result from *reduced* reading times in the primed condition (facilitation of the appropriate rule) or *increased* reading times in the unprimed condition (inhibition of the appropriate rule).

It might be possible to distinguish a pure facilitation account from a pure inhibition account by comparing reading times in three conditions: primed, 'anti-primed' (i.e. preceded by a sentence with the competing structure), and preceded by a sentence with an unrelated structure. Under a pure facilitation account, we would expect to find reduced reading times only in the primed condition; under a pure inhibition account, we might expect to find reduced reading times in two conditions, where the preceding sentence has the same structure and where the preceding sentence has an unrelated structure, since in neither case will there be inhibition of the relevant rule from the preceding sentence.

Although it might turn out to be the case that one of these pure accounts is correct, I believe it is most likely that the correct model will turn out to be a mixed model, in which priming has a major facilitatory effect for the appropriate rule, as Bock (1986b) proposed, but in which it may also inhibit competing analyses. This is the model which I have tacitly assumed until now, and I will continue to assume it in the remainder of the thesis.

One final issue which should be discussed is the possibility of ceiling and floor effects. If the rule already has a high base activation (as in the preferred analysis in a strong garden path) or a low base activation (the dispreferred analayis in a strong garden path), the rule's activation may already be at such an extreme that it cannot be raised/lowered any further. In that case, the preferred analysis might be inhibited following a prime with the dispreferred structure but not facilitated following a prime with the same structure; conversely, the dispreferred analysis might be susceptible only to facilitation and not to inhibition. This must again remain a question for future research.

7.6.5 Can priming affect the preferred analysis ?

Another issue of interest which is linked to this is whether priming can affect both the preferred and the dispreferred analysis. There are two reasons why we might find no effect for the preferred analysis. Firstly, if we assume a processing theory in which initial parsing decisions are irrevocably determined on the basis of fixed principles (such as Frazier's (1979) Minimal Attachment, or Pritchett's (1992) Generalised Theta Attachment), we would not expect to find that anything could affect the time course of this decision. Alternatively, even if initial parsing decisions are not irrevocably fixed, it is possible that that the rule associated with the preferred analysis is so highly activated that it is subject to ceiling effects of the type discussed above. In either case, we would expect to find priming effects only for the preferred analysis in each pair.

In the complement/relative clause experiment, the priming effect appeared to be centred on the relative clause targets. In the main clause/reduced relative clause and subordinate transitive/intransitive experiments, priming effects appeared to be found for both types of targets. It is not clear that we can draw any strong conclusions from this, since we would ideally want a baseline against which to compare the two priming conditions. However, the results suggest that priming can in some circumstances affect the preferred analysis. This might reflect a simple repetition (i.e. non-competitive) priming effect, although this seems unlikely, given that no simple repetition priming effects were found for any of the unambiguous or easy garden path structures which were studied here. If the effect is a competitive priming effect, it could reflect facilitation of the preferred analysis in the primed condition or inhibition of the preferred analysis in the unprimed condition, i.e. following a sentence with the dispreferred structure. Again, this could be straightforwardly investigated by comparing reading times following a prime sentence with the same structure, one with a competing structure, and one with an unrelated structure. Facilitatory or not, the existence of apparent priming effects for the preferred analysis, whilst not counterevidence against theories such as those of Frazier and Pritchett, sits somewhat uncomfortably with them.

7.6.6 Can priming alter initial preferences ?

A further issue related to this is whether priming can actually alter initial parsing preferences: does priming simply modulate existing parsing patterns, or can it actually alter which analysis the parser attempts first? The results of the experiments presented here suggest that priming has a particularly strong effect upon the dispreferred analysis in strong garden path sentences. This suggests that priming can facilitate reanalysis by making the rule associated with the correct but dispreferred reading more accessible. It is possible that under certain circumstances, priming could raise its activation such that it temporarily becomes the preferred analysis. In particular, it seems plausible that priming is to some extent an additive effect and that multiple primes might have a stronger effect in this regard than the single primes used here.

Clearly, data from a whole-sentence self-paced reading experiment cannot be used to answer this question. However, data from a more sensitive on-line technique such as eye-tracking might be more helpful in this regard. The earlier that we could find evidence of priming (for example on first fixation or first pass measures), the more we could be convinced that priming can affect the initial choice of analysis. Such a finding would be problematic for any theory which proposes immutable syntactic strategies such as Frazier's (1979) 'Garden Path' theory.

7.6.7 Summary to Experiments 1–9

The experiments reported here show that sentence comprehension can be affected by the syntactic structure of previously encountered sentences. That is, syntactic priming effects occur in comprehension. From this, we can conclude that the processor is sensitive to the syntactic structure of the input during sentence comprehension and that this structure must be defined in terms of abstract representations which are specified for syntactic categories but not for individual lexical items. However, priming effects were only found with strong garden path sentences, which suggests that they have a strong competitive element. Although the existing evidence does not allow us to choose between them, I have discussed some of the ways in which priming might be effected and the possible implications for theories of language comprehension and syntactic representation.

7.7 Experiment 10

In the previous experiments, I showed that priming took place between sentences which did not share lexical or semantic content in common. From this I concluded that syntactic priming occurs in comprehension. Having established the existence of these effects, we can now use syntactic priming to examine in more detail which aspects of syntactic information are represented at the level which priming taps into.

In the discussion above, I suggested that, as in production, priming in comprehension appears to implicate representations which correspond to constituent structures. If this is correct, then priming should still occur when prime and target vary in other aspects of structure which could be termed syntactic. The particular aspect with which I am concerned here is thematic structure. There is evidence from production to support this. As we saw in the previous chapter, Bock & Loebell (1990) found syntactic priming effects between sentences which shared constituent structure but differed in their thematic structures, for example between *The 747 was landing by the control tower* and *The boy was stung by the bee*. Bock and Loebell's main conclusion from this was that the priming effect cannot be explained simply in terms of similarities in the type of event which prime and target describe, but it also suggests that thematic structure and constituent structure information are processed separately during production.

If priming in comprehension taps into the same aspect of language as priming in production, we would expect to find the same in comprehension. Finding evidence that priming occurs in comprehension between sentences which share constituent structure but not thematic structure would have two implications. Firstly, it would preclude any possible explanation of the priming effects found in the previous studies in terms of similarities in the types of events expressed by prime and target. Any more detailed semantic similarities have already been ruled out in the previous experiments. Secondly, it would suggest that thematic information is not relevant to the level of representation accessed by priming, but that constituent structure is relevant, in other words that constituent structure and thematic structure are not inextricably intertwined. This would be in agreement with existing theories of language comprehension, as the section below will argue.

7.7.1 Thematic roles in language comprehension

Thematic structure has been the subject of a great deal of interest in recent studies of language comprehension. In particular, emphasis has been laid upon the way in which it can form a point of contact between syntax, semantics and discourse structure (Frazier 1990; Carlson & Tanenhaus 1988). A number of studies have shown that thematic structure can affect comprehension in a wide range of sentence types. For example, Rayner, Carlson & Frazier (1983) examined recovery from reduced relative sentences. They found that the ease and probability of accurate recovery was related to the goodness of fit between the ambiguous constituents and the thematic grid corresponding to the correct analysis. Trueswell, Tanenhaus & Garnsey (1994) also studied reduced relative clauses in an eye-tracking experiment. They found that the plausibility of the subject NP as an agent or a patient affected first-pass reading times at the disambiguating word. Stowe (1988) found that reading times for the disambiguating word in subordinate clause ambiguities were affected by the plausibility of subject of the subordinate clause as an agent or a theme.

Hence there is evidence that thematic information is important in sentence comprehension. However, these processing theories agree that thematic structure is dissociable from constituent structure. They argue that constituent structure and thematic structure are constructed separately, then evaluated for goodness of fit.[6] For example, Frazier suggested that '...thematic-role assignment (and predication) is accomplished by a processing module distinct from the syntactic module,' (Frazier 1990, p.418) and similarly Tanenhaus *et al* argued that '...thematic processing depends at least partially on the output of syntactic processing,' (Tanenhaus, Carlson & Trueswell 1989, p.231). Thus these processing theories would predict

[6] There remains disagreement about whether thematic information can affect the initial analysis pursued by the processor (cf. Frazier (1990) and Tanenhaus, Carlson & Trueswell (1989)).

that it should be possible to find effects of constituent structure processing in which thematic structure plays no part. Evidence of syntactic priming effects in comprehension between sentences with different thematic roles would support this argument.

7.7.2 Experimental issues

The aim of this experiment was to test this hypothesis. If thematic structure is intrinsic to the syntactic representations which are created during comprehension, then the processor will only treat a prime sentence and a target sentence as being related if they share both phrase structure and thematic structure. If however the processor differentiates between constituent structure and thematic structure, there is no reason why priming should not take place between two sentences which share constituent structure but not thematic structure (nor indeed is there any reason why a distinct priming effect should not occur at the level of thematic processing).

Hence we would expect that priming could occur between (7.28a) and (b) below, where both sentences involve transitive subordinate clauses of the type which we have already seen are susceptible to syntactic priming effects, but (7.28a) involves Percept and Experiencer roles and (7.28b) involves Agent and Patient roles.

(7.28) a. Because the storm was frightening the girl the mother sang softly.
b. Because the boy was polishing the belt the buckle shone brightly.

By hypothesis, the processor will apply the same syntactic rules to the second sentence as to the first sentence because they have the same constituent structure, resulting in priming effects. This will not be prevented by the thematic differences because thematic information is represented (and processed) separately. (The claim here is that parallel constituent structures are a necessary and sufficient condition for priming to occur; there may well be additive effects if both constituent and thematic structure are parallel, perhaps because of an additional thematic priming effect).

This experiment could also allow us to investigate an issue of some theoretical linguistic interest. According to some theories, (7.29a) and (b) below do not have related syntactic representations. This is because *frightening* is an adjective whereas *polishing* is a verb. This means that there should be no priming effect between (7.29a) and (b) because the processor will not treat them as being related. If these linguistic theories are correct in their characterisation of syntactic structure, then, we would expect to find priming between (7.28a) and (7.28b) but not between (7.29a) and (7.29b).

(7.29) a. Because the storm was frightening the mother sang softly.
b. Because the boy was polishing the buckle shone brightly.

According to other theories, however, the two sentences are related. In Head-driven Phrase Structure Grammar (HPSG) (Pollard & Sag 1987,1994), for example, *frightening* and *polishing* share the head feature [+PRD], meaning that they are both predicative and hence can occur as complements to the copula.[7] Pollard and Sag (1987) pointed out that the same collection

[7] The linguistic grounds for introducing such a feature include the possibility of coordination between constituents which are apparently distinct, as in *John is a linguist and proud of it*, where an NP and an AdjP are coordinated.

of categories which can appear as complements to the copula also cooccur in a number of other syntactic environments, suggesting strongly that they form a natural class (see Pollard and Sag 1987, p.64–67 for detailed discussion). The [+PRD] feature therefore seems to be well-motivated on theoretical linguistic grounds.

This feature might also be recognised by the processor. In that case, it is possible that the rules into which priming taps are specified in terms of [+/-PRD]. In that case, the rule which applies to (7.29a) might also apply to (7.29b) and priming could occur between them. If we did find priming effects, it would therefore be support for theories which recognise a relationship between (7.29a) and (b). If priming does not occur between (7.29a) and (b), it would be difficult to draw any strong conclusions. It could mean either that the two sentences are not related, as some theories would suggest, or alternatively that they are related (sharing the feature [+PRD]) but that priming only occurs if the prime and the target share *all* of their head features including category information. Hence a failure to find priming effects could not in principle argue against either type of linguistic theory.

The aim of this experiment is therefore to examine whether priming does occur between sentences with different thematic structures, and if so, whether it takes place not only between those sentences which are uncontroversially analysed as related but also between sentences whose relatedness is more controversial. In addition, finding priming effects between two sentences with unrelated thematic structures would confirm that priming does not arise from semantic similarities between sentences with respect to the type of event which the sentences describe.

7.7.3 Method

Subjects

The subjects were 36 paid volunteers recruited from the student communities of the Universities of Edinburgh and Glasgow.

Materials

The pair of constructions which were tested consisted of transitive/intransitive subordinate clause constructions. A total of 32 sets of materials were constructed. Each consisted of a prime sentence and a target sentence. The sentences had the same phrase structures but differed in the thematic roles borne by the NPs in the subordinate clause. In the prime sentences (7.30), these were Experiencer and Percept roles, whereas in the target sentences (7.31) they were Agent and Patient roles.

(7.30) a. Although the delay was annoying the handsome pilot the steward started humming.

b. Although the delay was annoying the handsome pilot started humming.

(7.31) a. Although the farmer was harvesting the ripened barley the carrots began rotting.

b. Although the farmer was harvesting the ripened barley began rotting.

Half of the sentences were separated by a full stop and half by the conjunction *and*. The materials were designed so that there was no semantic or open-class lexical overlap between the prime and target sentence.

As before, four versions of each material were prepared, in a crossed design (A prime–A target; A prime–B target; B prime–A target; B prime–B target). These materials were run as part of the experimental session described in Study 2; see discussion of Study 2 for details. Simple yes–no questions were produced for 12 materials. As before, half referred to the first sentence and half to the second sentence, and were equally split between 'yes' and 'no' answers.

Procedure

See Study 2 for details.

Design and data analyses

There were two independent variables, prime sentence type and target sentence type. These were crossed to yield four conditions. Each subject saw 32 materials, 8 in each condition. Each material was presented to 36 subjects, 9 in each condition.

Analyses of variance were carried out, with separate analyses treating subjects and items as random effects. The dependent variable was the time spent reading the target sentence in each condition.

7.7.4 Results

All trials which included a response under 400 ms (including some button box errors), or over 20000 ms were removed automatically. In addition, data points more than 2.5 standard deviations from the mean calculated for each trial position (prime, target or question position) for each subject were replaced with the cut-off value for that subject. These procedures were carried out as part of the same procedures outlined in Study 2 above. Table 7.3 below presents reading times for in the prime and target sentences.

	Prime sentence	*Target sentence*
Trans–Trans	5367	4001
Trans–Intrans	5275	3989
Intrans–Trans	4157	4138
Intrans–Intrans	4275	3921

Table 7.3: Reading Times (ms) for Prime and Target Sentences

In prime sentence position, there was a main effect of construction type: intransitive sentences were read faster than transitive sentences (F_1 (1,35) = 73.15, p = .0001; F_2 (1,31) = 116.136, p = .0001). There was no such effect in target sentence position (all Fs < 1). The interaction of interest between prime sentence type and target sentence type showed a very weak tendency in the predicted direction but was not significant (F_1 (1,35) = 2.07, p = .16; F_2 (1,31) = 2.21, p = .15). No other effects achieved significance (all Fs < 1).

7.7.5 Discussion

The results of the experiment were not significant: there was no reliable difference in reading time associated with previous exposure to a sentence with the same structure. We cannot therefore conclude on the basis of this experiment that priming occurs between sentences which share syntactic structure in common but do not share their thematic structure. These results contrast with those of Bock and Loebell (1990) in production, who found reliable priming effects in production between sentences which shared constituent structure but not thematic structure.

Thus, although one would not wish to draw strong conclusions from a null effect (with a weak tendency in the predicted direction), these results alone do not allow us to rule out the possibility that in language comprehension, unlike in language production, thematic structure is an inextricable part of the syntactic structure which is constructed during processing. This would mean that production and comprehension involve different syntactic representations, since the former would involve 'bare' phrase structure representations at some level whereas the latter would involve representations encoding both phrase structural and thematic role information in a single representation. Furthermore, if correct, it would suggest that thematic information is a proper part of the syntax and not – as some people have claimed – a point of contact between syntax and semantics. Such a state of affairs would not sit comfortably with theories of comprehension in which thematic information has a rapid effect, but one which is subsequent to initial phrase structural processing, for example Frazier (1990). These results could also leave open the possibility that the priming effects in the previous experiments reflected similarities in the types of event described in prime and target, however unlikely that might seem (for example, it is not obvious that there is a great difference between an event described by an optionally transitive verb used intransitively and one described by an optionally transitive verb used transitively, as in the previous subordinate clause ambiguity experiment).

However, there is reason to believe that this may not be the case and that the tendency found in this experiment is indicative of a real but weak effect. I suggested above that repetition of constituent structure would be a necessary and sufficent condition for priming to occur, but that the effects might be weaker in this experiment because of the differences in thematic structure. It is possible that the method being used here, whole-sentence self-paced reading, is insufficiently sensitive to pick up small effects. In that case, the very weak tendency which is revealed by the results could be indicative of a real effect which might be detected using a more sensitive technique. In fact, although Experiment 10 did not find a significant priming effect, there is recent evidence from another source that priming does occur between sentences of the type studied here. Urbach, Pickering, Branigan and Myler (1995) reported the results of a priming experiment using Event Related Potentials. We studied transitive/intransitive subordinate clause sentences of the type studied here, using materials which were based upon those used in this experiment. As here, the prime sentence and the target sentence involved different thematic roles, either Experiencer–Percept or Agent–Other (in most cases, Patient or Location).[8]

[8] In half of our materials, the Experiencer–Percept sentence appeared as the prime and in the other half the Agent–Other sentence appeared as the prime.

