Chapter 1

Introduction

1 Sentence comprehension

Sentences are heard of read only in a piecemeal fashion, roughly on a word-by-word basis. In order to understand the sentence, the incoming words must be combined into larger syntactic and semantic units. This is not a trivial task. Consider, for instance, the following sentence fragment:

(1) Which poet...

This sentence can be completed in an infinite number of ways, with *which poet* occupying various grammatical roles, e.g. subject, as in (2a), direct object (2b) or object of a preposition (2c), to mention just a few.

(2) a. Which poet wrote *The Canterbury Tales*?
    b. Which poet do you like?
    c. Which poet did you dedicate a song to?

The syntactic role of *which poet* becomes clear only after an indefinite number of words have been processed. For instance in (2c), the ambiguous phrase *which poet* is separated from the preposition *to* it belongs to by five words. The distance may be even longer, as in (3).

(3) Which poet did William and the actors he had been hiring to perform the play dedicate the hilarious song they had written in just one midsummer night to?

The syntactic function of phrases such as *which poet* is thus at least temporarily ambiguous. It is unlikely that the analysis of the ambiguous phrase is delayed till the end of the sentence: memory capacity is limited. Furthermore, some sentences remain completely ambiguous. Hence, people must have a way to assign functions to ambiguous phrases when sentences are heard or read on a word-by-word basis.

A great deal of sentence comprehension research has been aimed at specifying how such ambiguities are resolved: Which reading is preferred? On the basis of which information? And how do the preferences change over time? Answers to these questions may tell us more about the processes and sources of information involved in sentence processing in general.
Chapter 1

The present study is directed at specifying the relative contribution of various sources of information to sentence comprehension, concentrating on the processing of subject-object ambiguities in Dutch. This chapter serves as a brief introduction to the field. In Section 2, I will first discuss three subtasks of sentence processing and sources of information. Current approaches to sentence processing differ with respect to the way in which the various sources of information are used during ambiguity resolution. I will discuss this issue in Section 3. I will specify the aim of the present study in more detail in Section 4. An overview of the following chapters is given in Section 5.

2 The tasks of the sentence processor

Sentence comprehension research is concerned with what happens between word recognition and the point at which the complete sentence is understood. The complex of cognitive processes devoted to this task is generally referred to as the sentence processing mechanism or sentence processor. Several subprocesses can be distinguished. First, words must be combined into larger units as they are recognized. A second task is to identify the semantic roles played by the noun phrase referents in the event expressed by the verb. Third, a discourse model is created or modified such that the noun phrases in the sentence refer to an entity in this model. Many more processes can be distinguished, but these three are relevant to the discussion in the next chapters. I will discuss them in more detail below. The reader should bear in mind that the order in which they are presented does not necessarily correspond to the order in which they actually occur.

2.1 Combining words to phrases

When a word is read or heard, a representation of the word is activated in the mental lexicon. In the mental lexicon all kinds of information concerning the word are stored: its orthography, pronunciation, aspects of its meaning, and its syntactic category (whether it is a noun, a verb, or is of another category), among other things. Word category information is used to combine words into larger units. For instance, the determiner (D), adjective (A) and noun (N) in (4a) can be combined to a noun phrase (NP), as represented by the labelled bracketing in (b).

\[(4) \quad \begin{align*}
\text{a. } & \text{the}_n \text{famous}_a \text{poets}_n \\
\text{b. } & [\text{the}_n \text{famous}_a \text{poets}_n]
\end{align*}\]

There are various restrictions on how words combine to phrases. This information is stated in the grammar of the language in question. Syntactic knowledge can be stated either in terms of specific phrase structure rules (Chomsky, 1965), or in terms of more general rules and restrictions (Chomsky, 1981, and later work). This syntactic information is used to construct a representation of the incoming sentence. For instance, in English, an article cannot follow the noun it is a
determiner of. Thus, in (5), the three words cannot be combined to form a complete NP. Instead, the determiner signals that another NP is coming up, as e.g. the king in (5b).

