Processing subject-object ambiguities in Dutch
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Chapter 6

General discussion

1 Introduction

One of the goals of sentence processing research is to specify the sources of information that play a role in ambiguity resolution and to determine to what extent they can influence the resolution process. Previous research on word order ambiguities in Dutch and similar constructions in German has shown a general preference for a reading in which the subject precedes the object. This suggested that resolution of word order ambiguities was primarily driven by syntactically based strategies or generalizations independent of specific lexical information, that favor a subject-object order. The present work was aimed at investigating whether this syntactic bias could be enhanced or counteracted by the nature of the first and second NP of the clause.

Below, first the results from the experiments reported in Chapters 3 and 4 and the corpus study in Chapter 5 will be summarized. Next, the Syntactic and the Discourse Hypothesis will be discussed. It will be shown that neither accounts for the present data in a straightforward way, rather several factors appear to contribute to the resolution of word order ambiguities. Which order is ultimately preferred is determined by the relative strength of these factors. In Section 3, four current theories of sentence processing will be discussed in the light of the present results. Finally, in Section 4, some suggestions will be given for future research.

2 The influence of the NPs on word order preferences

2.1 A summary of the findings

The central question of the present investigation has been whether the general subject-object preference for Dutch could be influenced by the type of the first and second NP used in the clause, and if so, to what extent. The type of the NPs was expected to influence the order preference for the following reasons.

First, the nature of the first NP may trigger additional discourse or syntactic processes. A sentence-initial definite NP requires special prosodic or contextual cues if it is the object rather than the subject of the clause. In addition, an object-subject declarative may be structurally more complex than a subject-object declarative. In contrast, if the sentence-initial NP is a wh-phrase, subject-object and object-subject main clauses do not differ in these respects. The subject-
object preference was therefore expected to be stronger when the sentence-initial NP was a definite NP than when it was a *wh*-phrase.

Second, the nature of the second NP was expected to have an effect on order preferences. In natural discourse, pronouns generally appear as the subject of a clause. The use of a pronoun rather than a non-pronominal definite NP as second NP was therefore expected to counteract the syntactic bias for the subject-object order.

In brief, the experiments and the corpus data showed the following results. First, in accordance with the results reported in the literature (cf. Chapter 2), the present data show a general preference for a subject-object order:

- Both main clause *wh*-questions and declaratives showed a preference for a subject-initial order (Experiment 1);
- Embedded *wh*-clauses showed a preference for a subject-initial order, at least when no information was provided by a second NP (Experiment 2);
- Embedded *wh*-clauses containing an ambiguous pronoun showed a (non-significant) tendency for a subject-object interpretation when the ambiguous region was fairly short (Experiment 6).
- Embedded *wh*-clauses with a definite NP following the *welke*-N (‘which’-N) phrase showed a weak subject-object preference when the clause was disambiguated by number information at the finite verb (Experiment 7);
- Subject-initial *wh*-clauses were shown to be more frequent than object-initial questions, at least when transitive and intransitive predicates were collapsed (Corpus data reported in Chapter 5).

Second, the strength of this subject-object order preference was affected by the type of the first NP:

- The subject-object preference was less strong when the initial NP of the main clause was a *welke*-N phrase than when it was a definite NP (Experiment 1).
- The nature of the first NP apparently did not have an immediate effect on the order preference, however: although the subject-object preference was already (weakly) present at the point of disambiguation itself, the interaction of the type of first NP and order only started at the word following the disambiguating auxiliary.
Third, the subject-object bias could be overridden when a pronoun instead of a non-pronominal definite NP was used as the second NP:

- Embedded *wh*-clauses with a case-marked pronoun following the *welke*-N phrase showed an off- and on-line preference for the object-subject order (Experiments 3-5). This object-subject preference was visible at or immediately after the point of disambiguation, and at some later positions. No sign of a subject-object preference was obtained.

- When the pronoun was ambiguous with respect to case (*jullie*), and the clause was disambiguated by number information at the finite verb downstream, an object-subject preference was obtained if the ambiguous region was fairly long (Experiment 6).