We showed that in prime sentence position, the intransitive sentences elicited a characteristic positive deflection in the waveform between 500 and 800 ms after the onset of the disambiguating word. This is in accordance with the Syntactic Positive Shift (Hagoort & Brown 1994a) or P600 effect (Osterhout & Holcomb 1992), a characteristic positive deflection in the waveform which has been found to occur approximately 500-800 ms after the onset of the disambiguating word in a range of garden path constructions. In target sentence position, we found that the positive deflection elicited by the disambiguating word was attenuated if the target sentence had been preceded by a sentence with the same phrase structure (though a different thematic structure). In other words, the positive deflection was smaller in the primed condition compared to the unprimed condition. We concluded from these results that the previous processing of a garden path prime reduces the processing difficulty when a garden path target is subsequently encountered. We also proposed that since the ERP effect occurred at the disambiguating word, priming appears to modify the course of structural computation which occurs at that point rather than processing which takes place downstream.

Hence it appears that although we did not find reliable evidence for it in Experiment 10, an experiment using essentially the same materials but a more sensitive technique found that syntactic priming takes place when constituent structure is repeated despite differences in thematic structure. This confirms that priming does not arise from semantic similarities between two sentences in terms of the type of event which is described; we have already seen in the previous experiments that priming cannot reflect any more detailed semantic similarities. It also argues strongly in support of theories which propose that thematic structure is processed (and represented) separately from constituent structure during comprehension.

Furthermore, the existence of priming effects between sentences like (7.29a) and (b) could be evidence that the processor treats the two sentences as being related, suggesting that theories such as HPSG which recognise a relationship between the two may be better characterisations of the linguistic distinctions which are mentally represented than theories which do not recognise a relationship between them.

7.7.6 Summary to Experiment 10

This experiment did not provide clear evidence concerning the role of thematic structure in syntactic representation. However, research reported by Urbach *et al* (1995) which used a different experimental measure has confirmed the weak tendency found in this experiment for a syntactic priming effect in comprehension between sentences which share constituent structure but not thematic structure. This suggests that there is a level of representation at which constituent structure information and thematic structure information are separated. This is compatible with Bock and Loebell's (1990) findings for production.

On a methodological note, the results outlined here suggest that there are some instances of priming may be hard to detect and that whole-sentence self-paced reading may not be a sufficiently sensitive measure to detect priming effects of this type. Subsequent work in this area would benefit from using a different experimental measure.

7.8 Summary

In this chapter, I have shown that the comprehension of a sentence can be affected by the syntactic structure of a previous sentence, in other words that syntactic priming effects occur in comprehension. This suggests strongly that comprehension involves processing which is syntactic in nature. We can also draw some tentative conclusions about the representations which are involved in this. Although a self-paced reading experiment reported here did not produce significant results, work using essentially the same materials suggests that constituent structure information but not thematic information is represented. The experiments also suggest that priming has a strong competitive component, affecting the way in which the processor chooses an analysis. However, a number of outstanding questions remain open for further research, including whether priming can alter the processor's initial choice of analysis, and whether it is a faciliatory or inhibitory effect, or a combination of the two. Overall, the priming effects found in comprehension are compatible with those found in production, and I suggest that the same explanation can be given for each: priming affects the activation of a syntactic rule and makes it more accessible for subsequent application.

Chapter 8

Syntactic priming from comprehension to production

8.1 Introduction

In the previous two chapters, I presented the results of studies which examined syntactic priming effects in language production and comprehension. I suggested that priming affects the activation of abstract syntactic rules such that producing a sentence with a particular structure makes it easier to produce a subsequent sentence with the same structure and comprehending a sentence with a certain type of local ambiguity makes it easier to comprehend a subsequent sentence with the same type of ambiguity. However, it was left open as to whether these rules should be interpreted as processes (which may be specific to production or comprehension, or may be common to both) or whether they should be interpreted as statements in the knowledge base which underlies use of language. In this chapter, I will be concerned with exploring this question. I will begin by discussing what sorts of evidence could be used to distinguish between the alternatives, arguing that bidirectional syntactic priming offers a means of doing this. I will then review whether there is any existing evidence for bidirectional syntactic priming. The main part of this chapter presents the results of an experiment investigating syntactic priming from comprehension to production and the implications of these results.

8.1.1 Unidirectional syntactic priming and its interpretation

The evidence presented in the previous two chapters suggests that both production and comprehension involve the computation of syntactic structure. The syntactic structure is specified in terms of abstract categories, which I suggested are related with respect to local domains. This bears a close resemblance to the statements, or rules, of theoretical linguists' grammars (e.g. phrase structure rules (GPSG) (Gazdar, Pullum, Klein & Sag 1985), signs/immediate dominance schemata (HPSG) (Pollard and Sag 1987, 1994), X-bar schema (GB) (Chomsky 1981,1982,1986), c-structures (LFG) (Bresnan 1982b)). In the preceding chapters, I suggested that the effect of priming was to facilitate the application of a particular rule. Previous use of a rule raised its activation and hence made it a better competitor for subsequent application.

However, I left the precise nature of these rules open.

One possibility, suggested by Bock (1986b), is that they are procedures which are responsible for the creation of syntactic structure. In that case, priming occurs because use of a particular procedure, which may be specific to production or comprehension, predisposes its subsequent re-use. For example, priming of a reduced relative structure in comprehension would occur because the process responsible for creating a reduced relative structure from an unstructured string of words would be more highly activated. An alternative possibility is that the rules correspond to statements which encode knowledge of syntactic structure. That is, priming taps into the knowledge of language which underlies language use. In that case, the effect of priming is to raise the activation of one of the statements which constitute knowledge of language and which are common to both production and comprehension. For example, priming of a double object structure in production would occur because the statement in the knowledge base which states that a VP may consist of a verb and two NP arguments (and equally that a verb and two NP arguments may form a VP) would be more easily accessed following its previous use. Such a statement could be accessed by both production processes and comprehension processes.

All of the experiments presented in the previous two chapters investigated unidirectional priming, i.e. priming from comprehension to comprehension or from production to production. The priming effects found in those experiments are compatible with both of the possibilities described above, since in unidirectional priming, both the same procedures and the same knowledge are involved in processing the prime and target. Hence unidirectional priming does not allow us to distinguish between a priming effect based upon repetition of procedures and one based on repeated accessing of the same knowledge statement.

However, it is in principle possible to rule out the possibility that priming effects are caused by the activation of modality-specific processes, in other words processes which are specific to comprehension or to production. (In what follows, I will refer to comprehension and production as different modalities. This is a non-standard use of the term 'modality', but there is no alternative terminology in common use). This could be achieved by demonstrating that priming takes place bidirectionally, from comprehension of a structure to production of that structure or alternatively from production of a structure to its comprehension. An account based upon activation of modality-specific processes would predict no priming effect under these circumstances, since processing of the prime would activate processes which are distinct from those involved in processing the target. Hence any priming effect found here would have to be explained in terms of something common to both comprehension and production, either common processes or underlying knowledge which is drawn upon in both cases. The reasoning here is similar to that of Marslen-Wilson, Tyler, Waksler & Older (1994), who used cross-modal priming to studying lexical representation. They suggested that cross-modal priming effects must be mediated through something which is modality-independent and cannot be explained in terms of lower-level overlap in modality-specific processes or representations.

8.1.2 Existing evidence for bidirectional priming

So far, almost all of the work which has been carried out on syntactic priming has concentrated on production-to-production priming and comprehension-to-comprehension priming. The only research which has involved priming across modalities is that of Levelt & Kelter (1982), discussed in Chapter 6. To recapitulate, Levelt and Kelter carried out a series of experiments which examined what they termed 'the correspondence effect' in question–answer sequences which involved either PPs or NPs. In their experiments, subjects listened to questions, either over headphones or over the telephone, and then answered them. Levelt and Kelter found that the form of the question affected the form of the answer: questions involving PPs (8.1a) tended to elicit answers involving PPs, either full sentences as in (8.1b) or in the vast majority of cases, an elliptical answer as in (8.1c), whereas questions involving NPs (8.2a) tended to elicit answers involving NPs as in (8.2b) and (8.2c).

(8.1) a. Aan wie laat Paul zijn viool zien ?
To whom lets Paul his violin see ?
'To whom did Paul show his violin ?'

b. Aan Toos laat hij zijn viool zien.
To Toos lets he his violin see
'He showed his violin to Toos'.

c. Aan Toos.
To Toos
'To Toos.'

(8.2) a. Wie laat Paul zijn viool zien ?
Whom lets Paul his violin see ?
'Whom does Paul show his violin ?'

b. Toos laat hij zijn viool zien.
Toos lets he his violin see
'He shows Toos his violin'

c. Toos.
Toos
'Toos.'

Hence the form of a question which subjects heard affected the form of an answer which they produced. As such, these results might be evidence of bidirectional syntactic priming, i.e. priming from comprehension of a structure to its subsequent production.

However, it is not clear that we can conclude from Levelt and Kelter's results that bidirectional priming is generally possible. Firstly, as already discussed in Chapter 6, the possibility of a lexical priming effect based on repetition of the preposition cannot be excluded. Most responses were elliptical, as in (8.1c) and (8.2c), and so consisted of just an NP or a preposition and an NP. Since the question and the answer always involved the same preposition (*aan* in the example above), at least part of the effect could have resulted from repetition of the preposition. Secondly, Levelt and Kelter's investigation was limited to question-answer pairs.

Questions and answers are by their nature very strongly related. For example, the responses in Levelt and Kelter's experiments required either the repetition (as in (8.1b) and (8.2b) above) or the ellipsis (as in (8.3b) below) of the question, except for the replacement of a Wh-NP with a non-Wh-NP. (The elided words are represented in square brackets).

(8.3) a. Aan wie laat Paul zijn viool zien ?
To whom lets Paul his violin see ?
'To whom does Paul show his violin ?'

b. Aan Toos [laat hij zijn viool zien].
To Toos [lets he his violin see]
'(He shows his violin) to Toos.'

As the possibility of a reflexive pronoun in (8.4b) shows, an elliptical answer falls in many ways within the scope of the question to which it forms a response.

(8.4) a. Who does John love ?

b. Himself.

Thus questions seem to create an expectation for a particular type of response. It is possible that repetition of the syntactic structure of the question is a characteristic of answers and hence that the syntactic repetition found in these circumstances does not represent a general syntactic priming effect.

There is some experimental evidence that question and answer sequences are closely associated during processing. Malt (1985) reported the results of a series of experiments investigating verb ellipsis. She found that an elliptical sentence was easier to process when it constituted a possible answer to a preceding question than when it followed a declarative sentence or when it could not be interpreted as the answer to the question. Malt suggested that because questions project an expectation for a response, they are retained in short-term memory until the response has been processed. Since the correct interpretation of verb ellipsis depends upon the syntactic structure of the antecedent, this would suggest that the listener retains not only the meaning of a question but also its syntactic structure in short-term memory. This could in turn affect the form of the response.

Thus while Levelt and Kelter's work may demonstrate a bidirectional priming effect, there are a number of confounding factors which could allow alternative explanations for their findings. It is not clear that lexical factors can be ruled out and even if the effect could be shown to be syntactic, it is not clear that it can be generalised from question-answer sequences, since a syntactic repetition effect may be inherent in exchanges of this type because of the prime and target are so strongly connected. We would wish to demonstrate that comparable effects can be found between sentences which are not in a question–answer relationship before concluding that bidirectional syntactic priming occurs. The experiment presented in the remainder of this chapter set out to examine this issue.

8.2 Bidirectional priming: Experiment

8.2.1 Experimental issues

To recapitulate, I have suggested that bidrectional priming offers us a way of determining whether or not priming effect arise from the facilitation of modality-specific processes. However, research on bidirectional priming has so far been limited to Levelt and Kelter's (1982) work, which focused on repetition effects in question–answer sequences. The experiment which is presented here was designed to explore whether bidirectional syntactic priming effects could be found between sentences which were not related in this way and hence to provide more reliable evidence concerning the locus of syntactic priming.

In principle, if bidirectional priming occurs, it should be possible to find evidence of priming occurring in two ways: from production to comprehension, or from comprehension to production. This in turn gives rise to two possible modes of investigation. We could study the effects when subjects comprehend a sentence after first producing another sentence (production-to-comprehension priming); or alternatively the effects when they produce a sentence after comprehending a sentence (comprehension-to-production priming). In the first case, we might expect comprehension of a sentence to be facilitated if a sentence with the same structure had just been produced. In the second case, we might expect that subjects would be more likely to produce a sentence with a particular structure following comprehension of a sentence with that structure.

Production-to-comprehension priming

In this experiment, as in Levelt and Kelter's experiment, comprehension-to-production priming was investigated. This was for essentially practical considerations. In Chapter 6, it was shown that at least a major component of priming seems to be linked to competition between alternative structures and hence priming effects were only detectable (using whole sentence self-paced reading) in sentences involving strong garden paths. If priming effects are essentially competitive in nature, this means that in order to detect any priming effect, we would have to ensure that the priming sentence which subjects produced had a structure corresponding to one of the alternative structures for the target sentence, for example sentence involving a reduced relative clause. Although not impossible, this would be difficult. It would be difficult to elicit the appropriate types of structure using a sentence completion task of the type used in the production-to-production experiments described in Chapter 6, whilst the method used by Bock and her colleagues (Bock 1986, 1989; Bock and Loebell 1990; Bock, Loebell and Morey 1992), repeating a sentence presented by the experimenter, would be inappropriate here. To see why, let us consider the example of reduced relative clause sentences, as in (8.5) below.

(8.5) The woman handed the package thanked the postman.

In this case, the rule of interest is that which associates a VP (*handed the package*) with an $\bar{N}$ (*woman*). The aim of the experiment is to investigate whether priming occurs when prime and target are processed in different modalities and so to rule out the possibility of priming reflecting the activation of modality-specific processes. Using an experimental method where the subject repeats the prime sentence would not allow us to do this, because in order to reproduce the prime sentence correctly, the subject must initially comprehend it (Potter & Lombardi 1990). Hence any priming effect which was found for the target could be caused by the repetition of a comprehension-specific process which had been applied during initial comprehension of the prime sentence. In this case, initial comprehension of the prime sentence would require the application of the process associated with reduced relative clauses. This process could then be more highly activated and hence a better competitor during comprehension of the target.

Comprehension-to-production priming

By comparison, comprehension-to-production priming is straightforward to investigate, since the experimenter can control the form of the prime sentence and then use stimuli which have been shown to be effective in previous experiments to elicit a target sentence (e.g. sentence completion). With comprehension-to-production priming, it might not be necessary for the prime sentence to involve a local ambiguity. It may not be immediately clear why this is the case. In the previous chapter, it was shown that syntactic priming affected the comprehension of a sentence if that sentence involved a competition between alternative structures. The effect of priming appeared to be to raise the activation of one structure relative to another. Hence it was not possible to facilitate the comprehension of – for example – a prepositional object sentence. However, this does not necessarily mean that priming has no effect upon the relevant rule in such sentences. As pointed out in the previous chapter, the activation of the relevant rule might well be raised, but since it is the only possible rule to apply in any case, priming cannot make it a better competitor. In other words, syntactic priming may raise its activation but this may have no behavioural effect on subsequent comprehension of a sentence with the same structure.

If this is correct, then although comprehension of an unambiguous structure may have no effect upon subsequent comprehension, the fact that the relevant rule is raised above its base activation will make it a better competitor for subsequent application during production. Hence for the purposes of comprehension-to-production priming, it should not matter whether the prime sentence involves a local ambiguity or not, which obviously broadens the range of structures which can be investigated and also allows the experimenter to choose structures which he/she knows can be elicited during production.

The structures which were investigated in this experiment were prepositional and double object sentences, since they had already been studied in previous unidirectional priming experiments. The method which was used was a variant of the sentence-completion method used in previous production priming experiments. In this case, subjects read a priming sentence with either a prepositional object or double object structure before completing a target sentence which allowed either structure.

It would be possible to present the prime and target sentences in a list, with subjects alternately reading and completing sentences. This method was not used, however, for two reasons. Firstly, it was felt that this might seem an unnatural task to subjects and that it would be difficult to provide a convincing cover story for the experiment. Secondly, it seemed likely that in these circumstances, subjects might not read and process the prime sentences

properly, reducing any priming effect. In order to avoid these problems, the sentences were presented in the form of three-sentence short stories to read and complete, as in (8.6) below. The second sentence of each story was the priming sentence and the third sentence was the target. Presenting the experimental materials in this format gave the subjects a reasonably natural task to carry out, and encouraged them to read the priming sentences carefully.

(8.6) An extremely urgent package had just arrived at the reception desk for the busy executive.
The courier handed the receptionist the package.
The receptionist took ...

If priming does occur bidirectionally, then we would expect to find more target fragments completed as double objects following a double object prime sentence and more fragments completed as prepositional objects following a prepositional object prime sentence. If priming does not occur bidirectionally, then we would not expect to find any difference in the proportions of each type of response between conditions.

8.2.2 Method

Subjects

The subjects consisted of 24 paid undergraduate students from the University of Glasgow.