(5) a. famous poets the
b. Famous poets, the king will always invite.

Similarly, in (6a), the preposition (P) from cannot form a complete unit with the preceding words, but combines with a following NP, yielding a prepositional phrase (PP). Together with the noun poets, this PP forms a more complex NP, cf. (6b):

(6) a. poets from
b. [ NP poets N [ PP from N continent ]]

Complete NPs and PPs can combine with a verb (V) to form a clause. Syntactic functions such as subject and object can be defined in terms of hierarchical position of the NPs in the clause. The NP that combines with the verb to form a VP is an object; the NP that combines with a VP is the subject of the clause. This is illustrated in (7):

(7) a. The poets greeted the king.
b. [ clause [ NP SUBJECT the poets ] [ VP greeted [ NP OBJECT the king ] ] ]

In (7), the king is the object. It combines with the verb to form a VP. The NP the poets is the subject of the clause: together with the VP it forms a complete clause. Again, certain syntactic restrictions apply. In simple English declaratives, the subject NP precedes the verb, and the verb precedes the object NP. This information is made use of while a structural representation of an incoming clause is constructed.

This task of combining words into larger phrasal units and assigning syntactic functions is thus for a great deal driven by syntactic information. This is information that abstracts away from the specific semantic content of the words and the discourse context in which the sentence is uttered.

2.2 Assigning thematic roles to NPs

A second task of the sentence processor is to assign thematic roles to the NPs in the clause. Thematic information is provided by the (lexical) verb. A verb describes an event (or state) and specifies the roles that the referents of the NPs play in this event (state). For instance, a verb like to hit expresses an activity that someone, the agent, does to someone or something, the patient or theme (cf. Gruber, 1976). These thematic roles are usually assumed to be stated in the lexical entry of the verb in the mental lexicon, and are activated when the verb is
recognized. One task of the sentence processor is to relate the thematic roles to the NPs in the sentence. For instance, in (8), the poet fulfills the agent role of the hitting event; the farmer the theme.

(8) The poet hit the farmer.

How the roles are assigned to the NPs is subject to grammatical restrictions. In English, the sequence in (8) can only mean that the poet hit the farmer, and not that the farmer hit the poet. In general, if a verb selects an agent and a theme role, the agent role is assigned to the subject of the clause, the theme to the object. The syntactic position of the NPs thus has consequences for the meaning of the clause.

Although the assignment of thematic roles is restricted by the syntactic position of the NPs, thematic role assignment cannot be reduced to the assignment of syntactic functions or vice versa. This is exemplified in (9). The sentence-initial NP, poets, is the subject of the clause. This becomes evident already at the finite auxiliary (were), or even earlier. However, the thematic role of this NP becomes clear only at the lexical verb provided later in the input. Note that the subject NP does not always fulfill the agent role: the verb can assign a variety of thematic roles. For instance, the first NP is the theme of the action in (9a), experiencer in (b), and the cause in (c):

(9) Poets were...
   a. hit.
   b. surprised.
   c. making the king laugh.

The assignment of a syntactic function must therefore take place independently of the assignment of a thematic role. The reverse situation can also occur. There is some evidence that the assignment of a thematic role can take place before the syntactic position of the NP is realized in the input (e.g. Pickering and Barry, 1991; Boland, Tanenhaus, Garnsey and Carlson, 1995; Traxler and Pickering, 1996). In sum, during sentence processing, NPs must be assigned a thematic role provided by the verb. This task is distinct from the task of constructing a syntactic representation and assigning syntactic functions to the NPs.

2.3 Establishing NP referents

Another subtask of sentence processing is to establish the referents of the NPs in a mental discourse model (e.g. Heim, 1982). A discourse model is a mental representation of the entities that have been mentioned in the discourse. An NP can either refer to something that has been mentioned before and, hence, is already part of the discourse model, or introduce a new entity into the model.
Different types of NP impose different restrictions on their referents. Consider for instance (10).