- The nature of the second NP also affected the frequency of the order of subject-object and object-subject *welke*-clauses in naturally produced texts (corpus data): although the object-subject was the most frequent for transitive *welke*-questions in general, this order was relatively more frequent when the second NP was a pronoun than when it was a non-pronominal definite or an indefinite NP.

### 2.2 The two hypotheses

What do these results tell us about the impact of the nature of the NPs on the order preferences? In Chapter 2, two hypotheses were formulated representing two extreme views on this issue. These hypotheses are repeated below:

1. **The Syntactic Hypothesis**
   
   Syntactic information takes precedence; other information (lexically specific, semantic, discourse, etc.) may only have a relatively late effect on ambiguity resolution.

2. **The Discourse Hypothesis**

   If available, discourse-related information takes precedence over syntactic information in ambiguity resolution and does so immediately.

Neither of the two hypotheses receives full support from the data, but neither can be rejected, either. First, consider the Syntactic Hypothesis. According to this hypothesis, order preferences are hardly affected by the discourse-related properties of the NPs. The syntax-based preference for the subject-object order dominates. If specific properties of NPs (including discourse-related properties) have any effect at all, they will only affect processing preferences at a later stage.
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The Syntactic Hypothesis receives support from the apparently delayed effect of the first NP in the main clause experiment. In addition, *wh*-clauses containing a case-ambiguous pronoun only showed an object-subject preference when the ambiguous region was fairly long. These facts suggest that the NP-specific information is not made use of immediately, but is delayed. This is in accordance with the predictions of the Syntactic Hypothesis. However, other data seem to be somewhat problematic for this hypothesis: in embedded *wh*-clauses containing a pronoun as the second NP, no significant subject-object preference was found. If the pronoun was case-marked, an immediate object-subject preference was seen, instead. This suggests that the discourse-related properties of the second NP can very rapidly affect processing preferences, in contrast to the predictions of the Syntactic Hypothesis.

The Syntactic Hypothesis, however, cannot be rejected on the basis of the present data. The immediate preference for the object-subject order may have been only apparent: an initial subject-object preference may have been obscured by the use of case information to disambiguate the structure.

Now let us consider the Discourse Hypothesis. According to this hypothesis, the nature of the NPs should have an immediate effect on the order preference. Furthermore, this effect is expected to be stronger than the syntactic bias for a subject-object interpretation. The data do not fully support this hypothesis, either. The first NP did not immediately affect word order preferences in main clauses. In addition, no immediate effect of a pronominal second NP was seen in embedded *wh*-clauses when the pronoun was case-ambiguous and the clause was disambiguated by number information: in these cases, an object-subject preference was seen only if the ambiguous region was fairly long. But also here, the results may have been somewhat confounded: the categorial ambiguity of the pronominal form used may have rendered the object-subject order more difficult to obtain in the case-ambiguous conditions.

The two hypotheses can therefore neither be supported nor rejected on the basis of the present data. Note that the two hypotheses were formulated mainly for reasons of exposition. This allowed me to formulate clear predictions with respect to the outcomes of the experiments, assuming that either syntactic biases or the discourse biases mediated by the properties of the NPs is more important in processing. The experimental results reported here suggest that the properties of the NPs indeed affect order preferences, and can sometimes even override the subject-object preference. However, the differences among the experiments suggest that the strength and time course of this effect is not fixed, but depends on other factors. Below I will discuss two of these factors: type of disambiguating information (case marking versus number agreement) and point of disambiguation.
2.3 Manner of disambiguation

One of the factors that appear to affect the strength of the order preference and the influence of the NP specific properties on the ambiguity resolution is the manner in which the clause is disambiguated. Compare, for instance, the main clause wh-questions disambiguated by number (Experiment 1) to the embedded wh-clauses disambiguated by case (Experiments 4-5). In both cases, the disambiguating information immediately followed the wh-phrase. However, a subject-object preference was seen only in the main clauses disambiguated by number. This suggests that it is harder to obtain the syntactically non-preferred object-subject reading when number rather than case information is used to disambiguate the clause. Furthermore, the nature of the (first) NP had a relatively late effect in the main clauses disambiguated by number; in the embedded clauses disambiguated by case, the discourse-related properties of the (second) NP had an immediate effect. This suggests that the general subject-object preference is harder to counteract with lexical discourse-related information when number rather than case enforces an object-subject order.