Materials

The materials for the experiment consisted of 20 sets of priming materials. Each set consisted of a short story comprised of two complete sentences and a sentence fragment. The first complete sentence in each story provided a context for the story and was syntactically unrelated to the prime and target sentences. The second complete sentence was a priming sentence and included a subject NP, a ditransitive verb and two object NPs. The sentence fragment comprised the target. It consisted of a subject NP and a ditransitive verb only. The verbs employed in each set were always different, and a wide range of ditransitive verbs were employed. Each sentence was presented on a separate line.

Two alternative versions of each set of materials were constructed; examples are given in (8.7) and (8.8) below. In both versions, the context-setting sentence (*The cricket umpire suspected that the ball had been tampered with*) and the target fragment (*The umpire showed ...*) were identical. However, the prime fragments differed: both versions involved the same subject NP, the same verb, and the same object NPs, but differed in their syntactic structure. In one version, the prime sentence consisted of a prepositional object sentence (8.7); in the second version, it consisted of a double object sentence (8.8).

(8.7) The cricket umpire suspected that the ball had been tampered with.
The bowler threw the ball to the umpire.
The umpire showed ...

(8.8) The cricket umpire suspected that the ball had been tampered with.
The bowler threw the umpire the ball.
The umpire showed ...

Thus for each set of materials, subjects read either a prepositional object priming sentence or a double object priming sentence; they then produced a completion for a fragment which consisted of just a subject NP and a ditransitive verb and so was compatible with either structure.

There was some concern that presenting the target fragment as part of a short story might predispose subjects to produce completions which included pronouns referring back to entities introduced in the previous two sentences, and that this might affect the form of subjects' responses, for reasons which I will return to in section 8.2.4. To encourage subjects not to use pronouns in their responses, the contexts were constructed to include multiple referents where possible, such that use of a pronoun would lead to referential ambiguity. A complete list of materials is provided in Appendix D.

An additional 28 filler materials were constructed. These were identical in form to the experimental materials, consisting of two complete sentences followed by a sentence fragment which together formed a short story. The filler materials contained sentences of various types but no ditransitive verbs appeared in them. An example of a filler material is given in (8.9) below.

(8.9) The architect won the competition to design the new museum.
The trustees of the museum liked his classical design.
The builders began ...

Two presentation lists were constructed from these materials. Each list contained 10 materials of the type shown in (8.7) and 10 materials of the type shown in (8.8), giving a total of 20 priming trials, interspersed with the 28 fillers. The experimental materials and the fillers were randomised with the constraint that at least one filler intervene between each experimental item. The materials were then printed out as eight-page booklets. The order of the pages was randomised for each subject. Thus the order of the materials on each page was the same for each subject but each subject saw the pages in a different order.

The instructions on the cover of each booklet explained that we were interested in seeing what sorts of stories people produce. The instructions asked the subjects to read the sentence beginnings carefully and then complete the final fragment in each story in any way that they liked, as quickly as they could, with the first completion that came to mind. It was stressed that subjects should read the beginning carefully, that they should ensure that their completion formed a grammatical sentence, that they should complete the stories in order, and that they should write down the first completion which they thought of.

Procedure

Subjects were each given a booklet to complete and told to hand it back to the experimenter when they had finished. The experimenter answered any questions that the subjects had about the task. The booklet took about 15 minutes to complete.

Scoring

For each fragment, the first legible response made by the subject was scored as a prepositional object sentence, a double object sentence or other. The scoring criteria were essentially the same as those used by Bock and Loebell (1990).

A sentence was scored as a prepositional object sentence if the first NP following the verb was the patient/theme, followed by the beneficiary as the object of the preposition *to*. To be scored as a double object sentence, the verb had to be followed by two NPs; the first NP following the verb had to be the beneficiary and the second NP had to be the patient/theme. To be scored in either category, a description had to have a grammatical alternative in the other category where the positions of patient/theme and beneficiary were reversed (this was to ensure that each prepositional object completion allowed a control form and vice versa).

'Other' responses were those which did not meet the scoring criteria. These were sentences which were completed with alternative structures, such as simple transitive sentences etc.

Design and data analyses

There was one independent variable, prime sentence type (prepositional object versus double object). This yielded two conditions. Each subject completed 20 experimental materials, 10 in each condition. Each material was presented to 24 subjects, 12 in each condition.

Two types of analysis were carried out. The first considered all target completions, including those that involved pronouns. The dependent variables in this analysis were the numbers of prepositional and double object targets produced following prepositional object primes, expressed as a proportion of *all* the responses which were produced after a prepositional object prime; and the number of prepositional/double object targets produced after a double object prime, expressed as a proportion of all the responses produced after a double object prime.

The second type of analysis, which I will term the 'full NP' case, excluded completions which included a pronominal object NP. In this case the dependent variables were the number of prepositional/double object targets which did not include pronominal object NPs produced after prepositional object primes, as a proportion of the total number of responses (including pronominal responses) produced after prepositional object primes; and the number of prepositional/double object targets which did not include pronominal object NPs produced after double object primes, as a proportion of all responses produced after double object primes.

A further analysis was carried out on the full NP completions to ascertain whether any priming effect was dependent upon the prime and target having identical syntactic structures, or whether priming would still occur if the prime and target differed in some aspect of syntactic structure. This analysis therefore considered only those full NP responses where the internal structure of at least one of the object NPs in the target differed from the internal structure of the corresponding object NP(s) in the prime. The dependent variables in this analysis were the number of prepositional/double object targets meeting these criteria which were produced after prepositional object primes, as a proportion of the total number of responses produced after prepositional object primes; and the number of prepositional/double object targets meeting these criteria which were produced after double object primes, as a proportion of the total number of responses produced after double object primes.

Analyses of variance were carried out on the data, with separate analyses treating subjects and items as random effects.

8.2.3 Results

Results for all responses

Out of the 480 priming trials, there were 356 (74%) successful priming trials, i.e. trials where the target was completed as either a prepositional object sentence or a double object sentence, and 124 (26%) trials where the target response did not fall into either category. An approximately equal proportion of the target responses were completed as prepositional/double object sentences in each condition: 73% following double object primes and 75% following prepositional object primes.

In Table 8.1 below, the percentages of each type of response following each type of prime are presented.

	PObj Prime	*DObj Prime*
PObj target	51 (21%)	38 (16%)
DObj target	125 (52%)	142 (59%)
Other response	64 (27%)	60 (25%)

Table 8.1: All responses following PObj/DObj prime

The tables above show that when all responses are considered, subjects produced many more double object completions than prepositional object completions. An analysis of variance confirmed a main effect of target sentence type ($F_1(1,23) = 73.73$, $p = .0001$; $F_2(1,19) = 17.02$, $p = .0006$). In strictly numerical terms, subjects produced more prepositional object completions following prepositional object primes (21% of responses) than following double object primes (16% of responses), and double object target completions were produced more frequently following a double object prime (59% of responses) than following a prepositional object prime (52% of responses). Overall, subjects completed the target sentence with the same structure as that of the priming sentence 40% of the time and with the alternative structure 34% of the time. However, the prime sentence type by target sentence type interaction did not achieve statistical significance. Subjects were not reliably more likely to produce the structure used in the previous fragment than the other structure ($F_1(1,23) = 2.19$, $p = .15$; $F_2(1,19) = 2.16$, $p = .16$). There was no main effect of prime sentence type (all $Fs < 1$).

Results excluding pronominal object NPs

The results presented above considered all prepositional and dative object responses. In this section, I will concentrate on those completions which included only full object NPs, e.g. *The secretary showed the fax to the ambassador*; I will exclude from consideration those completions where at least one of the object NPs was pronominal, e.g. *The secretary showed it to the ambassador.* There were 176 (37%) successful priming trials which did not involve pronominal object NPs and 180 (38%) which did involve pronominal object NPs. Table 8.2

presents a breakdown of the full NP responses to each type of prime; the 'other' category includes those double/prepositional object responses which involved pronominal object NPs. For completeness, the figures for these pronominal responses are presented in Table 8.3.

	PObj Prime	*DObj Prime*
PObj target	37 (15%)	27 (11%)
DObj target	43 (18%)	69 (29%)
Other response	160 (67%)	144 (60%)

Table 8.2: Full NP responses following PObj/DObj prime

	PObj Prime	*DObj Prime*
PObj target	14	11
DObj target	82	73

Table 8.3: Dobj/Pobj responses containing pronominal object NPs: Total tokens

I will begin by briefly discussing the results for responses involving pronouns. As Table 8.3 shows, most of the responses involving pronominal object NPs were double object responses. The most important point to note is that the incidence of pronominal responses did not seem to be affected by the priming manipulation: pronominal responses occurred in similar proportions after both types of prime sentence. This suggests that the pronominal responses added noise to the overall pattern, by greatly increasing the proportion of double object responses, but did not fundamentally alter it. Hence we can be reasonably certain that excluding the pronominal responses from consideration does not distort any priming effect which exists, but instead removes extraneous noise and so makes the priming effect clearer.

Turning to the full NP responses, the results show that subjects tended to complete fragments with the same structure as a previous sentence which they had read. Overall, 22% of target completions had the same structure as the priming sentence and 15% had the alternative structure. An analysis of variance confirmed that subjects were more likely to produce the structure which appeared in the previous fragment than the other structure ($F_1(1,23) = 8.67$, $p = .007$; $F_2(1,19) = 6.62$, $p = .02$). Planned means comparisons showed that the effect was centred upon double object responses: subjects were significantly more likely to produce a double object target following a double object prime (29% of target completions) than following a prepositional object prime (18% of target completions) ($F_1(1,23) = 8.64$, $p = .007$, $F_2(1,19) = 6.76$, $p = .02$). However, although subjects produced numerically more prepositional object completions following a prepositional object prime (15% of target completions) than following a double object prime (11% of target completions), this effect was not statistically significant ($F_1(1,23) = 1.50$, $p = .23$, $F_2(1,19) = 1.08$, $p = .31$). The results also show that subjects produced more double object completions (112 in total) than prepositional object completions (64 in total), confirmed by a main effect of target sentence type, significant by subjects and marginal by items ($F_1(1,23) = 13.94$, $p = .001$; $F_2(1,19) = 3.43$, $p = .08$). No other effects approached significance (all $Fs < 1$).

Full NP responses involving different object NP structures

In this section, I am concerned with the subset of full NP responses where the internal structure of at least one of the object NPs in the target completion differed from that of the corresponding object NP(s) in the prime sentence. There were 48 (10%) successful priming trials which fulfilled these criteria. Table 8.4 presents a breakdown of the responses following each type of prime; because the numbers involved are small, I will present the percentages to one decimal place.

	PObj Prime	*DObj Prime*
PObj target	10 (4.2%)	7 (2.9%)
DObj target	13 (5.4%)	18 (7.5%)
Other response	217 (90.6%)	60 (89.6%)

Table 8.4: Full NP responses (different object NP structure) following PObj/DObj prime

The results suggest that even when the prime and target differed with respect to the internal structure of at least one object NP, subjects tended to complete fragments with the same structure as a previous sentence which they had read. Overall, 11.7% of target completions had the same structure as the priming sentence and 8.3% had the alternative structure. An analysis of variance confirmed that subjects were more likely to complete a target fragment using the same structure as that in the preceding sentence, significant by subjects though not by items ($F_1(1,23) = 5.09$, $p = .03$; $F_2(1,19) = .90$, $p = .35$). The effect appeared to be centred on double object completions: double object primes increased the production of double object target completions by 2.1 %, from 5.4% to 7.5%. Prepositional object primes also increased the proportion of prepositional object target completions, but by only 1.3%, from 2.9% to 4.2%. Planned means comparisons confirmed that double object completions were produced more frequently following a double object prime than following a prepositional object prime, significant by subjects though not by items ($F_1(1,23) = 5.73$, $p = .03$; $F_2(1,19) = 1.30$, $p = .27$). However, prepositional object completions were not produced reliably more frequently following prepositional object primes (all $Fs < 1$).

8.2.4 Discussion

The results suggest that under certain circumstances, comprehension of a sentence with a particular syntactic structure can affect the syntactic structure which is produced for a subsequent sentence. This manifested itself as an increase in the proportions of double object and prepositional object sentence completions which were produced following comprehension of double object and prepositional object sentences respectively. This effect was reliable for completions which contained only full NPs but not for completions containing pronominal object NPs. The effect did not seem to be dependent upon the prime and target sentences having globally identical structures: a priming effect which was reliable by subjects was found when only those target sentences where the internal structure of at least one of the object NPs differed from that in the prime sentence were taken into consideration.

Excluding other explanations

Discourse and semantic influences do not seem able to account for the syntactic repetition effect found in this experiment. The prepositional and double object sentences studied in this experiment express the same information, and do not seem to differ in their discourse structure. Subjects always had a choice between producing a prepositional object completion and producing a double object completion for each target fragment. As the results show, they could and did produce both types of structure in both conditions. The systematic differences in the proportions of each type of completion depending on the structure of the previous sentence cannot therefore be attributed to differences in meaning.

Neither can the effect be explained in terms of lexical influences. Repetition of open class lexical items would not explain the syntactic alternation which was found, since such items could appear in either structure. Hence any explanation based upon lexical factors would have to relate to closed class items. This source of explanation can also be ruled out. The only difference between prepositional and double object completions with respect to closed class items is the presence/absence of a preposition. Thus if the syntactic repetition effect resulted from lexical priming, it could only be by priming the preposition and hence we would expect to find the effect only for prepositional object completions. In this experiment, however, the syntactic repetition effect occurred significantly in the double object case where no preposition appears. Hence the syntactic repetition effect cannot be attributed to lexical priming of the preposition. Finally, the effect cannot be explained in terms of the repetition of a subcategorisation frame associated with a particular verb, i.e. priming lexical access of a particular verb–subcategorisation frame combination, because the prime and the target always involved different verbs.

Note also that the priming effect must have transferred from comprehension to production: subjects read a prime sentence and then produced a completion for the target sentence. Processing the prime sentence did not involve language production in any way and although subjects had to comprehend the target fragment in order to produce a grammatical completion, the fragment consisted of just a subject NP and a verb. Thus there could be no comprehension-specific process which was relevant to the structure of the VP and which was used in both prime and target. In any case, any such process could not – by definition – affect the form of the completion which was produced.

It therefore appears that the effects found in this experiment cannot be explained in terms of semantic or lexical factors. I suggest that the systematic variation in the proportion of prepositional/double object sentences resulted from similarities between the prime and the target at the level of syntactic structure. This similarity existed even when the prime and target sentences were processed in different modalities (where – as stated above – the term 'modality' is used to distinguish between production and comprehension). Hence we can conclude that bidirectional syntactic priming from comprehension to production can occur in some circumstances: comprehending a sentence with a particular structure can increase the likelihood of subsequently producing a sentence with that structure. In the following sections, I will consider how the results of the previous experiment fit with those from previous experiments before discussing the implications of bidirectional priming and the circumstances under which it occurs.

Comparing the present results with previous results

The results of the present experiment are compatible with those found in previous experiments. As in previous experiments, priming took place from a prime sentence involving one verb and its arguments to a target fragment involving a different verb and different arguments. This is consistent with the proposal that syntactic priming effects occur when a syntactic rule of some sort, specified in terms of abstract syntactic categories (such as 'verb'), is applied more than once in succession.

The results also provide some support for the hypothesis that such rules specify local syntactic relations, in this case the structure of the VP (V NP NP or V NP PP). Comprehension of a sentence involving the structure V NP NP made production of a V NP NP structure for a subsequent sentence more likely, but the prime and the target often differed in other respects, such as the internal structure of the NPs. If the rules which priming taps into specified entire sentences, or perhaps the structure of the entire VP, then the result of priming would be to elicit the production of target sentences whose global syntactic structure was identical to that of the prime sentence or targets whose VP structure was identical to the prime's VP structure. However, the analyses presented in section 8.2.3 show that a significant priming effect was found for target completions which differed from the prime in terms of their detailed syntactic structure, i.e. with respect to the internal structure of object NPs, for example through the addition or omission of adjectives, relative clauses and so on.[1] Hence the effect of priming seems to have been to influence a choice about the immediate expansion of the VP, not the structure of the entire sentence or the detailed structure of the entire VP.

The results are also consistent with the hypothesis which has been outlined in previous chapters concerning the way in which priming effects occur. It has been suggested that whenever a rule is applied, its activation is raised. If there is subsequently a competition in which this rule takes part, this raised activation will make it a better competitor, resulting in a priming effect. Priming is therefore proposed to be essentially a competitive effect: it increases the likelihood of making one choice rather than another. This approach draws a distinction between the initial activation of a rule and the priming effect which may result from this raised activation. Hence repeated application of a rule will always result in raised activation but may not result in a priming effect.

The result of the present experiment provides support for this hypothesis: comprehension of a double object sentence resulted in a priming effect for the production of double object structures, even though we saw in the previous chapter that comprehension of a double object sentence does not result in a priming effect for the subsequent comprehension of double object structures. This can be explained if we assume that the comprehension of a double object sentence raises the activation of the rule associated with double object structures but that this raised activation will only give rise to a priming effect where there is a competition between alternative rules.

[1]The results were not significant by items, but I suggest that this is a problem of power, resulting from the small number of items involved.