(10) A poet walked by.

The NP *a poet* refers to something that has not been mentioned before. This is signalled by the use of an indefinite determiner *a*. A new entity is therefore set up in the discourse model. Other NPs in subsequent sentences may refer to this entity. Now consider (11).

(11) The poet was singing.

The use of the definite determiner *the* implies that there is one poet who can be uniquely identified. This means that such an entity either is already present in the discourse model, or can easily be inferred. If (11) is part of the discourse initiated by (10), the NP can licitly refer to the poet already present in the model. If, however, (11) is uttered out of the blue, the inference is made that there is a unique poet which the sentence is a statement about. A corresponding entity will be set up in the discourse model.

Briefly put, part of sentence processing is to identify the referents of the NPs in the sentence. This is done either by linking them to already mentioned entities, or by setting up new or inferring known entities in the discourse model. Note that the syntactic process of creating an NP need not be completed before a referent of this phrasal unit can be established. If the context is sufficiently restricted, people identify an NP referent even before all words constituting this NP have been encountered (Eberhart, Spivey-Knowlton, Sedivy and Tanenhaus, 1995).

2.4 Summary

In sum, at least three subtasks in sentence processing can be distinguished: first, words must be combined to phrases, and phrases to clauses (which also includes the assignment of syntactic functions as object and subject); second, thematic roles provided by the lexical verb must be assigned to NPs and, third, the referents of the NPs must be established. Correspondingly, different sources of information can be distinguished: syntactic, thematic and discourse information. In addition other types of information play a role in sentence processing (e.g. prosody, world knowledge) but these are not dealt with here.

3 Ambiguity resolution

An important issue in sentence processing theory has been whether the process of combining words into larger units is initially sensitive to syntactic information only, or whether other information plays a role, as well. One way to investigate
this issue is by looking at how structural ambiguities are resolved. As has been mentioned previously, natural language is abundantly ambiguous: when sentences are read or heard on a word-by-word basis, the words can frequently be combined into larger units in more than one way. Investigating which information (syntactic, thematic, discourse, or other) affects the resolution of such ambiguities, and at which point specific kinds of information are used, may tell us more about the nature of the sentence processing mechanism. Below, two opposing views, syntax-first and interactive approaches, will be discussed. However, as will become clear from later discussion, the two approaches are hard to distinguish empirically.

3.1 Syntax-first approaches

According to syntax-first approaches (e.g. Frazier, 1979, 1987a, 1990a), the sentence processor contains an initial syntactic stage of analysis. This stage is sensitive to syntactic information only, that is, word category information and grammatical knowledge. In such a model, structural ambiguity is initially resolved on the basis of structural strategies. One such syntactic strategy is the principle of Minimal Attachment. Frazier (1979:24) defines this principle as follows:

(12) \textit{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.

This implies that in cases of structural ambiguity the syntactic representation is built that is the least complex in terms of the number of phrase markers (i.e. labels such as NP and VP).

Let me illustrate the workings of this strategy with an example. A well-studied English ambiguity is the reduced relative/main clause ambiguity (for an overview, cf. MacDonald, Pearlmutter and Seidenberg, 1994). For instance, the fragment in (13) can be continued in two ways, (a) and (b):

(13) The defendant examined....

a. the evidence.

b. by the judge turned out to be unreliable.

In (13a) the verb \textit{examined} is the main clause verb. In (b), the verb is a passive participle introducing a reduced relative clause which modifies the first NP. The unambiguous equivalent of (13b) is given in (14):

(14) The defendant who was examined by the judge turned out to be unreliable.
Generally, speakers of English prefer one reading of fragments like (13), namely the one in which the first verb is interpreted as the main clause verb (13a). This becomes clear when reading times for reduced (13b) and unreduced relatives (14) are compared at the disambiguating by-phrase. Reading times at this position are generally longer for the reduced version. This suggests that the verb examined in (13) is initially interpreted as a main clause verb. This analysis is incompatible with the by-phrase, leading to an increase in processing effort and hence, to an increase in reading times at this position.