Independent evidence that the manner of disambiguation affects order preferences comes from experiments on German (cf. Chapter 2). In German not only pronouns but also full NPs are case-marked; the difference between case and number disambiguation found in these experiments can therefore not be related to the presence of a pronominal element. Both Meng (1995) and Schlesewsky et al. (to appear) report a strong subject-object preference for German main clause wh-questions which are disambiguated by number information at the finite verb. However, results are much less robust when clauses are disambiguated by case information at the second NP: Meng (1995) reports no order preference at all; Schlesewsky et al. (to appear) found a subject-object preference that appeared only at the end of the sentence; and Farke (1994) reports an object-subject preference for total reading times.

Differences between number and case disambiguation have also been found for embedded clauses, although in these cases the difference also involves a confounding difference with respect to the point of disambiguation. For instance, Meng (in preparation) reports a strong subject-object preferences for embedded wh-clauses disambiguated by number information at the clause-final verb; however, no significant difference was obtained when the clauses were disambiguated immediately by case marking at the wh-phrase. Also ERP data reported in Friederici et al. (1996) suggest that late disambiguation by number is probably more difficult than early disambiguation by case in embedded clauses (cf. Chapter 2).

Apparently, the syntactically less-preferred object-subject order is easier to obtain when the clause is disambiguated by nominative case at the second NP rather than a number mismatch between the first NP and the finite verb. A possible explanation for this difference is that case information, and especially nominative case, provides a more direct cue concerning the ultimately correct
structure than number information. This idea is based on Fodor and Inoue’s (1994) Diagnosis model. Fodor and Inoue try to account for the observation that obtaining the correct analysis of a sentence is easy or difficult depending (among other things) on the information available to guide reanalysis. Fodor and Inoue cite the following example from Gibson (in press).

(3)  
   a. She put the candy in her mouth on the table  
   b. She put the candy in her mouth onto the table

In (3) the first PP in her mouth is initially taken to be the directional PP of the verb put. But this interpretation is contradicted by presence of a second PP. It takes more effort come up with the correct analysis in (a) than in (b). Fodor and Inoue claim that this is because the parser can more easily diagnose the source of the error and repair it in (b) than in (a). In (b) onto clearly signals that the PP in question is a directional argument. It therefore cannot serve as a modifier of the preceding NP, but rather must be the argument of the verb put. Once this inference is made, there is no other possibility for the PP in her mouth but to modify the NP the candy. In (a) on the other hand, there is no direct indication that the final PP is a directional argument. Initially the PP may be analyzed as a modifier of mouth. This leads to a pragmatically implausible interpretation, which signals that this analysis is probably not the one intended. The parser does not have any concrete cues how to correct the error, however.

I would like to propose that the difference between number and case disambiguation of the object-subject order is similar to the difference between to and onto. Nominatively marked NPs are (inherently) subjects. Just as the onto PP denotes a direction irrespective of the verb, a nominatively marked NP does not need verb agreement or other elements to be recognized as the subject. Hence, if the parser initially prefers a subject-first analysis, but encounters a nominatively marked NP, such as der Bauer in the German example in (4), it has direct, positive evidence that this NP is the subject of the clause, even though the first NP is initially preferred as the subject on the basis of syntactic principles.\footnote{This assumes that the parser keeps track of whether the first NP was nominative or ambiguously marked. If it did not, the parser would end up having two subjects in cases where the second NP is nominative, and would have contradictory cues concerning the correct analysis, cf. Gorrell (1996; to appear).}

(4)  
   Welche Dichterin sah der Bauer?  
   [OS]  
   which poetess saw the-NOM farmer
   ‘Which poetess did the farmer see?’
Now let us turn to disambiguation by number information. Number inflection does not positively signal which NP is the subject; it only provides negative evidence that a particular NP cannot be the subject. Let me illustrate this by giving a Dutch example:

(5) Welke dichter heeft...
    which poet-SG has-SG...