The implications of bidirectional priming

So far I have suggested that the results provide evidence for bidirectional syntactic priming. Comprehension of a sentence with a particular structure affected the way in which a subsequent sentence fragment was completed at a particular level of structure (the immediate expansion of the VP). This is compatible with the results of previous experiments which suggest that priming arises from the facilitation of abstract syntactic rules. It now remains to discuss the implications of these findings.

In previous chapters, two possibilities were put forward concerning the way in which priming is effected and so – by extension – the nature of the syntactic rules to which I have been referring. The first possibility is that suggested by Bock (1986b): priming facilitates the use of particular 'cognitive procedures responsible for the realization of syntactic structure,' (Bock 1986b, p.379). In that case, the syntactic rules which I have been discussing would correspond to processes. Priming would then result from the facilitation of dynamic processes which operate over abstract syntactic categories. For example, priming of a prepositional object structure would occur when the process responsible for creating V NP PP structures had been applied previously and as a result had a raised activation, making it susceptible to subsequent use. In principle, these processes could be modality-specific, i.e. specific to production or to comprehension, or common to both modalities.

The alternative possibility is that priming taps into knowledge about possible relationships between different syntactic categories, i.e. knowledge of language. In that case, the syntactic rules alluded to in the discussion above are rules of the sort familiar to theoretical linguists: statements which encode knowledge, not dynamic processes. For example, the rule VP $\rightarrow$ V NP PP simultaneously encodes the facts that a VP may consist of a V, an NP and a PP, and that a V NP PP sequence may comprise a VP. According to this view, a priming effect occurs when one of the statements in the knowledge base which underlies use of language has been previously accessed and so has a raised activation. This statement is then more easily accessed in subsequent language use. Under this view, priming of a prepositional object structure would occur when the statement in the knowledge base which licenses prepositional object structures (such as the rule given above) was repeatedly accessed.

In the present experiment, we found priming effects from comprehension of a structure to production of that structure. On the basis of these results, we can immediately rule out one possibility. If priming resulted purely from the repetition of processes restricted to comprehension or to production, we would expect to find unidirectional priming only, never bidirectional priming. By definition, comprehension and production have no modality-specific processes in common; there is therefore no way under an account of priming based upon the repetition of modality-specific processes in which comprehension of a double object structure could predispose production of that structure. Hence priming cannot be explained purely in terms of modality-specific processes. Instead, the results found in this experiment can only be explained in terms of something which is common to both modalities, in other words some aspect of the human language faculty which is relevant to both production and comprehension.

This would not a priori rule out the possibility of priming resulting from the repetition of processes of some sort. It is possible that production and comprehension have some processes in common and that the priming effect observed in this experiment occurred when one of these processes was repeatedly used. However, this seems unlikely. Production and comprehension involve fundamentally different processes. Production involves mapping from a functional structure, where grammatical relations are specified, to a constituent structure. Comprehension, on the other hand, involves mapping from a string of hierarchically unstructured words to a constituent structure. Hence although the output is the same in each case (constituent structures), the input differs substantially (functional structures versus unstructured strings). It is not obvious that we would expect to find common processes, nor indeed how such processes might be realised.

It therefore seems unlikely that the bidirectional priming effect found in this experiment can be explained in terms of processes which are common to production and comprehension. In that case, the only way in which it can be explained is in terms of knowledge which is shared by production and comprehension. That is, both production and comprehension must make reference to a single knowledge base which encodes information about possible syntactic relations. I suggest that a priming effect occurs when a statement in this common knowledge base is repeatedly accessed. Because this knowledge is common to both modalities, it is immaterial whether prime and target are presented in the same modality: the same statement in the knowledge base will be relevant to both comprehension and production. For example, comprehension of a double object structure involves accessing (and hence raising the activation of) the statement which encodes the knowledge that a V NP NP sequence may comprise a VP and a VP may consist of a V NP NP. This knowledge is also accessed during production of a double object structure. Hence comprehension of a double object sentence raises the activation of the statement licensing double object structures, relative to that licensing prepositional object structures, and hence primes the subsequent production of a double object structure.

This is not to deny the possibility that in unidirectional priming experiments, we may additionally be tapping into procedures. In other words, unidirectional priming effects may result in part from the facilitation of certain procedures associated with syntactic structure. However, the results of this experiment suggest that there is, in addition to any effect based upon modality-specific procedures, an effect which is based on something shared between production and comprehension, for which the most plausible candidate is knowledge associated with syntactic structure. If this is correct, then priming experiments tap into knowledge about syntactic structure, and evidence from bidirectional priming experiments can constitute direct evidence about the form of that knowledge.

In that case, the inferences which we draw about knowledge of language on the basis of evidence from bidirectional priming do not rely upon the ultimate validity of the strong competence hypothesis. In this thesis, I have assumed that the strong competence hypothesis is correct, and that there is an isomorphism between the statements of the competence grammar and the operations/representations of the processor. Under this assumption, inferences about the form of the competence grammar can be made from evidence about processing operations/representations. Under the weak competence hypothesis, however, the relationship between the competence grammar and the operations/representations of the processor need not be straightforward. Hence if the weak competence hypothesis ultimately turned out to be correct, inferences about the form of the competence grammar could not be drawn from

evidence about processing. It follows that if priming arose from the repeated use of particular processes, the evidence which priming experiments provide could only be interpreted as evidence about the form of the competence grammar under the assumption that the strong competence hypothesis is correct. If bidirectional priming taps into representation directly, however, as I suggest, the validity or otherwise of the strong competence hypothesis becomes irrelevant: any evidence which we find in bidirectional priming experiments constitutes direct evidence about knowledge of syntactic structure itself.

In this experiment, we have only examined one pair of constructions, prepositional object sentences and double object sentences. However, there is no reason to believe that bidirectional priming effects will be restricted to this pair of constructions: we would expect to find priming effects occurring between other types of sentence (recall, for example, that Bock (1986b) found syntactic priming effects for active/passive sentences); we would also expect to find priming effects at other levels of structure, for example with respect to NP structure. Hence in principle, it should be possible to use bidirectional priming experiments to examine other aspects of syntactic knowledge and how it is represented, for example the nature of the rules which are associated with the internal structure of NPs. They might also be used to investigate more contentious issues about syntactic structure; I will return to this point in Chapter 9.

The absence of priming effects with pronouns

One final point which must be discussed is why there was no reliable priming effect for target completions containing pronouns. There are two possible explanations for this. One is that the prime and the target did not involve the same rules, in other words that the rule associated with double object VPs involving full NPs was not the same as that associated with double object VPs involving pronouns. In that case, activation of the rule associated with the prime would be irrelevant with respect to the realisation of the target sentence. The second possibility is that the relevant rule was activated but that its activation was not sufficient to produce a reliable priming effect.

The first possibility rests on the assumption that full NPs and pronouns are not members of the same syntactic category. In other words, although linguists might propose on the basis of distributional evidence and grammaticality judgements that pronouns and full NPs both constitute members of a single class, they are mentally represented distinctly. In that case, the rule which encodes the knowledge underlying processing of (8.10a) below would be distinct from that encoding the knowledge which underlies (8.10b) below, since the rules would have to be specified in terms of different categories. For example, (8.10a) might be captured by (8.11a), where FNP represents a full NP, whereas (8.10b) might be captured by (8.11b), which contains specifications for a PRN (= pronoun).

(8.10) a. The teacher gave the boy the pen.
b. The teacher gave him the pen.

(8.11) a. VP $\rightarrow$ V FNP FNP
b. VP $\rightarrow$ V PRN FNP

In that case, priming would not occur between a prime sentence involving full NPs and a target sentence involving pronouns, since the rule activated during processing of the prime sentence (such as (8.11a) would not be the same as that activated during processing of the target (such as (8.11b)).

This explanation seems highly unlikely. If it were correct, then for every rule which allows a full NP to appear in some position, there would have to be another rule specifying exactly the same information except for the fact that a pronoun could appear in place of the full NP. For example, three separate rules would be necessary to capture the double object structure exemplified above, since in addition to the two rules in (8.11), there would also have to be a VP → V PRN PRN rule to capture the possibility of VPs containing two pronouns, as in *The teacher gave him it.* In the absence of any supporting evidence that pronouns and full NPs are represented as forming distinct categories, I suggest that distributional evidence and parsimony argue against this possibility, although it could be tested relatively straightforwardly by using prime sentences which themselves involved pronouns.

The alternative explanation assumes that pronouns and full NPs form a single category and that the same rules which apply to sentences involving pronouns apply to sentences involving full NPs. According to this view, there is no reliable priming effect with sentences involving pronouns because the activation of the primed rule is outweighed by other processing considerations. Essentially, priming increases the likelihood of selecting one structure over another, all other things being equal. However, any priming effect can be overridden if there are other factors working in favour of the alternative structure. For example, in two experiments Bock (1986b) found no priming effect for passive structures when the target involved a human agent. She attributed this to the strong preference for human agents to appear as subjects (resulting in an active sentence) outweighing the priming effect from a preceding passive prime. I suggest that the same explanation can be put forward for target completions which involved pronouns. In neutral contexts, there is a preference for pronouns to appear earlier in the sentence than full NPs: (8.12a) and (8.13a) below sound more natural than (8.12b) and (8.13b). (8.12b) and (8.13b) both require a contrastive stress pattern (and hence a contrastive context) to sound felicitous.

(8.12) a. The teacher gave him the heavy textbook.

b. The teacher gave the heavy textbook to him.

(8.13) a. The teacher gave it to the young boy.

b. The teacher gave the young boy it.

There are (at least) two plausible reasons for this. The first is that pronouns are syntactically less complex than full NPs. As we saw in Chapter 3, there is evidence that the syntactic complexity of a constituent can affect its position in the developing structure: syntactic encoding of less complex constituents will tend to be completed more quickly than encoding of syntactically complex constituents, with the result that syntactically less complex constituents will tend to precede more complex ones. Hence we would expect pronouns to be encoded more quickly than full NPs and hence to appear earlier in the sentence than them. In addition, pronouns usually refer back to entities which have already been mentioned and hence are salient

and easily accessible. Research has shown that 'old' information (information which is already present in the discourse context) usually precedes new information (Clark & Haviland 1977), again resulting in a tendency for pronouns to appear early in the sentence.

Thus for any functional structure involving a pronominal object NP and a non-pronominal object NP, both of the factors described above encourage the production of a structure in which the pronoun appears earlier in the sentence than the full NP. It is plausible to assume that the combined strength of these two factors can outweigh any benefit bestowed by the priming manipulation. Hence in a competition between an unprimed structure in which the pronoun precedes the full NP and a primed structure where the full NP precedes the pronoun, it seems likely that the strength of the factors favouring the unprimed structure will be greater than the priming effect favouring the other structure. The way in which this preference will manifest itself depends upon which participant is pronominalised. If it is the beneficiary, then the structure which allows the pronoun to appear earlier is the double object structure; if it is the patient, then it is the prepositional object structure. The examples in (8.14) exemplify this, with the pronouns italicised for clarity.

(8.14) a. The shop assistant showed *him* the video player.

b. The shop assistant showed *it* to the customer.

Since human entities tend to be more salient in discourse, we would expect more completions where it is the beneficiary which is pronominalised and hence more double object completions.

The results seem to bear this out. In 90% of the target responses involving pronominal object NPs, there was one pronoun and one full NP; in 96% of these cases, the pronoun preceded the full NP, as we would predict from the discussion above. The results also show that most of the completions involving pronouns were double object structures, again as predicted. The results are therefore consistent with the suggestion that no priming effect was found when completions involving pronouns were included in the analysis because the use of pronouns encourages the production of structures which allow the pronoun to precede the full NP, and this outweighs any priming effect. The prevalence of double object structures reflects the preference for pronominalising human entities.

On a methodological note, the ability of these factors to disrupt any priming effect suggests that in future experiments using this method, greater efforts should be made to discourage subjects from using pronouns in their completions. This could be done by explicitly telling subjects to avoid the use of pronouns, as in Bock and her colleagues' experiments, but this runs the risk of alerting subjects' attention to the form of their responses, and would also make their task more unnatural, both of which would be undesirable. An alternative strategy would be to provide subjects with multiple referents in the context so that the use of pronouns would be confusing. This strategy was used for some materials in this experiment but in some cases it was felt that providing multiple referents might make the contexts too complicated. Another potential disadvantage of this strategy is that subjects might be led to use pronouns contrastively. However, the contrastive use of pronouns seems to be restricted to spoken language, where the contrast is expressed prosodically, and I think it is unlikely that it would be a genuine problem in the written task used here. On balance, it might be preferable to make systematic use of this strategy, i.e. to use more complicated contexts in order to substantially reduce the use of pronouns.

8.2.5 Summary

In this chapter, I have investigated whether bidirectional syntactic priming effects occur. I have demonstrated that in certain circumstances syntactic priming can take place from comprehension of a particular structure to production of that structure. I argued that such a finding precludes the possibility of priming being based purely upon the repetition of modality-specific processes. Instead, the priming effect found here must be based upon something which is common to production and comprehension. This could in principle be either modality-independent processes or the knowledge of language which underlies language use. I have suggested that the former possibility is unlikely and that the bidirectional priming effect found in the experiment reported here is most likely to reflect repeated access of a statement in the competence grammar. Hence I propose that syntactic priming offers us a way of tapping into knowledge of language and how it is mentally represented.

Chapter 9

Conclusions

This thesis has been concerned with syntactic structure. It has aimed to address three issues. The first two issues are theoretical: how is syntactic structure mentally represented and how is it implicated in language processing? The third is methodological: how can these theoretical questions be investigated? These issues have important implications, both for theories of language processing and for linguistic theories which claim to be theories about mental representation. In keeping with this, the research reported here has taken an interdisciplinary approach, using experimental psychological methods to study questions which are usually considered to be the province of theoretical linguistics, and equally investigating how concepts developed in theoretical linguistics can be applicable to psychological processing theories. In order to gain as wide a picture as possible, both language production and language comprehension were explored. In what follows, I will begin by summarising the results, before drawing more general conclusions and highlighting possibilities for further research.

9.1 Summary of findings

I argued that assumptions about syntactic representation are fundamental to all theories of language processing. Every processing model must specify the nature of the input/output representations associated with each process and the knowledge which each process draws upon. In addition, these representations place constraints upon the possible processing algorithms. Most processing theories assume a representational system which is based on some linguistic theory, on the assumption that linguistic theories provide an appropriate characterisation of the mental representation of syntactic structure. In principle, since at least some linguistic theories claim to be theories about mental representation, this should be the case. However, most linguistic theories make use of a single source of evidence, grammaticality judgements, and the data which is collected in this way has been demonstrated to be unreliable. I argued that there is no principled reason why the investigation of syntactic representation should be limited in this way and proposed that alternative methods should be explored.

I began by exploring how corpora can be put to use in the study of syntactic representation and syntactic processing. I suggested that they are potentially a rich source of information about language processing, in particular language production. Corpora can be used not only to test, but also to generate, hypotheses about the processes and representations, including those relating to syntactic structure, which are involved in language production. I exemplified this with a case study of finite relative clauses in a corpus of spoken English. I showed that their distribution matched that predicted by some models of language production along two dimensions: the position of the relative clause in the matrix clause, and the grammatical function upon which relativisation took place. The corpus analysis also revealed an unexpected pattern of data with respect to zero relative clauses; this converged with the pattern which one would predict on the basis of one particular linguistic analysis of their syntactic structure. I suggested that the processing data could be viewed as empirical support for the theoretical linguistic analysis, and also proposed that the linguistic analysis could provide a pointer towards possible explanations for the processing data.

I then examined how two experimental methods, agreement error elicitation and syntactic priming, could be used to draw inferences about syntactic representation. I suggested that experimental evidence about the occurrence of subject–verb agreement errors is not only informative about the processes which underlie language production – the focus of such research to date – but also about syntactic representation, since different types of modifier induce different patterns of agreement errors. It is possible to investigate which types of modifier display common behaviour and hence form a class with respect to processing. The results of two experiments were presented. The first demonstrated that agreement errors occur in the production of written English, and showed that PP and complement clause modifiers induced distinct patterns of errors. The second experiment examined whether there was any behavioural evidence that predicate+argument units form a single class ('clause'), irrespective of finiteness, as many linguistic theories would suggest. It compared the occurrence of agreement errors following three types of predicate+argument modifier and following a PP modifier. The results suggested that predicate+argument modifiers do pattern together in a way distinct from that of PP modifiers. I argued from this that there is a convergence between a class of units for which there is behavioural evidence in language production and a class of units which linguists have identified on the basis of grammaticality judgements.