The principle of Minimal Attachment accounts for this main clause preference in the following way. First, consider the syntactic structure corresponding to the alternative readings. The representation in (15a) corresponds to the interpretation in which examined in (13) is taken to be the main clause verb; (15b) is a possible representation of a reduced relative (the relative clause is labeled RC).

(15)  a. \[ _{np} \text{the defendant} \] \[ _{vp} \text{examined}... \]

b. \[ _{np} \{ _{np} \text{the defendant} \} \{ _{rc} \text{examined}... \} \] \[ _{vp} ... \]

Clearly, a reduced relative interpretation involves more structure than a main clause analysis: in the least, it requires an additional node within the NP: together, the relative clause and the preceding NP form a larger NP. According to the Minimal Attachment principle, the main clause analysis in (15a) is preferred, as this analysis involves the least number of nodes. When other information comes in that is not compatible with this analysis (e.g. the by-phrase in (13b)), an increase in parsing difficulty is the result, as the preferred syntactic analysis has to be revised.

The initial syntactic stage (structural building stage) is assumed to be informationally encapsulated, that is, it can only make use of syntactic information. This implies that the initial preference for a main clause interpretation is not influenced by the specific thematic, semantic and other properties of the NPs and Vs, even if this information is already available. Such non-structural information may be used only at later stages: when non-syntactic information is incompatible with the syntactic analysis, it may trigger a revision of the structural representation.

3.2 Interactive approaches

According to interactive models, not only syntactic information but all other information (lexically specific thematic information, discourse information, etc.) can influence the resolution of structural ambiguities as soon as this information becomes available (Taraban and McClelland, 1988; MacDonald, Pearlmuter and Seidenberg, 1994; Trueswell and Tanenhaus, 1994; Spivey-Knowlton and Tanenhaus, 1994).
Some evidence in favor of an interactive model can be found in e.g. Trueswell, Tanenhaus and Garnsey (1994). Trueswell et al. report effects of thematic information on the way in which the reduced relative/main clause ambiguities are resolved. Trueswell et al. compared the sentences in (16), among other things. In contrast to the sentence in (13), the first NP in (16) is a suitable theme of the verb examined.

(16)  a. The evidence examined by the lawyer turned out to be unreliable.
    b. The evidence that was examined by the lawyer turned out to be unreliable.

No differences in reading times were attested at the by-phrase for the ambiguous and unambiguous versions in (16), in contrast to what was found for clauses in which the first NP denoted an animate entity, as in (13b) versus (14). This suggests that the thematic fit of the NPs with the verb affects ambiguity resolution.

In an interactive approach, the thematic fit of the NP and the V is taken into account as soon as an interpretation is assigned to the incoming sentence. The fact that sentences like (16a) are easier to process than sentences like (13b) is thus accounted for in a straightforward way. A number of other experimental results support the view that non-syntactic information such as thematic and discourse information very rapidly influence the resolution of structural ambiguity (e.g. Tanenhaus, Boland, Garnsey, and Carlson, 1989; Trueswell and Tanenhaus, 1991; Stowe, Tanenhaus and Carlson, 1991; Britt, Perfetti, Garrod and Rayner, 1992; Boland, Tanenhaus, Garnsey and Carlson, 1995; Altmann, Garnham and Dennis, 1992; Spivey-Knowlton, Trueswell and Tanenhaus, 1993; Ni, Braze, Conway, Crain and Shankweiler, 1996; cf. also Chapter 2, Section 5.1).