Although the first NP *welke dichter* has the same number and person features as the finite verb, this is no guarantee that the first NP actually is the subject of the clause. Consider, for instance (6):

(6) Welke dichter heeft de boer gezien?
    which poet-SG has-SG the farmer-SG seen

Here, the verb is followed by another singular NP *de boer*, that may be the subject instead of *welke boer*. Hence, if an NP bears the same number features as the finite verb, it may be the subject of the clause, but it need not be. As opposed to nominative case marking, number agreement does not provide positive evidence that the NP in question is the subject. Number information can only provide negative evidence. Consider for instance (7):

(7) Welke dichters heeft...
    which poets-PL has-SG

Here, the sentence-initial NP does not agree with the verb. The general syntactic bias favors a subject interpretation of this NP. The number mismatch indicates that the first NP cannot licitly fulfill this function, however. No direct cues are given concerning which NP is the subject instead. The parser will start looking for another NP that is grammatically possible as a subject and might agree with the verb. If another NP is not available yet as in (3), the processor may either infer that such an NP may be coming up; or regard the sentence as an ungrammatical utterance (cf. also Fodor and Inoue, 1994: fn. 6; Meng, 1995).

Hence, the syntactically non-preferred object-subject reading may be easier to obtain when clauses are disambiguated by nominative case rather than by number information. Nominative case directly identifies the NP as the subject of the clause. Number information only provides negative information that the NP that is currently favored as the subject cannot licitly fulfill this function. Which NP is the correct subject is not directly indicated; this information must be inferred, instead.

In sum, there is some evidence suggesting that the syntactically less preferred reading is easier to obtain when case rather than number information is used to disambiguate the clause. The use of case-marking in Experiments 3-5 may therefore have reduced the processing difficulty for object-subject clauses. This
reduction in difficulty could affect the use of discourse-related information on the second NP. When the clauses were disambiguated by number information (the main clauses in Experiment 1; the *jullie* conditions in Experiments 6 and 7), the syntactically preferred subject-object reading may have been harder to overcome. This may have caused the apparent delay in use of the discourse-related properties of the NPs in these conditions.

2.4 Point of disambiguation

Also the position in the sentence of the disambiguating information may have had an effect on the strength of the order preferences. First, the subject-object preference was more robust for main clause *wh*-questions (Experiment 1) than for embedded clauses containing a definite NP (Experiment 7). In both cases number agreement was used to disambiguate the clause. However, the length of the ambiguous region was different: main clauses were disambiguated immediately after the *wh*-phrase, whereas the embedded clauses were disambiguated much later. Second, in embedded clauses which were disambiguated by number information and contained a case-ambiguous pronoun, an object-subject preference was seen only when a six-word PP separated the pronoun from the point of disambiguation (Experiment 6). No preference for either reading was obtained when the ambiguous region was four words in length (Experiment 7); when only one word intervened even a (non-significant) tendency for a subject-object preference was seen (Experiment 6). These results suggest that the subject-object preference is weaker when the ambiguous region is longer, at least when the same kind of disambiguation is used. This, too, suggests that the point of disambiguation is important: the syntactically less preferred object-subject order seems to be easier to obtain when the ambiguous region is longer, assuming the manner of disambiguation to be the same in both cases.

Why should this be so? First, the syntactic subject-object preference may decay and other factors biasing an object-subject order may become stronger simply as a function of time. However, in addition to, or instead of, this purely temporal factor, the words constituting the ambiguous region may provide information that can either support or inhibit a particular reading. Below I will illustrate how the nature of the ambiguous region may have affected the order preferences in the present experiments.