Following this, I discussed the significance of an experimental method, syntactic priming, which is more directly informative about representation. I argued that priming effects provide evidence that the processor recognises a relationship at some level of structure between two stimuli. If other factors can be ruled out, a priming effect between two stimuli can be attributed to the processor recognising that they are related at the level of syntactic structure. I showed that syntactic priming effects occur in written language production: people are more likely to complete a sentence with one structure if they have just completed another sentence with the same structure. This effect occurred between sentences which had no lexical items in common, implying that the relationship which the processor recognised between the two sentences was defined in terms of abstract syntactic categories. In addition, it appeared that the priming effect did not arise from repetition of the structure of an entire sentence, but from repetition of a substructure, suggesting that the processor makes reference to smaller chunks of structure than sentences. I suggested that the relevant unit consists of a local structure, i.e. a mother node and its daughters. I also demonstrated syntactic priming effects in language comprehension, such that comprehension of a sentence involving a local ambiguity

was facilitated following comprehension of a sentence with the same ambiguity. I showed that the priming effect is sensitive to constituent structure but does not appear to be sensitive to thematic structure: there is evidence that priming occurs between sentences involving the same structural ambiguity even if they involve different thematic structures. Overall, these results suggest that syntactic structure is represented in terms of schemata, or rules, which specify (possibly local) relationships between abstract syntactic categories but do not contain thematic information. I argued that priming is primarily a competitive effect, which occurs when one of these rules is applied and hence its activation is raised. The raised activation makes this rule a better competitor if there is subsequently a choice between alternative rules. Finally, I showed that bidirectional syntactic priming effects occur: comprehension of a structure can increase the likelihood of subsequently producing that structure. This implies that priming is not facilitating processes which are modality-specific; instead it must be tapping into something which is modality-independent, i.e. shared between comprehension and production. I suggested that the most obvious candidate for this is the knowledge base which underlies use of language.

9.2 Evaluation of findings

This research was originally inspired by the observation that although theoretical linguistics and psycholinguistics are fundamentally concerned with the same subject matter – human language – and each field can potentially inform the other, in practice each field has tended to work in isolation. In particular, the issue of syntactic representation has been left to theoretical linguists, who, although accepting that experimental evidence could in principle be informative about syntactic representation, have eschewed the experimental methods offered by psychology in favour of a reliance on grammaticality judgements. This thesis has been based on the beliefs that the mental representation of syntax is as much the concern of psycholinguistics as it is of theoretical linguistics, and that by adopting a monodisciplinary approach, we unnecessarily restrict our research resources. Thus in addition to the specific findings outlined in the previous section, this research can be evaluated in terms of the success of the overall approach, how these findings fit with other research and their implications.

9.2.1 Methodological implications

Firstly and perhaps most importantly, the results suggest that syntactic representation is amenable to experimental study: the syntactic representations which are involved in language production and language comprehension, and perhaps also the representations which encode knowledge of language, can be studied using a variety of methods. These include experimental methods which are not commonly recognised as being informative about representation and are instead usually used to investigate processing issues, in addition to those which are commonly accepted to be informative in this respect (such as priming). As we saw in Chapter 5, for example, the results of experiments which elicited agreement errors have implications not only for models of processing, but also provide evidence about representation. Similarly, Chapter 4 has demonstrated that corpora are potentially a rich source of evidence about syntactic processing and syntactic representation. Equally, as the agreement error experiments also showed, theoretical linguistic notions can be useful for hypothesis generation with regard to language processing. At a methodological level, then, one major conclusion of this research is that syntactic representation can be the focus of psychological research in practice as well as in principle and such research can make use of theoretical concepts and data from a wide variety of sources.

9.2.2 The characteristics of syntactic structure

A second issue concerns the picture of syntactic structure which the findings reported here give us, and how this relates to other views of syntactic representation. In terms of the overall architecture of the representational system, the results of the priming experiments suggest that syntactic structure is represented in terms of abstract categories which subsume individual lexical items with common properties, such as ditransitive verbs, but which do not contain thematic information. The results are also compatible with the hypothesis that syntactic structure is specified over spans of structure smaller than an entire sentence, perhaps in terms of mother–daughter relationships. The existence of bidirectional priming effects suggests further that these relationships are specified in a knowledge base common to production and comprehension. In addition, the results provide evidence about more specific issues concerning particular syntactic categories and types of structure. For example, they suggest that predicate+argument units of various types form a syntactic class.

To what extent do these findings converge with (conceptualist) linguistic theories of syntactic representation? If grammaticality judgements are informative about the mental representation of syntactic structure, as some linguists claim, then we would expect to find agreement between the representations proposed by theoretical linguists and those for which we have found evidence here. In other words, the picture of syntactic representation outlined in the previous paragraph should converge with the picture of syntactic representation developed in theoretical linguistics.

Reassuringly, the findings reported in this thesis are compatible with the proposals made by linguistic theories. At the most fundamental level, such theories assume that there is a knowledge base, or competence grammar, which encodes knowledge of language and which underlies both production and comprehension. With respect to the vocabulary and overall architecture of syntactic representation, all linguistic theories (of which I am aware) include statements which specify the possible syntactic structures of the language in terms of abstract categories which subsume individual lexical items. The exact form of these statements varies from theory to theory – in some theories, they are phrase structure rules, in others, immediate dominance schemata – but they all capture the same underlying idea, that syntactic structure is specified in terms of relationships between hierarchically structured abstract categories. Equally, all linguistic theories propose that these relationships hold over spans of structure which are smaller than an entire sentence; most theories specify relationships which hold over local domains, such as mother–daughter relations. At the level of specific linguistic structures, the clause – composed of a predicate and its arguments – seems to be a theoretical primitive for most linguistic theories. Hence there is a convergence between the representations for which

we have found experimental evidence and the constructs of theoretical linguistics.

9.2.3 Wider implications and possibilities for future research

This brings us to a third issue. As one might expect, interdisciplinary research can cast light upon issues which are of concern to the contributing disciplines. What then are the implications of these findings for linguistic theories? In Chapter 2, I discussed two major types of linguistic theories: those which purport to be psychological theories and those which do not. I also noted that with regard to the first type of theory, any evidence which has a bearing upon the mental representation of language is in principle relevant. In that case, experimental evidence of the type reported in this thesis is not only relevant to psycholinguistic models of the language faculty, it also has implications for linguistic theories. More specifically, any linguistic theory which claims to characterise knowledge of language must be compatible with the representations for which we find experimental evidence.

The work presented has concentrated on basic issues concerning the mental representation of syntactic structure, such as the vocabulary and domain of syntactic rules. As we have seen, the results of these experiments are in agreement with the assumptions of many linguistic theories. Hence there is no way in which the results can arbitrate between alternative possibilities. However, future work could focus upon more contentious issues. For example, in the same way that one priming experiment investigated whether constituent structure is represented separately from thematic structure, we could investigate whether tense and aspect are intrinsic dimensions of constituent structure.

In addition to questions about the overall architecture of syntactic representation, there are also specific questions about the syntactic structure of specific sentences which are of considerable theoretical interest. For example, the structure of sentences such as (9.1) below is contentious: according to some linguists, these sentences have the same structure as a double object sentence (Pollard & Sag 1994); according to others, they have a quite different ‘small clause’ structure (Stowell 1983).

(9.1) The teacher called the boy a liar.

This issue has not been resolved by theoretical debate, since there is distributional evidence for and against both analyses. Experimental evidence could be helpful in determining how these sentences are mentally represented, for example in a production priming experiment. We would only expect to find priming effects between a sentence like (9.1) and a sentence like (9.2) if the processor recognised them as being syntactically related.

(9.2) The girl gave the hungry dog a bone.

Evidence of priming effects in these circumstances would be incompatible with any theory which assigns (9.1) and (9.2) unrelated representations. Thus if we did find priming effects here, it would constitute evidence against a small clause analysis of these sentences.

I therefore suggest that the type of evidence presented here has implications for linguistic theories, and that although the results reported in this thesis do not distinguish between alternative theories, in future there may be some experiments which provide evidence which supports or argues against particular theories or particular analyses.

This research also has implications for theories of language processing, with respect to the representational assumptions which they make. In particular, the finding that syntactic structure is represented in terms of relations between abstract categories argues against any processing theory in which syntactic structure is associated with individual lexical items only. For example, as we saw in Chapter 3, MacDonald, Pearlmutter & Seidenberg (1994) proposed a model in which syntactic processing is constraint-based, driven in part by the syntactic preferences associated with individual lexical items. In their model, these preferences are captured through differential weights on connections which associate lexical entries with fragments of syntactic structure. They allowed for two possible realisations of this model: one in which each fragment of structure was shared between all lexical entries with the same syntactic characteristics (such that every ditransitive verb's lexical entry would be linked to the same V NP NP fragment); and one in which each lexical entry was associated with its own unique fragments of structure. The evidence reported here argues against the latter possibility, since it is not clear how a model in which syntactic structure is tied to individual lexical items could account for priming effects between sentences involving different lexical items. This research therefore supports theories of processing which assume that syntactic structure is defined over classes of lexical items.

There also remain a number of unanswered questions concerning language processing which this research has raised, for example concerning the suggestion that working memory and cognitive overload may have an affect on the incidence of agreement errors, which warrant further investigation. There are also issues concerning the precise mechanisms which underlie priming. Further work, perhaps employing different experimental techniques, may be able to cast some light on whether priming is solely a competitive effect, whether it depends upon the same type of ambiguity occurring in both prime and target, whether it can affect the initial choice of analysis and so on. These issues could have a bearing upon models of processing. For example, if it turned out that priming can affect the analysis which the processor initially chooses in comprehension, this might be difficult to reconcile with models of processing in which the initial choice of analysis is fixed (see for example Frazier (1979)).

9.3 Conclusion

The mental representation of syntactic structure has received relatively little attention in psycholinguistics in recent years. The aim of this thesis has been to demonstrate that syntactic representation can be explored using the methods of experimental psychology. The research reported here has shown that a variety of methods can be informative about syntactic representation. These results are relevant not only to models of language processing, but also to linguistic theories which claim to characterise knowledge of language.

Appendix A

Agreement error materials

Experiment 1

1 The report of the fast spreading forest fire(s)/that they started the forest fire(s)
2 The dream about the old haunted castle(s)/that vampires haunted the castle(s)
3 The story about the sleazy new scandal(s)/that Jill discovered the scandal(s)
4 The concept of the lethal laser weapon(s)/that they buy the laser weapon(s)
5 The explanation for the delayed evening train(s)/that they will delay the train(s)
6 The notice about the weekly board meeting(s)/that Nick had cancelled the meeting(s)
7 The suggestion about the forthcoming traffic project(s)/that engineers plan the traffic project(s)
8 The threat of the terrorist letter bomb(s)/that they would send the letter bomb(s)
9 The warning about the huge mountain avalanche(s)/that skiers caused the avalanche(s)
10 The regulation about the green chemical(s)/that they store the chemical(s)
11 The response to the suggested peace treaty(ies)/that they sign the new peace treaty(ies)
12 The claim about the foolproof scientific technique(s)/that John developed the foolproof technique(s)
13 The solution to the complicated problem(s)/that Don work on the hard problem(s)
14 The request for the improved software programme(s)/that they improve the programme(s)
15 The implication of the published newspaper article(s)/that Sam published the detailed article(s)
16 The conclusion of the management committee(s)/that they sack the big committee(s)
17 The illusion of the shimmering desert lake(s)/that Dan found the shimmering lake(s)
18 The joke about the slippery banana skin(s)/that Paul slipped on the banana skin(s)
19 The decision about the old-fashioned science museum(s)/that they close the old-fashioned science museum(s)
20 The hope about the international summit conference(s)/that Ann could attend the summit conference(s)
21 The reports of the latest government policy(ies)/that he altered the government policy(ies)
22 The hints of the impending political upset(s)/that Pat knew of the political upset(s)
23 The rumours of the terrible aeroplane accident(s)/that Peter saw the aeroplane accident(s)
24 The legends about the spooky graveyard(s)/that ghosts live in the graveyard(s)

Experiment 2

1 The obvious explanation to give the rioting demonstrator(s)/for the rioting demonstrator(s)/that Nick gave the demonstrator(s)/concerning the rioting demonstrator(s)
2 The most damning report to send the corrupt city councillor(s)/about the corrupt city councillor(s)/that John sent the city councillor(s)/naming the corrupt city councillor(s)
3 The crucial document to show to the city lawyer(s)/about the keen city lawyer(s)/that Phil

showed the city lawyer(s)/implicating the keen city lawyer(s)
4 The best story to tell the little kid(s)/about the really little kid(s)/that Pam told the little kid(s)/involving the really little kid(s)
5 The most embarrassing experience to describe to the therapist(s)/with the trainee therapist(s)/that Liz described to the therapist(s)/involving the trainee therapist(s)
6 The most worrying TV programme to show to the student doctor(s)/about the student doctor(s)/that Tim showed the doctor(s)/describing the student doctor(s)
7 The scariest myth to tell the foreign prince(s)/about the foreign prince(s)/that Henry told the prince(s)/mentioning the foreign prince(s)
8 The worst suspicion to disclose to the police detective(s)/about the police detective(s)/that Bill told the police detective(s)/concerning the police detective(s)
9 The famous picture to show to the ambassador(s)/of the sinister ambassador(s)/that Mary showed the ambassador(s)/portraying the sinister ambassador(s)
10 The funniest rumour to tell the eccentric professor(s)/about the eccentric professor(s)/that Dan told the professor(s)/mentioning the eccentric professor(s)
11 The scariest film to show to the teenager(s)/about the local teenager(s)/that Bob showed the teenager(s)/attracting the local teenager(s)
12 The first proposal to submit to the finance officer(s)/for the new finance officer(s)/that Mark submitted to the officer(s)/concerning the new finance officer(s)
13 The most convincing theory to suggest to the American astronaut(s)/about the injured American astronaut(s)/that Matt suggested to the astronaut(s)/involving the injured American astronaut(s)
14 The least incriminating statement to make to the aggressive journalist(s)/about the very aggressive journalist(s)/that Ian made to the aggressive journalist(s)/concerning the very aggressive journalist(s)
15 The most extreme opinion to express to the market researcher(s)/about the persistent market researcher(s)/that Kim expressed to the market researcher(s)/regarding the persistent researcher(s)
16 The new regulation to impose on the catering company(ies)/for the outside catering company(ies)/that Neil imposed on the company(ies)/covering the outside catering company(ies)
17 The latest law to explain to the village shopkeeper(s)/about the local village shopkeeper(s)/that Rick explained to the shopkeeper(s)/annoying the local village shopkeeper(s)
18 The vital claim to submit to the company insurer(s)/about the stingy company insurer(s)/that Frank submitted to the insurer(s)/involving the stingy company insurer(s)
19 The most common fear to confide to the airline steward(s)/about the efficient airline steward(s)/that Paul confided to the steward(s)/affecting the efficient airline steward(s)
20 The important message to pass to the radio announcer(s)/for the professional radio announcer(s)/that Kate passed to the announcer(s)/interrupting the professional radio announcer(s)
21 The critical assumption to explain to the sales manager(s)/about the qualified sales manager(s)/that Sue explained to the manager(s)/bothering the qualified sales manager(s)
22 The second leaflet to describe to the planning committee(s)/about the town planning committee(s)/that Lucy described to the committee(s)/concerning the town planning committee(s)
23 The most stringent rule to explain to the army parachutist(s)/for the young army parachutist(s)/that Anna explained to the parachutist(s)/worrying the young army parachutist(s)
24 The most vital secret to give to the special agent(s)/about the cunning special agent(s)/that Jeff gave the special agent(s)/eluding the cunning special agent(s)
25 The best description to pass to the young cadet(s)/of the young army cadet(s)/that Sid passed to the cadet(s)/evoking the young army cadet(s)
26 The least helpful idea to suggest to the new chef(s)/for the incompetent new chef(s)/that Mike suggested to the chef(s)/involving the incompetent new chef(s)
27 The most imaginative plan to submit to the school governor(s)/about the elected school governor(s)/that Jack submitted to the governor(s)/impressing the elected school governor(s)
28 The best project to propose to the medical school(s)/for the renowned medical school(s)/that Emma proposed to the school(s)/developing the renowned medical school(s)

29 The most popular song to perform for the suntanned tourist(s)/about the handsome suntanned tourist(s)/that Tom performed for the tourist(s)/describing the handsome suntanned tourist(s)
30 The funniest anecdote to tell to the forgetful gardener(s)/about the old forgetful gardener(s)/that Cath told the forgetful gardener(s)/involving the old forgetful gardener(s)
31 The last programme to broadcast to the big city(ies)/about the run-down big city(ies)/that Meg broadcast to the city(ies)/concerning the run-down big city(ies)
32 The most damaging confession to make to the powerful magistrate(s)/about the stern powerful magistrate(s)/that Beth made to the magistrate(s)/implicating the stern powerful magistrate(s)
33 The latest tale to relate to the gossip columnist(s)/about the notorious gossip columnist(s)/that Susan related to the columnist(s)/entertaining the notorious gossip columnist(s)
34 The worst script to show to the Hollywood producer(s)/for the insincere Hollywood producer(s)/that Colin showed the Hollywood producer(s)/mentioning the insincere Hollywood producer(s)
35 The detailed map to fax to the Scottish university(ies)/of the well-known Scottish university(ies)/that Jean faxed to the university(ies)/describing the well-known Scottish university(ies)
36 The frightening warning to send to the nuclear power station(s)/about the huge nuclear power station(s)/that terrorists sent to the power station(s)/concerning the huge nuclear power station(s)
37 The long document to fax to the investigative committee(s)/about the special investigative committee(s)/that Donald faxed to the committee(s)/intriguing the special investigative committee(s)
38 The most recent article to show to the managing editor(s)/about the controversial managing editor(s)/that Ted showed the managing editor(s)/criticising the controversial managing editor(s)
39 The most serious allegation to mention to the investigator(s)/about the accident investigators/that Janet mentioned to the investigators/concerning the accident investigators
40 The shortest headline to read to the grandparent(s)/about the murdered grandparent(s)/that Helen read to the grandparent(s)/describing the murdered grandparent(s)
41 The oldest legend to recount to the late-night visitor(s)/of the mysterious late-night visitor(s)/that Andy recounted to the visitor(s)/concerning the mysterious late-night visitor(s)
42 The most popular event to recount to the news reporter(s)/for the eager news reporter(s)/that Amy recounted to the reporter(s)/interesting the eager news reporter(s)
43 The first exhibition to show to the art historian(s)/for the enthusiastic art historian(s)/that Pam showed the art historian(s)/attracting the enthusiastic art historian(s)
44 The crucial sign to point out to the conference delegate(s)/about the recently arrived conference delegate(s)/that Luke pointed out to the conference delegate(s)/confusing the recently arrived conference delegate(s)
45 The most interesting book to lend to the retired actor(s)/about the weird retired actor(s)/that Tony lent the retired actor(s)/describing the weird retired actor(s)
46 The gory fairy tale to read to the lively youngster(s)/about the clever lively youngster(s)/that Becky read to the youngster(s)/entertaining the clever lively youngster(s)
47 The latest solution to explain to the council department(s)/for the overstretched council department(s)/that Vicky explained to the department(s)/involving the overstretched council department(s)
48 The strictest regulation to impose on the office cleaner(s)/for the busy office cleaner(s)/that Gerry imposed on the cleaner(s)/bothering the busy office cleaner(s)
49 The most horrifying reports to give to the national paper(s)/about the biased national paper(s)/that Fred showed the national paper(s)/describing the biased national paper(s)
50 The most detailed documents to send to the politician(s)/about the inquisitive politician(s)/that Anne sent the politician(s)/impressing the inquisitive politician(s)
51 The most attractive photographs to display in the art gallery(ies)/of the local art gallery(ies)/that