3.3 Empirical evidence is not conclusive

Psycholinguistic research has for a long time been directed at obtaining evidence in favor of or against either syntax-first or interactive models. Theoretically, the two approaches differ with respect to the point at which non-syntactic information is made use of in sentence processing. According to syntax-first models, the influence of non-syntactic information should be delayed relative to syntactic information, as non-syntactic information only has access to the output of the syntactic stage. Interactive theories predict no such delay. It is however hard to empirically distinguish syntax-first and interactive theories.

First, as has already been mentioned, there is some evidence that non-syntactic information such as thematic and discourse information is made use of very rapidly in the resolution of structural ambiguities. This has been claimed to support interactive models. However, one cannot exclude a syntax-first model on the basis of these data: after the initial syntactic stage, non-syntactic information may lead to a quick, cost-free revision of the initial syntactic analysis. The current
experimental methods might just not be sensitive enough to track this very first syntactic stage. The data cited above are therefore not incompatible with a syntax-first approach.

Some studies, on the other hand, report a delay of non-syntactic information on ambiguity resolution, or no effect at all (e.g. Ferreira and Clifton, 1986; Mitchell, 1987; Clifton and Ferreira, 1989; Mitchell, Corley, and Garnham, 1992; Rayner, Garrod and Perfetti, 1992; Murray and Liversedge, 1994). This may be interpreted as counterevidence for interactive models: according to these models all information should be used immediately. However, proponents of interactive models do not claim that all sources of information have an equally strong effect on ambiguity resolution. Some information, e.g. some syntactic constraints, may introduce such a strong bias for a particular reading that other information hardly has a noticeable effect, even if this information is made use of immediately (MacDonald, Pearlmutter and Seidenberg, 1994). Furthermore, quantitative models are currently being developed which show that apparently delayed effects of non-syntactic information can be accounted for in an interactive approach (cf. Spivey-Knowlton, Hanna and Tanenhaus, 1996). At present, syntax-first and interactive models can therefore not easily be distinguished on the basis of the temporal characteristics of syntactic versus non-syntactic resources.

3.4 Summarizing remarks

Previous research has shown that various kinds of information (e.g. syntactic, thematic, discourse and others) influence processing preferences in the resolution of structural ambiguities. An important question has been whether a first, strictly syntactic stage of parsing can be distinguished, or whether all kinds of information are made use of immediately. However, the experimental evidence available to date is not decisive between syntax-first and interactive approaches. What the apparently contradictory results do suggest is that some sources of information have a stronger effect on ambiguity resolution than others, and that the impact of a certain source of information is not fixed, but varies depending on other factors. Rather than trying to distinguish syntax-first from interactive approaches to sentence processing, research should first be directed at collecting data on the relative impact of the various kinds of information involved in ambiguity resolution.

4 The present study

The present study is primarily aimed at obtaining a clearer picture of the effect of various kinds of information on ambiguity resolution. More specifically, this study is directed at providing more insight into the interplay of syntactic and discourse-
related lexical information in sentence processing by looking at the resolution of subject-object ambiguities in Dutch.\(^1\)

As will be explained in more detail in the next chapter, Dutch has a number of clause types in which the syntactic function of the NPs is at least temporarily ambiguous. For instance, (17) can be interpreted with the first NP `welke dichter` as the subject and the second NP `de boer` as the object of the clause, cf. the paraphrase in (18a); or with `de boer` as the subject, and `welke dichter` as the object, cf. (18b).

(17) *Welke dichter heeft de boer gegroet?*

which poet has the farmer greeted

(18) a. Which poet greeted the farmer?

b. Which poet did the farmer greet?

As will be discussed in the next chapter, there is abundant evidence in the literature that a subject-object order (cf. 18a) is favored on syntactic grounds. This renders the Dutch word order ambiguity a suitable paradigm for investigating the strength of syntactic biases relative to other sorts of non-syntactic information.