Sarah displayed in the art gallery(ies)/showing the local art gallery(ies)
52 The best pictures to paint for the rich oil tycoon(s)/of the extremely rich oil tycoon(s)/that Keith showed the rich oil tycoon(s)/showing the extremely rich oil tycoon(s)
53 The silliest cartoons to draw for the old editor(s)/about the really old editor(s)/that Pat drew for the old editor(s)/annoying the really old editor(s)
54 The easiest games to teach to the clumsy boy(s)/for the very clumsy boy(s)/that Ted taught to the clumsy boy(s)/involving the very clumsy boy(s)
55 The worst rumours to tell to the frightened refugee(s)/about the extremely frightened refugee(s)/that Paul told the frightened refugee(s)/terrifying the extremely frightened refugee(s)
56 The only explanations to give to the strange teacher(s)/about the extremely strange teacher(s)/that Harry gave to the strange teacher(s)/convincing the extremely strange teacher(s)
57 The most boring lectures to give to the medical student(s)/for the young medical student(s)/that Jill gave the medical student(s)/involving the young medical student(s)
58 The vital clues to show to the prosecution lawyer(s)/for the dedicated prosecution lawyer(s)/that Lisa showed the prosecution lawyer(s)/convincing the dedicated prosecution lawyer(s)
59 The critical plans to explain to the army general(s)/about the senile army general(s)/that Tina explained to the army general(s)/worrying the senile army general(s)
60 The unexpected results to describe to the peace conference(s)/of the recent peace conference(s)/that Adam described to the peace conference(s)/following the recent peace conference(s)
61 The most romantic poems to read to the beautiful girl(s)/about the incredibly beautiful girl(s)/that Bruce read to the beautiful girl(s)/describing the incredibly beautiful girl(s)
62 The longest headlines to read to the irritable politician(s)/about the rather irritable politician(s)/that Terry read to the irritable politician(s)/mentioning the rather irritable politician(s)
63 The rudest remarks to make to the spotty youth(s)/about the pink spotty youth(s)/that Jenny made to the spotty youth(s)/upsetting the pink spotty youth(s)
64 The most detailed statements to submit to the auditor(s)/about the unqualified auditor(s)/that Rachel submitted to the auditor(s)/concerning the unqualified auditor(s)

Appendix B

Production priming: Experimental materials

Experiment 1

1 The yachtsman loaned the spare lifejacket/the angler. The happy child gave the present/the teacher. The generous girl lent ...
2 The unscrupulous salesman sold the timeshare apartment/the gullible tourist. The champion cyclist showed the bicycle pump/the team manager. The tennis fan handed ...
3 The pub offered a free beer/the loyal customers. The American penpal mailed a scenic postcard/the Greek woman. The injured climber ...
4 The messenger handed the unsigned note/the countess. The senior lecturer loaned the main textbook/the visiting professor. The head waiter gave ...
5 The ambulanceman offered the steaming hot drink/the shivering accident victim. The disgruntled employee wrote a letter of complaint/the managing director. The spotty apprentice offered ...
6 The structural engineer gave the detailed report/the solicitor. The waiter offered the bubbling champagne/the celebrating couple. The ambassador lent ...
7 The thoughtful friend loaned some money/the impoverished student. The kind landlord rented the small cottage/the homeless faimily. The research assistant sent ...
8 The footman served the roast potatoes/the dinner guest. The doting mother gave the expensive toy car/the baby. The medical researcher sent ...
9 The lonely sailor wrote a long letter/his girlfriend. The polite man passed the salt/the other customer. The estate agent showed ...
10 The enthusiastic youngster showed the book/a friend. The angry voter sent a vitriolic letter/the politician. The art historian loaned ...
11 The booking clerk mailed the concert tickets/the anxious customer. The barman offered the cocktail/the depressed customer. The driving examiner handed ...
12 The lifeguard threw the long rope/the drowning child. The blackmailer posted the incriminating letter/the Tory M.P. The hostess gave ...

Experiment 2

1 The teacher gave the book that frightened the child/frightened the child that gave the book/gave the youth that frightened the child/frightened the child that gave the youth. The barrister showed ...
2 The artist showed the picture that intrigued the collector/intrigued the collector that showed the picture/showed the sculptor that intrigued the collector/intrigued the collector that showed the sculptor. The chemist gave ...

3 The executive sent the letter that horrified the manager/horrified the manager that sent the letter/sent the assistant that horrified the manager/horrified the manager that sent the assistant. The kids showed ...
4 The librarian lent the book that shocked the teenager/shocked the teenager that lent the book/lent the girl that shocked the teenager/shocked the teenager that lent the girl. The postman handed ...
5 The student sent the leaflet that irritated the lecturer/irritated the lecturer that sent the leaflet/sent the secretary that irritated the lecturer/irritated the lecturer that sent the secretary. The boxer lent ...
6 The workman loaned the handbook that confused the apprentice/confused the apprentice that loaned the handbook/loaned the foreman that confused the apprentice/confused the apprentice that loaned the foreman. The author sent ...
7 The waiter offered the drink that disgusted the barman/disgusted the barman that offered the drink/offered the banker that disgusted the barman/disgusted the barman that offered the banker. The auctioneer gave ...
8 The chairman showed the report that praised the secretary/praised the secretary that showed the report/showed the client that praised the secretary/praised the secretary that showed the client. The florist sent ...
9 The electrician showed the problem that dismayed the apprentice/dismayed the apprentice that showed the problem/showed the inspector that dismayed the apprentice/dismayed the apprentice that showed the inspector. The opera singer gave ...
10 The butler offered the tray that annoyed the footman/annoyed the footman that offered the tray/offered the guest that annoyed the footman/annoyed the footman that offered the guest. The courier handed ...
11 The actor loaned the costume that interested the director/interested the director that loaned the costume/interested the director/interested the director that loaned the actress. The farmer gave ...
12 The coach gave the ball that hit the goalie/hit the goalie that gave the ball/the striker that hit the goalie/hit the goalie that gave the striker. The skier loaned ...
13 The grandmother sent the present that astounded the youngster/astounded the youngster that sent the present/sent the friend that astounded the youngster/astounded the youngster that sent the friend. The shop assistant showed ...
14 The judge gave the weapon that terrified the witness/terrified the witness that gave the weapon/gave the suspect that terrified the witness/terrified the witness that gave the suspect. The actress gave ...
15 The guide lent the map that baffled the tourist/baffled the tourist that lent the map/lent the villager that baffled the tourist/baffled the tourist that lent the villager. The secretary sent ...
16 The doctor gave the pills that cured the patient/cured the patient that gave the pills/gave the specialist that cured the patient/cured the patient that gave the specialist. The salesman loaned ...
17 The lorry driver lent the trailer that unnerved the learner/unnerved the learner that lent the trailer/lent the motorcyclist that unnerved the learner/unnerved the learner that lent the motorcyclist. The receptionist handed ...
18 The professor loaned the equipment that irritated the technician/irritated the technician that loaned the equipment/loaned the student that irritated the technician/irritated the technician that loaned the student. The explorer gave ...
19 The magistrate sent the report that appalled the victim/appalled the victim that sent the report/sent the lawyer that appalled the victim/appalled the victim that sent the lawyer. The student lent ...
20 The soldiers offered a truce that infuriated the general/infuriated the general that offered a truce/offered the major that infuriated the general/infuriated the general that offered the major. The researcher showed ...
21 The builder showed the house that astonished the architect/astonished the architect that

showed the house/showed the customer that astonished the architect/astonished the architect that showed the customer. The dancer loaned ...
22 The chef offered the cake that impressed the manager/impressed the manager that offered the cake/offered the waitress that impressed the manager/impressed the manager that offered the waitress. The mechanic handed ...
23 The publisher lent the novel that scandalised the politician/scandalised the politician that lent the novel/lent the writer that scandalised the politician/scandalised the politician that lent the writer. The detective showed ...
24 The programmer loaned the manual that puzzled the analyst/puzzled the analyst that loaned the manual/loaned the hippy that puzzled the analyst/puzzled the analyst that loaned the hippy. The tourist sent ...

Appendix C

Comprehension priming: Experimental materials

Study 1

Active/Passive

1 The motorbike injured the walker/the walker was injured by the motorbike and the avalanche buried the skier/the skier was buried by the avalanche. Was the walker injured by the motorbike?/Was the walker injured by the motorbike?
2 The bee stung the donkey/The donkey was stung by the bee and the fox caught the ferret/the ferret was caught by the fox. Did the ferret catch the fox?/Was the fox caught by the ferret?
3 The missile sank the battleship/The battleship was sunk by the missile and the laser zapped the satellite/the satellite was zapped by the laser. Did the missile sink the battleship?/Was the battleship sunk by the missile?
4 The youngster approached the pop singer/The pop singer was approached by the youngster and the bouncer ignored the disc jockey/the disc jockey was ignored by the bouncer. Did the disc jockey ignore the bouncer ?/Was the bouncer ignored by the disc jockey?
5 The assistant picked the rose/The rose was picked by the assistant and the chambermaid lit the fire/the fire was lit by the chambermaid.
6 A thorn pricked the ranger/The ranger was pricked by a thorn and a wave drowned the swimmer/the swimmer was drowned by a wave.
7 A cameraman takes the photo/The photo is taken by a cameraman and a glazier mends the window/the window is mended by a glazier.
8 The contractor bribed the industrialist/The industrialist was bribed by the contractor and the consultant saw the telephonist/the telephonist was seen by the consultant.
9 The minister sacked the civil servant/The civil servant was sacked by the minister and the murderer stabbed the social worker/the social worker was stabbed by the murderer.
10 The oven burnt the baker/The baker was burnt by the oven and the gutter cut the roofer/the roofer was cut by the gutter.
11 The potter shaped the jug/The jug was shaped by the potter and the runner won the race/the race was won by the runner.
12 The plumber repaired the cisterns/The cisterns were repaired by the plumber and the children opened the parcels/the parcels were opened by the children.
13 The rock smashed the glass/The glass was smashed by the rock and the wire scratched the paint/the paint was scratched by the wire.
14 The noise scared the child/The child was scared by the noise and the soot choked the sweep/the sweep was choked by the soot.
15 The magician frightened the boy/The boy was frightened by the magician and the archbishop reproved the monk/the monk was reproved by the archbishop.

16 The thief grabbed the earrings/The earrings were grabbed by the thief and the boy cleaned the hatchback/the hatchback was cleaned by the boy.
17 The gardener pruned the tree/The tree was pruned by the gardener. The engineer worked the crane/The crane was worked by the engineer. Did the gardener prune the tree?/Was the tree pruned by the gardener?
18 The wind blew away the hillwalker/The hillwalker was blown away by the wind. The train knocked over the signalman/The signalman was knocked over by the train. Did the wind knock over the signalman?/Was the signalman knocked over by the wind?
19 The shopping centre impressed the tourists/The tourists were impressed by the shopping centre. The control tower alerted the pilots/The pilots were alerted by the control tower. Did the control tower alert the pilots?/Were the pilots alerted by the control tower ?
20 The interviewer rejected the application/The application was rejected by the interviewer. The terrorist selected the detonator/The detonator was selected by the terrorist. Did the interviewer accept the application?/Was the application accepted by the interviewer?
21 The speaker inspired the crowd/The crowd was inspired by the speaker. The lawyer answered the judge/The judge was answered by the lawyer.
22 The alarm clock woke the nightwatchman/The nightwatchman was woken by the alarm clock. The cricket ball hit the spectator/The spectator was hit by the cricket ball.
23 The explorer followed the guide/The guide was followed by the explorer. The assassin smothered the king/The king was smothered by the assassin.
24 The dockers unloaded the boxes/The boxes were unloaded by the dockers. The servants polished the tables/The tables were polished by the servants.
25 The insurer tidied the cupboard/The cupboard was tidied by the insurer. The hijacker started the engine/The engine was started by the hijacker.
26 The results shocked the scientist/The scientist was shocked by the results. The hydrant soaked the fireman/The fireman was soaked by the hydrant.
27 The lion stalked the gazelles/The gazelles were stalked by the lion. The whale watched the dolphins/The dolphins were watched by the whale.
28 The pianist observed the drummer/The drummer was observed by the pianist. The commando attacked the general/The general was attacked by the commando.
29 A soldier started the revolution/The revolution was started by a soldier. A chemist invented the superglue/The superglue was invented by a chemist.
30 The policeman arrested the arsonist/The arsonist was arrested by the policeman. The secretary applauded the treasurer/The treasurer was applauded by the secretary. 31 The victim described the mugger/The mugger was described by the victim. The cowboy heckled the sheriff/The sheriff was heckled by the cowboy.
32 The lightning struck the church/The church was struck by the lightning. The hammer bent the spade/The spade was bent by the hammer.

Prepositional/double objects

1 The agent sent a briefing to the journalist/the journalist a briefing and the striker kicked the football to the goalkeeper/the goalkeeper the football. Did the agent send a briefing?
2 The banker spares some change for the tramp/the tramp some change and the builder hands some paint to the girl/the girl some paint. Does the girl hand the builder some paint?
3 The politician showed a statement to the press/the press a statement and the executive wrote a letter to the firm/the firm a letter. Did the executive write a letter?
4 The lecturer baked the biscuits for the students/the students the biscuits and the grandfather read the stories to the youngsters/the youngsters the stories. Did the students bake the biscuits?
5 The butler delivered the notes to the countess/the countess the notes and the bowler offered the stumps to the umpire/the umpire the stumps.

6 The sergeant saved a ticket for the inspector/the inspector a ticket and the waiter gave a vodka to the customer/the customer a vodka.
7 The booking clerk mailed a report to the boss/the boss a report and the icecream man sold a lolly to the kid/the kid a lolly.
8 The governess made a pie for the princess/the princess a pie and the rescuer threw a rope to the climber/the climber a rope.
9 The poet wrote a sonnet for the monarch/the monarch a sonnet and the barman served a cocktail to the hostess/the hostess a cocktail.
10 The stallholder showed a T-shirt to the tourist/the tourist a T-shirt and the showjumper fed an apple to the pony/the pony an apple.
11 The traffic warden issued a ticket to the driver/the driver a ticket and the flower seller ordered a bouquet for the cellist/the cellist a bouquet.
12 The artist painted a portrait for the celebrity/the celebrity a portrait and the postman handed a parcel to the shopkeeper/the shopkeeper a parcel.
13 The storyteller told a fairy tale to the children/the children a fairy tale and the ambulance-man took a steaming drink to the victim/the victim a steaming drink.
14 The photographer found a watch for the model/the model a watch and the shepherdess showed a lamb to the farmer/the farmer a lamb.
15 The businessman repaid the money to the bank/the bank the money and the librarian issued the novel to the girl/the girl the novel.
16 The author loaned a manuscript to the publisher/the publisher a manuscript and the door-man hailed a minicab for the industrialist/the industrialist a minicab.
17 The designer sewed a jacket for the actress/the actress a jacket. The prisoner slipped a package to the warder/the warder a package. Did the designer sew a jacket?
18 The director reserved a seat for the critic/the critic a seat. The consultant offered a cake to the doctor/the doctor a cake. Did the doctor offer a cake?
19 The illustrator designed a logo for the company/designed the company a logo. The black-mailer posted a letter to the embassy/the embassy a letter. Did the blackmailer post a letter?
20 The sailor tossed a line to the captain/the captain a line. The mother bought a toy for the baby/the baby a toy. Did the captain toss a line?
21 The examiner passed a pen to the pupil/the pupil a pen. The ambassador lent a car to the envoy/the envoy a car.
22 The hurdler gave the whistle to the judges/the judges the whistle. The foreman paid the wages to the workmen/the workmen the wages.
23 The diplomat faxed a visa to the astronaut/the astronaut a visa. The saleswoman showed a jumper to the customer/the customer a jumper.
24 The coastguard sent the warning to the anglers/the anglers the warning. The blacksmith made the stirrup for the riders/the riders the stirrup.
25 The carpenter built a bookshelf for the neighbour/the neighbour a bookshelf. The messen-ger brought a parcel to the client/the client a parcel.
26 The secretary copied the file for the magistrate/the magistrate the file. The barrister despatched the deeds to the company/the company the deeds.
27 The father sang the lullaby to the toddler/the toddler the lullaby. The banker leased the office to the swindler/the swindler the office.
28 The landlord rented a flat to the family/the family a flat. The dealer acquired a vase for the collector/the collector a vase.
29 The travel agent booked the holiday for the couple/the couple the holiday. The local chemist gave the prescription to the lady/the lady the prescription.
30 The dentist offered an injection to the patient/the patient an injection. The weaver made a tapestry for the client/the client a tapestry.
31 The welder handed a helmet to the apprentice a helmet/the apprentice a helmet. The actress prepared an omelette for the architect/the architect an omelette.
32 The man sold some cherries to the girl/the girl some cherries. The clown passed some streamers to the child/the child some streamers.

Subject/object relative clauses

1 The researcher that disliked the typist/the typist disliked was in the laboratory and the tech-nician that despised the fitter/the fitter despised was near the embassy. Did the researcher dislike the typist?/Did the typist dislike the researcher?
2 The badminton player that assaulted the inspector/the inspector assaulted jogs by the river and the geography student that insulted the villager/the villager insulted works in the library. Did the inspector assault the badminton player?/Did the badminton player assault the inspec-tor?
3 The dancer that hated the agent/the agent hated appeared on the game show and the bookie that cheated the gambler/the gambler cheated escaped to the seaside. Did the bookie cheat the gambler?/Did the gambler cheat the bookie?
4 The dustman that noticed the instructor/the instructor noticed needs a flat and the dentist that treated the optician/the optician treated wants a yacht. Did the instructor notice the dustman?/Did the dustman notice the instructor?
5 The cobbler that knew the tailor/the tailor knew moved to the town and the driver that saw the robber/the robber saw works for the firm.
6 The writer that recognised the historian/the historian recognised has published a novel and the diver that respected the billionaire/the billionaire respected has received a payrise.
7 The shoplifter that threatened the store detective/the store detective threatened looked shifty and the geologist that abused the site engineer/the site engineer abused seemed busy.
8 The manager that angered the executive/the executive angered has taken leave and the abseiler that aided the mountaineer/that the mountaineer aided has eaten lunch.
9 The fellow that disliked the salesman/the salesman disliked signed the form and the sprinter that envied the hurdler/the hurdler envied failed the test.
10 The hunters that resented the squire/the swuire resented owned the guns and the children that surrounded the guards/the guards surrounded threw the stones.
11 The actor that loved the girl/the girl loved promised to sing and the lady that thumped the boy/the boy thumped started to shout.
12 The person that prodded the assistant/the assistant prodded arrived at the stop and the colleague that employed the designer/the designer employed shivered in the cold.
13 The secretary that suspects the diplomat/the diplomat suspects boards the liner and the illustrator that detests the editor/the editor detests leaves the building.
14 The barrister that indicated the defendant/the defendant indicated walked towards the jury and the constable that preceded the motorist/the motorist protected stood beneath the tower.
15 The fighter pilot that rewarded the sculptor/the sculptor rewarded came to the basement and the social worker that telephoned the expert/the expert telephoned stayed at the office.
16 The lorry driver that strangled the hooligans/the hooligans strangled came from the city and the rugby player that enjoyed the spectators/the spectators enjoyed played in the final.
17 The manufacturer that adored the writer/the writer adored built a factory. The superin-tendant that tackled the raider/the raider tackled called a sergeant. Did the manufacturer adore the writer?/Did the writer adore the manufacturer?
18 The officer that deserted the cadet/the cadet deserted hid in the hills. The teenager that criticised the teacher/the teacher criticised sat on the toys. Did the teacher criticise the teenager?/Did the teenager criticise the teacher?
19 The cleaner that avoided the caretaker/the caretaker avoided met the crossing lady. The lawyer that mistrusted the investor/the investor mistrusted checked the filing cabinet. Did the lawyer mistrust the investor?/Did the investor mistrust the lawyer?
20 The administrator that bribed the housing officer/the housing officer bribed copied the details. The psychiatrist that knew the civil engineer/the civil engineer knew spotted the damage. Did the housing officer bribe the administrator?/Did the administrator bribe the

housing officer?
21 The mafia boss that poisoned the drugs pusher/the drugs pusher poisoned owned three casinos. The company clerk that admired the zoo keeper/the zoo keeper admired wrote two articles.
22 The curator that watched the postman/the postman watched went to the museum. The commitee that praised the surgeon/the surgeon praised met in the studio.
23 The yachtsman that trusted the smuggler/the smuggler trusted fell overboard. The butler that bullied the footman/the footman bullied drank heavily.
24 The vocalist that married the drummer/the drummer married broke a plate. The conductor that observed the cellist/the cellist observed wore a tie.
25 The foreman that advised the surveyor/the surveyor advised understood the problem. The wrestler that repelled the ringmaster/the ringmaster repelled repeated the story.
26 The singer that introduced the percussionist/the percussionist introduced made the tea. The miner that encountered the philosopher/the philosopher encountered parked the car.
27 The man that cited the researcher/the researcher cited travelled to the park. The youth that rescued the pensioner/the pensioner rescued resigned from the job.
28 The woman that quoted the announcer/the announcer quoted put a picture on the desk. The stranger that mentioned the professor/the professor mentioned took a taxi to the town.
29 The foreigner that stopped the passer-by/the passer-by stopped had followed several courses. The physicist that heard the lecturer/the lecturer heard had written many papers.
30 The ranger that annoyed the ecologists/the ecologists annoyed boiled the water. The dealer that convinced the specialists/the specialists convinced bought the petrol.
31 The nurse that called the hospital/the hospital called cancelled the dinner. The friend that pushed the bookseller/the bookseller pushed ordered the flowers.
32 The electrician that irritated the uncle/the uncle irritated tested the toaster. The householder that contacted the council/that the council contacted fastened the cover.

Subordinate clause ambiguities

1 While the woman was eating the creamy soup (the pudding) went cold and while the man was knitting the woolly socks (the jumper) got wet. Did the pudding/soup go cold?
2 Although the boy watched the gory film (the plot) was too frightening and although the girl sang the soppy song (the tune) was not popular. Was the tune/song popular? 3 After the cowboy left the smoky saloon (the room) went quiet and after the druid drank the bubbling liquid (the pool) turned cloudy. Did the druid drink the liquid?/Did the liquid turn cloudy?
4 As the man enjoys driving the small car (the moped) is used by the youngster and as the king dislikes riding the white horse (the donkey) is kept in the stable. Does the man enjoy driving the moped?/Does the man drive the small car?
5 Since the athlete always jogs twenty-one miles (the race) seems short and since the housemaid often dusts the wooden shelves (the vase) is/are clean.
6 As the publisher was reading the boring book (the paper) fell on the fire and as the officer was polishing the leather belt (the buckle) stayed in the box.
7 While the artist was painting the large picture (the easel) stood in the corner and while the student was ironing the smart jacket (the t-shirt) lay on the sofa.
8 Although the gardener is weeding the concrete paths (the borders) are overgrown and although the dressmaker is sewing the pleated skirts (the trousers) are unfinished.
9 Before the secretary finished typing the short invoice (the post) was brought in and before the fireman began climbing the steel ladder (the hose) was set up.
10 Whenever the toddler visited the eccentric aunt (the uncle) got angry and whenever the doctor assisted the senior nurse (the matron) was jealous. 11 While the computer was running the alarm systems (the sirens) kept going off and while the submarine was sinking the ocean liners (the navy) came sailing up.
12 As the carpenter was hammering the rusty nail (the tip) bent and as the teenager was mending the faulty plug (the fuse) blew.
13 When the greengrocer opened the expensive shop (the street) was busy and when the magistrate entered the unpainted court (the crowd) was noisy.
14 As the guard wished to help the injured major (the general) issued the order and as the child asked to watch the cheerful actor (the mother) bought the ticket.
15 While the sculptor was sketching the marble bust (the pencil) broke in two and while the joiner was sawing the polished wood (the worktop) cracked in half.
16 As the musician played the silver flute (the tuba) shone brightly and as the apprentice cooked the sirloin steak (the pasta) smelt tasty.
17 When the lawyer argued the important case (the statement) was reported. When the choir practised the romantic song (the chorus) was recorded. Did the lawyer argue the case?/Was the case reported?
18 Although the preacher was inspiring the pious adults (the child) fell asleep. Although the princess was approaching the ragged hermits (the page) rode away. Did the hermits ride away?/Did the hermits approach the princess?
19 Because the sergeant is encouraging the young recruits (the soldiers) work harder. Because the banker is entertaining the rich clients (the bosses) are happy. Is the banker entertaining the clients ?/Is the banker entertaining the clients?
20 Although the conjuror was amusing the conference delegates (the staff) wanted a lunch break. Although the therapist was confusing the phobia sufferers (the nurse) trusted the technique. Did the delegates want a lunch break?/Were the delegates amusing?
21 As the surgeon moved the sterile scalpel (the needle) clattered to the floor. As the waiter stirred the lumpy porridge (the custard) simmered on the stove.
22 While the shepherd was sheltering the tiny lamb (the ewe) ran off. While the builder was measuring the crooked wall (the roof) crashed down.
23 While the composer hummed the famous overture (the opera) played on the speakers. While the policeman cleaned the dirty bicycle (the helmet) stayed in the cupboard.
24 Whenever the woman drew the reclining model (the expert) grumbled. Whenever the repulsive dentist phoned the baker (the plumber) answered.
25 While the keeper was calling the clever monkeys (the giraffe) rushed up. While the typist was walking the naughty puppies (the kitten) got out.
26 While the farmer was ploughing the stony field (the ground) was sodden. While the lady was pruning the thorny rose (the bush) was blooming.
27 When the grandmother scolded the bad adolescent (the grandfather) was pleasant. When the architect noticed the shy supervisor (the bricklayer) was worried.
28 After the psychiatrist understood the tricky problem (the solution) was not complex. After the receptionist explained the coding system (the document) was quite easy.
29 When the contestant answered the smarmy quizmaster (the audience) clapped. When the producer remembered the friendly director (the cameraman) laughed.
30 After the entertainer danced the sexy tango (the waltz) struck up. After the interviewer pushed the plastic panel (the door) gave way.
31 As the workman dug the deep trench (the pothole) filled with water. As the barman poured the weak beer (the cider) flowed from the tap.
32 While the farm worker is harvesting the small cabbages (the wheat) is left growing. While the tax dodger is deciding the main strategy (the file) is kept secret.

Complement/relative clauses

1 The executive instructs the artist that the rich heiress detested the awful painting/to sell the painting. The receptionist reminds the doctor that the sick patient contacted the antiques dealer/to take the sample. Did the heiress detest the artist?
2 The manager informs the chauffeur that the anxious guest wanted the long limousine/about the delay. The caretaker reminds the porter that the sleepy boss annoyed the old archi-

tect/about the alarm. Did the boss annoy the caretaker?
3 An assistant whispers to the tailor that the wealthy customer had observed the display/to be quiet. The translator suggests to the farmer that the new shopkeeper had spotted a problem/to get out. Did the shopkeeper spot the farmer?
4 The road sweeper suggests to the gardener that the park warden had spotted the broken benches/to be careful. The old woman mentions to the relative that the home helper had followed the limping stranger/to try harder. Did the gardener spot the park warden?
5 The barman explained to the cowboys that the angry man had asked for a whisky to drink/about the treasure map. The general confessed to the princess that the foreign spy had talked to the prisoners of war/about the plans.
6 The politician confessed to the clerk that the party worker had pointed to the man from Sheffield/about the events. The executive announced to the judge that the eager typist had spoken to the only witness/that he was leaving.
7 The announcer reminds the celebrity that the presenter had interviewed the famous rock singer/about the autographs. The director informs the cameraman that the apprentice had recorded the latest incident/about the incident.
8 The lawyer explained to the butcher that the other partners liked a long lunch break/about the deal. The woman mentioned to the singer that the tired bouncers thumped the conductor/about the song.
9 The secretary whispered to the clerk that the clients had relied on the crooked dealer/to seal the deal. The manservant hinted to the duke that the workers had argued with the wicked footman/to sack the cook.
10 The agent mentioned to the actress that the critic had despised the gala performance/about the performance. The warden explained to the suspect that the cleaner had witnessed the awesome disaster/about the disaster.
11 The audience shouted to the archer that the opponents had pointed to the angry referee/about the referee. The organist explained to the bridegroom that the relatives had waved to the tall photographer/about the prayerbook.
12 The producer reminds the skier that the reporters will meet with the winner of the race/about the procedure. The manager informs the owner that the customers will talk to the waiter in the bar/about the business plan.
13 The vicars remind the secretary that the four boys had imitated the archbishop/to send the reply. The pilots promise the passenger that the young child had identified the steward/to be careful.
14 The resident warned the fireman that the teenager had alerted the mad arsonist/to hurry the crew. The publican told the brewer that the inspector had visited the large warehouses/to strengthen the beer.
15 The woman confessed to the dentist that the detective had investigated the recent robbery/to being the robber. The major whispered to the corporal that the torturer had interrogated the escaped prisoner/to attempt an escape.
16 The nun whispered to the abbess that the cardinal had respected the pious novice/to fasten the door. The coach confessed to the boxer that the referee had disciplined the sparring partner/to fixing the match.
17 The technician revealed to the engineer that the astronaut had fired the booster rocket/about the crisis. The minister announced to the bureaucrat that the reporter had paid the civil servant/about the scandal.
18 The curator whispered to the commissioner that the queen had knighted the famous archivist/about the museum. The consultant explained to the photographer that the nurse had bandaged the bleeding protester/about the equipment. Did the nurse bandage the consultant?
19 The critic confides to the poet that the committee has rejected the dreary novelist/about the decision. The expert outlines to the sergeant that the inquiry has rewarded the clever inspector/about the evidence. Has the inquiry rewarded the sergeant?
20 The tutor taught the princess that the warrior had admired the haughty duchess/to write

an essay. The chemist told the student that the lecturer had greeted the lazy chairman/to find a beaker. Did the warrior admire the tutor?
21 The agent confessed to the playwright that the rival had criticised the costume designs/to needing the case. The captain whispered to the marksman that the general had promoted the youngest soldier/to target the guard.
22 The publicist reminded the director that the set designer had talked with the young journalist/to sketch the backdrops. The programmer instructed the apprentice that the car mechanic had dealt with the new customers/to take the readings.
23 The guide shouted to the climber that the runner had followed the stupid walker/to test the crampon. The girl hinted to the model that the lawyer had dismissed the handsome trainee/to read the letter.
24 The landlord informed the tenant that the housing officer had exploited the assistant engineer/about the legal contract. The banker advised the dustman that the council treasurer had demoted the senior foreman/about the mortgage payment.
25 The lifeguard told the woman that the swimmer had rescued the drowning youngster/to stay on the beach. The barmaid warned the sailor that the steward had bullied the frightened deckhand/to sit near the door.
26 The estate agent confessed to the optician that the buyers had met the careful surveyor/to losing the glasses. The physics teacher whispered to the headmaster that the pupils had kicked the irate policeman/to open the locker.
27 The count mentioned to the butler that the tourists had insulted the toilet attendant/about the broken chairs. The thief revealed to the woman that the watchmen had recognised the stolen articles/about the faulty locks.
28 The wife announced to the geologist that the counsellor had treated the moody teenagers/about the holidays. The youth explained to the pathologist that the magistrate had ignored the expert witnesses/about the accidents.
29 The man informed the writer that the inmates had injured the deputy governor/about the recent upsets. The vet advised the father that the children had adored the mischievous animal/about the likely outcome.
30 The solicitor explained to the forger that the constable had arrrested the other accomplice/about the fingerprints. The historian mentioned to the grocer that the commando had protected the fleeing refugees/about the manuscripts.
31 The clerk informed the plumber that the hotelier had punched the visiting millionaire/about suing the company. The priest advised the painter that the academic had trained the successful applicant/about joining the monastery.
32 The matron told the midwife that the mother had trusted the traditional techniques/to prepare the bottles. The sweeper warned the milkman that the driver had attacked the old age pensioners/to tidy the boxes.