The experiments presented in this thesis show that this syntactically based preference for the subject-object order is not as robust as previous experiments seem to suggest. Word order preferences can easily be influenced by discourse-related information, even if sentences are presented in isolation. In the present study, discourse information is manipulated by using different types of NP in the clause. First, order preferences are investigated as a function of the nature of the first NP. From a discourse point of view, a sentence starting with a definite NP triggers quite different inferences than a sentence starting with a *wh*-phrase such as *which poet*. This has consequences for the strength of the word order preference in declaratives versus *wh*-questions. Second, word order preferences differ depending on the type of NP which appears in the second position. Previous research has been mainly concerned with clauses containing a full definite NP as the second NP. In this study order preferences are investigated also in clauses containing a pronoun in second position. Pronouns and definite NPs differ with respect to the discourse status of their referents, and are for that reason differently biased to occupy the subject or object position of a clause. It will be shown that this discourse-related information is made use of in resolving word order ambiguities, leading to different order preferences depending on the type of second NP. In addition, the results suggest that the manner and point of disambiguation play a role in determining the strength of the order preferences.

\(^1\) Such ambiguities are also referred to as *word order* ambiguities, although, of course, the ambiguity does not concern the order of words, but rather the order of constituents.
It should be noted, however, that these conclusions are limited to the comprehension of visually presented, isolated sentences. Furthermore, in the experimental studies, only canonically transitive predicates are used: the verb selects an agent and a theme role, which is assigned to the subject and object position, respectively. Ditransitives, psych verb predicates and ergatives are not taken into consideration. Depending on how strong a role verb information plays in the processing of such constructions, a different pattern of results might be found with these sets of verbs.

5 Overview of this book

In Chapter 2 I will show that Dutch has a number of clause types in which the order of subject and object is (temporarily) ambiguous. I will discuss previous experimental research reporting a preference for the subject-object order. Several syntactic parsing strategies have been proposed to account for this preference. However, there are reasons to expect that discourse-related information plays a role, as well. I will argue that various type of NPs impose different requirements on the discourse context, and that this might affect the preferred order of subject and object, and the strength of this preference. Two hypotheses are formulated for explanatory purposes: the Syntactic Hypothesis, representing the view that syntactic information takes precedence and lexically induced, discourse-related information is delayed; and the Discourse Hypothesis, according to which lexically induced discourse-related information has a strong, immediate effect on the resolution of word order ambiguities.

The Syntactic and the Discourse Hypotheses are experimentally tested in the next chapters. In Chapter 3 the impact of the nature of the first NP is investigated. A self-paced reading study is conducted, comparing subject- and object-initial declarative main clauses and which-N questions (Experiment 1).

In Chapter 4 the impact of the second NP is investigated using embedded wh-clauses. Six experiments will be described. First, Experiment 2 shows that people have an off-line preference to interpret an embedded wh-phrase as the subject of the embedded clause, at least, in absence of any following verb or NP. Next, order preferences are investigated for wh-clauses containing a case-marked pronoun in the second NP position. One off-line (Experiment 3) and two on-line experiments (Experiments 4 and 5) are conducted, showing a preference for an object-subject order. Experiment 6 investigates whether the same results can be obtained when a case-ambiguous pronoun is used and the sentences are disambiguated by number information. In addition, this experiment tests whether the length of the ambiguous region has any effect. Experiment 7, finally, explicitly compares wh-clauses containing a pronoun with wh-clauses containing a definite NP.

In Chapter 5 some corpus data will be presented concerning the frequency of occurrence of subject- versus object-initial wh-clauses in Dutch. The data suggest that also in naturally produced texts the nature of the second NP has
some influence on the order of the subject and the object. Furthermore, the frequency data will be compared with the experimental data obtained in the previous chapters to obtain more insight in the way frequency of occurrence corresponds to processing preferences.

In Chapter 6 an overview is given of the experimental and corpus data. I will show that in addition to syntactic preferences and discourse-related properties of the NPs, the manner and point of disambiguation play a role in the resolution of word order ambiguities. I will discuss four current theories of sentence processing, and sketch how each of these might account for the present data. Some suggestions will be given for future research. A summary of the book is given in Chapter 7.