Study 2

NP complement/S complement

1 Two judges announced the winners of the prizes from the rostrum/would play again and the captain declared a ceasefire from the battle at the weekend/was not likely. Did the judges announce the winners of the prizes?/Would the winners of the prizes play again?
2 The manager decided the price of jackets for the spring sale/was far too high and the researchers discovered a cure for cancer by a strange chance/was years away. Did the researchers discover a cure for cancer ?/Was a cure for cancer years away?
3 The suspect denied the charge of murder to the jury/was quite valid and the author mentioned the book on tennis at the bookshop/the book on tennis was not useful. Did the suspect admit the charge?/ Did the suspect deny the charge was valid?
4 The lawyer argued the case against David to the committee/was not reasonable and the baker

explained the rules about parking to the apprentice/were too restrictive. Did the butcher explain the rules/Were the rules too lenient?
5 The younger son claimed the sickness benefit from the government/was not adequate and the master chef read the latest recipe in the magazine/was quite difficult. Did the younger son claim the benefit ?/Did the younger son think the benefit was inadequate?
6 The magistrate decided the penalty for speeding at the court/would be high and the rescuer accepted the award for bravery from the mayor/was too much. Did the rescuer turn down the award?/Did the rescuer think the award was too little?
7 The novelist found the story about the haunted theatre in the magazine/would be popular and the diplomat learned the speech about the foreign policy for the reception/had been tedious.
8 An official declared the contestants for medals at the major contest/were all very worthy and the charity mentioned the donation of money from the wealthy couple/had been very helpful.
9 The mother recalled the year of the dreadful floods to her children/was quite frightening and the vicar announced the prize for the sponsored walk in the paper/should be bigger.
10 The monarch decides the punishment for the plotters at the secret trials/is a heavy sentence and the spokesman denies the explosion of the missiles at the army bases/was a dreadful error.
11 The explorer found the idol from Peru in the temple/was quite heavy and the inspector knew the teacher of English from the meeting/would be working.
12 The actor accepted the oscar for the film at the wild party/could be quite useful and the banker discovered the value of the shares at the stock exchange/was not yet stable.
13 The stuntman found the bike with the basket at the garage/had been mended and the fireman saw the cause of the blockage in the tunnel/could be removed.
14 The scientist exclaims the answer to the problem with great confidence/is not obvious and the architect accepts the contract for the building from the hospital/is too demanding.
15 The tradesman recalled the machines with the copper fuses from the depot/were all damaged and the surgeon denied the account of the recent events to the police/was not truthful.
16 The manager explains the overtime pay to the workers/might be reduced and the minister suggests a tobacco tax for the budget/will be welcomed.
17 The milkman accepts some of the latest supply from the dairy/will be delayed. The colonel declares all of the crucial orders at the meeting/have been stolen. Does the milkman accept some of the latest supply?/Will some of the latest supply be delayed?
18 The lawyers announced the jury for the trial at the last minute/would stay in hotels. The tutor disclosed the venue for the class at the new college/would be on campus. Did the tutor disclose the venue for the class?/Will the venue for the class be on campus?
19 The weatherman reported a huge downpour to the coastguard/would come shortly. The chairperson suggested a good excuse to the warden/a good excuse might be needed. Did the weatherman report sunny weather ?/Would sunny weather come shortly?
20 The passenger accepts the rather greasy meal at the cafe/was good value. The mountaineer believes the very stupid guide at the hotel/was not careful. Was the guide very stupid?
21 The children heard the series on Radio Four in the car/was quite good. The sergeant wrote the reports on stolen cars at the desk/were not right. Did the children hear the series on Radio One?/Was the series on Radio Four popular?
22 The executive disclosed the location of the safe to the robber/had been altered. The politician explained the policy on the mines to the banker/would be changing. Did the politician explain the policy on the mines?/Was the policy on the mines staying the same?
23 The boy found the very large present near the oak cabinet/was a toy dinosaur. The maid knew the rather ill butler at the huge vicarage/took the pink medicine.
24 The driver saw a shortcut to the shop from the ringroad/would be quicker. The worker found the owner of the firm near the warehouse/had been stealing.
25 Jane discovered the source of the muddy stream near the tall mountains/was in the mountains. Phil remembered the route to the rocky cliffs from the small village/went through the village.
26 Sally found the solution to the difficulty for the friend/was quite hard. Peter showed the

appraisal by the inspectors to the boss/had been flawed.
27 The newspaper reported the crazy rumour on the front page/might not be true. The officer discovered the stolen lorry in the car park/had been bright red.
28 Jonathan guessed the first meeting place for the drama group/would be at the school. Rosemary heard the new indy band at the concert hall/would fly to the States.
29 The sponsor declared the result of the inquiry from the podium/was not worrying. The dancer revealed the problem with the conductor at the opera/might be serious.
30 The magician showed the really impressive trick to the children/was not easy. The activist proposed the very dangerous plan to the leader/would be worthwhile.
31 The farmer denied the feud with the neighbours to the police/was quite awful. The teacher explained the words in the story to the pupil/were all easy.
32 The editor considered the article on the famine with the assistant/was quite unusual. The headmaster reported the proposal for the tuckshop to the governor/was not popular.

Main clause/reduced relative clause

1 The artist sent the letter to the teacher/drew the teacher and the joiner brought the whiskey/thanked the workmate. Did the artist send the letter?/Did someone send the artist the letter?
2 The disc jockey played the song to the guitarist/praised the guitarist and the pop singer sold the car to the manager/fired the manager. Did the pop singer sell the car?/Did someone sell the pop singer the car?
3 The publisher read the manuscript to the editor/met the editor and the consultant passed the stethoscope to the researcher/called the researcher. Did the publisher sell the manuscript?/Did someone read the publisher an article?
4 The striker kicked the football straight past the goalkeeper/pushed past the goalkeeper and the agent mailed the photo off to the journalist/tipped off the journalist. Did the agent keep the photo ?/Did someone mail the agent a letter?
5 The woman painted the portrait near the house/liked the frame and the client repaid the money to the bank/cashed the cheque. Did the woman paint the portrait?/Did someone paint the woman the portrait ?
6 The actor reserved the ticket at the station/took the taxi and the lawyer despatched the report from the airport/left the airport. Did the lawyer burn the report?/Did someone despatch the lawyer a book ?
7 The student asked a difficult question in the classroom/fled the classroom and the conman leased an expensive office in the city/knew the city.
8 The comic told the awful joke to the youngster/thumped the youngster and the doctor mailed a birthday card to the patient/saw the patient.
9 The executive sent the blackmail letter to the chairperson/met the chairperson and the ambassador faxed the crucial visa to the traveller/phoned the traveller.
10 The teenager baked the birthday cake for the grandmother/kissed the grandmother and the architect sent the latest plans to the accountant/showed the accountant.
11 The charity rented the hall for the auction/held the auction and the hospital despatched the pills to the clinic/told the clinic.
12 The waiter handed the glass to the charming hostess/glimpsed the charming hostess and the chemist rented the flat from the shady landlord/feared the shady landlord.
13 The student mailed the postcard to the old woman/showed the old woman and the fireman passed the ladder to the tired colleague/saved the tired colleague.
14 The singer posted the details to the confused composer/helped the confused composer and the agent offered the booking to the famous magician/hired the famous magician.
15 The psychologist lent the book to the girl/woke the girl and the mathematician bought the wine for the nurse/loved the nurse.
16 The climber tossed the rope down to the injured mountaineer/yelled to the injured moun-

taineer and the builder passed the paint up to the spotty apprentice/talked to the spotty apprentice.
17 The barrister handed the verdict to the defendant/coaxed the defendant. The producer assigned the programme to the cameraman/sacked the cameraman. Did the barrister hand the verdict to the defendant ?/Did someone hand the barrister the verdict?
18 The psychiatrist fetched the report for the court trial/watched the court trial. The receptionist sent the parcel to the main office/passed the main office. Did the receptionist send the parcel ?/Did someone send the receptionist the parcel?
19 The major sent the order back to the barracks/blew up the barracks. The model passed the jacket up to the stylist/changed in the corner. Did the corporal send the order back?/Did someone send the major a parcel?
20 The announcer told the story to the producer/blamed the producer. The professor mailed the results to the lecturer/phoned the lecturer. Did the secretary mail the results?/Did someone mail the professor the questions?
21 The banker saved the seat next to the client/advised the client. The farmer built the house near to the village/hated the village. Did the client save the seat?/Did someone save the banker a ticket?
22 The programmer posted the software to the librarian/hugged the librarian. The grandparent knitted the jumper for the adolescent/teased the adolescent. Did the grandparent knit the jumper ?/Did someone knit the grandparent the jumper?
23 The man sold the popcorn to the tourists/chased the tourists. The kid bought the balloon near the buskers/liked the buskers.
24 The baby fed the spinach to the dappled pony/stroked the dappled pony. The umpire tossed the jumper to the cricket player/stopped the cricket player.
25 The prince served the meal to the princess/loved the princess. The witch brought the frog to the wizard/cursed the wizard.
26 The magistrate awarded the damages to the other journalist/sued the other journalist. The scientist allocated the equipment to the clever technician/shocked the clever technician.
27 The teacher taught the new methods to the pupils/scared the pupils. The foreman paid the low wages to the workers/loathed the workers.
28 The woman lent the van to the dentist/saw the dentist. The dancer poured the drink for the barman/thanked the barman.
29 The singer delivered the flowers to the actress/clapped the actress. The banker rented the villa to the writer/phoned the writer.
30 The man handed the present to the pretty gymnast/kissed the pretty gymnast. The spy posted the blueprints to the secret agent/told the secret agent.
31 The duchess served the tea to the viscount/snubbed the viscount. The convict slipped the file to the cellmate/bribed the cellmate.
32 The policeman told the news to the inspector/rang the inspector. The hiker lent the maps to the rescuer/helped the rescuer.

Study 3

Subordinate clauses (thematic role manipulation)

1 Although the delay was annoying the handsome pilot (the steward) started humming and although the farmer was harvesting the (ripened barley) the carrots began rotting. Did the steward/pilot hum ?
2 Because the sculpture was pleasing the pretentious woman (the husband) brought back a copy and because the artist was painting the enormous portrait (the easel) stood in the corner. Did the woman bring back/dislike the sculpture?
3 Although the film is frightening the young child (the mother) enjoys the plot and although the man is singing the theme tune (the chorus) annoys the crowd. Did the man sing the theme

tune?/Did the chorus annoy the crowd?
4 Although the story was charming the cheerful cast (the director) was uncertain and although the lady was knitting the turquoise socks (the cardigan) was unfinished. Was the lady knitting the cardigan?/Were the socks finished?
5 Since the case was intriguing the clever sergeant (the detective) noted down the details and since the nurse was bandaging the bleeding patient (the consultant) waited in the lobby. Did the detective note down the details?/Did the sergeant note down the details?
6 Because the route was tiring the injured walker (the helpers) stopped for a break and because the boy was ironing the yellow jacket (the trousers) hung on a chair. Did the girl iron the jacket?/Did the girl do the ironing?
7 Because the medallion was mesmerizing the rich guest (the hypnotist) laughed uncontrollably and because the carpenter was hammering the cheap nail (the plasterboard split) irretrievably.
8 While the applause was gratifying the shy novelist (the publisher) was scowling and while the teacher was interviewing the tall candidate (the secretary) kept smiling.
9 Since the stories were entertaining the rowdy children (the nurses) were happy to listen and since the princes were contributing the biggest prizes (the parties) were easy to arrange.
10 As the reports were discouraging the surly conscripts (the sergeant) was/were annoyed and as the lawyers were photocopying the crucial papers (the statement) was/were mislaid.
11 As the music was soothing the weeping father (the fireman) felt better and as the author was reading the awful novel (the paper) got grubby.
12 Although the document was convincing the stupid boss (the youth) was not taken in and although the magistrate was entering the noisy court (the crowd) did not settle down.
13 As the thunder was menacing the desperate yachtsman (the captain) returned to the port and as the rider was polishing the embossed buckle (the harness) glinted in the sun.
14 While the safari was exciting the naive tourist (the explorer) flipped through the brochure and while the musician was composing the splendid opera (the overture) played in the background.
15 Although the wind was chilling the exhausted refugees (the aid workers) seemed not to care and although the man was watching the amateur performers (the flute players) tried not to smile.
16 Although the steam was scalding the small child (the mother) was not aware of the danger and although the chef was carving the roast meat (the pudding) was not ready for the diners.
17 Since the complaint was worrying the apprehensive singer (the composer) tried to help. Since the doctor was assisting the incompetent surgeon (the inspector) asked to leave. Did the composer try to help?/Did the singer try to help?
18 Because the subject was confusing the history student (the teacher) asked a question. Because the toddler was visiting the generous uncle (the cousin) made a jelly. Did the student ask a question?/Was the subject easy?
19 Although the technique is relaxing the patient (the therapist) is not satisfied. Although the musician is practising the trombone (the violin) is still unpolished. Was the musician practising the trombone ?/Was the trombone unpolished?
20 Although the noise was distracting the little groups (the work) was very impressive. Although the boy was explaining the complex rules (the game) seemed rather difficult. Did the game seem easy?/Did the rules seem easy?
21 While the video was boring the old experts (the students) watched with great enthusiasm. While the scientist was choosing the best samples (the beakers) cooled in the refrigerator. Did the students find the film dull?/Did the experts find the film dull?
22 As the review was insulting the friendly producer (the actor) rang up the paper. As the student was programming the ancient computer (the keyboard) gave out strange noises. Did the keyboard make strange noises?/Did the computer make strange noises?
23 As the smell was sickening the unhappy cleaners (the chemist) switched on the fan. As the spy was scribbling the important details (the photos) lay on the shelf.
24 Because the landscapes were enchanting the fat duke (the chauffeur) was very cheerful. Because the grocers were opening the main shop (the pavement) was rather crowded.

25 Because the threat was shocking the pregnant woman (the culprits) were/was scared. Because the man was typing the final invoice (the reports) were/was late. 26 While the attack was terrifying the timid dentist (the gunman) was safe. While the youngster was nibbling the sticky meringue (the custard) went cold.
27 Since the diagnosis was perplexing the foreign clients (the manager) was/were rather irate. Since the adolescent was studying the latest textbooks (the dictionary) was/were very useful.
28 Although the disease was ravaging the weary sailors (the ship) was/were sent away. Although the butler was unpacking the leather cases (the trunk) was/were left outside.
29 Since the patrol was threatening the cowardly terrorist (the accomplice) fled speedily. Since the expert was directing the wonderful musical (the performance) went superbly.
30 While the evidence was dismaying the young defendant (the lawyer) was looking nervous. While the architect was surveying the whole property (the hillock) was being levelled.
31 While the fault was puzzling the clever woman (the friend) came up with a solution. While the youth was shovelling the sloppy cement (the earth) slid out of the wheelbarrow.
32 Since the illusion was amazing the incredulous child (the grandmother) was delighted. Since the barrister was arguing the sensational case (the evidence) was reported.

Appendix D

Comprehension-to-production priming: Experimental materials

1 The woman in the restaurant was complaining about the burnt pizza. The woman showed the pizza to the manager/the manager the pizza. The manager gave ...
2 The bank manager kept bothering the unemployed carpenter to repay a small loan. A rich friend lent two hundred pounds to the carpenter/the carpenter two hundred pounds. The carpenter sent ...
3 The cricket umpire suspected that the ball had been tampered with. The bowler threw the ball to the umpire/the umpire the ball. The umpire showed ...
4 The receptionist was expecting a large envelope with the latest test results. The doctor had sent several samples to the laboratory/the laboratory several samples. The postman handed ...
5 The sick woman asked the cancer specialist for some of the latest pills. Her GP had shown the case notes to the specialist/the specialist the case notes. The specialist gave ...
6 The car maintenance class had just started at the night school. The instructor was showing the technique to the student/the student the technique. The student handed ...
7 The young nurse had just got married and her old aunt kept nagging her for a photo of the wedding. The aunt sent a reminder to the nurse/the nurse a reminder. The nurse posted ...
8 The garage wrote to tell the family that their car was a write-off. The father read the letter to his friend/his friend the letter. The friend loaned ...
9 The student desperately needed a job to pay off his overdraft. He sent his C.V. to several employment agencies/several employment agencies his C.V. One agency offered ...
10 One of the customers in the pub was depressed because he had just got a letter from his girlfriend calling it all off. The barman gave a drink to the customer/the customer a drink. The customer showed ...
11 The gig was almost sold out but there were still a few tickets left. The booking clerk sold two tickets to the teenage fan/the teenage fan two tickets. The fan gave ...
12 All of the class had done exceptionally well in the exams. The teacher handed the certificates to the pupils/the pupils the certificates. The happy pupils showed ...
13 A soldier was in court, accused of attacking a young man. The victim showed his injuries to the judge/the judge his injuries. The judge gave ...
14 A young couple were looking for a cheap car. The salesman showed a green mini to the young couple/the young couple a green mini. He sold ......
15 It was almost the end of term, and money was running low. The student wrote a letter to his parents/his parents a letter. The parents sent ...
16 The little children were looking at a big book of fairy-tales. They showed the stories to their mother/their mother the stories. She read ...
17 An extremely urgent package had just arrived at the reception desk for the busy executive.

The courier handed the package to the receptionist/the receptionist the package. The receptionist took ......
18 The secretary interrupted the ambassador's meeting. Someone had faxed a message to the ambassador/the ambassador a message. The secretary showed ...
19 The trustees of the art gallery were asking for contributions to a special exhibition. The millionaire loaned two paintings to the gallery/the gallery two paintings. The trustees posted ...
20 The new microwave oven in the student flat wasn't working properly. The student showed the switch to the landlord/the landlord the switch. The landlord gave ...

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