2.4.1 The contents of the ambiguous region may resolve confounding ambiguities

In Experiments 6 and 7, the words in the ambiguous region may have influenced the time course of the object-subject preference by resolving a potentially confounding lexical ambiguity. The pronominal form used, *jullie*, is ambiguous between a possessive and a personal form. The availability of the possessive reading, and hence, the possibility of having a non-pronominal definite NP in second position, may have interfered with the pronoun bias for the object-subject
reading (cf. Chapter 4, Section 4.4.3). However, the longer the adverbial material following *jullie*, the less likely the possessive reading becomes, and the stronger the pronominal object-subject bias. The nature of the ambiguous region may thus have contributed to the late object-subject preference in the *jullie*-cases.

2.4.2 The contents of the ambiguous region may facilitate a non-preferred reading

Second, the ambiguous region may provide information that renders the syntactically less preferred object-subject reading easier. A factor that is likely to be relevant is the presence of a second NP before or at the point of disambiguation. There are two reasons why an object-subject reading may be easier when two NPs are available rather than one.

First, the presence of a second NP may facilitate reanalysis. As discussed in Section 2.1, number information may signal that the first NP cannot be the subject of the clause. In this case, another NP must be found that can grammatically fulfill the function of subject. It is easier to find such an NP if it has already appeared in the input than when it has not.

In addition, the presence of a second NP makes an object-subject reading more likely in probabilistic terms. Most clauses in the language contain a subject; the number of clauses with an object is smaller. For instance, the corpus used in Chapter 5 contained 607 *welke*-clauses, of which only 275 contained an object. If only one NP is encountered in the input, chances are therefore high that this first NP is the subject. When it is clear that the clause contains two NPs, the chance that the clause is object-initial increases somewhat as the clause contains both potential subject and object NP. The presence of a second NP in the clause thus renders an object-subject reading more probable. This has also been shown in the corpus data in Chapter 5. The subject-initial order was the most frequent for *wh*-questions, overall, but when counts were restricted to clauses containing at least two argument NPs, the object-subject order was most frequent.

The difference between main and embedded clauses may therefore also be due to the availability of the second NP before or at the point of disambiguation: main clause *wh*-questions were disambiguated immediately after the *wh*-phrase, whereas embedded *wh*-clauses were disambiguated after the second NP.

Data from Friederici *et al.* (1996) support the suggestion that the availability of a second NP affects the ease of obtaining an object-subject reading. Friederici *et al.* tested relative clauses that were immediately disambiguated by case marking on the relative pronoun. The ERPs showed a P600 for the object-subject clauses at the disambiguating relative pronoun itself. When, on the other hand, the clauses were disambiguated by case marking on the second NP, no effects were seen at the disambiguating phrase itself, but only at the sentence-final word. This effect was not a P600, but a P350. The P350 has been proposed to
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reflect easy reanalysis whereas the P600 reflects a more effortful revision process (cf. Friederici, 1995; Friederici and Mecklinger, 1996). If this is true, obtaining the correct object-subject analysis is easier when clauses are disambiguated at the second NP rather than at the first.

2.4.3 The contents of the ambiguous region may trigger additional processes

Third, the nature of the ambiguous region may introduce additional processes that render a particular reading more difficult. As discussed in Chapter 4, Section 5.4.4, the presence of adverbial material after the second NP may cause some additional processing difficulty in subject-object clauses. The syntactic representation of a subject-object clause may be more complex when the object NP is followed by adverbial material than when it is not. In addition, an object NP that is followed by adverbial material often refers to given information. More discourse inferences thus have to be made when the object is followed by adverbial material than when it is not. In contrast, the presence of adverbial material after the second NP does not affect the structural complexity or interpretation of object-subject clauses. The presence of adverbial material in the ambiguous region after the second NP may therefore reduce the difference in processing difficulty between subject-object clauses and object-subject clauses, even if the subject-object order is the most preferred.

This may have contributed to the difference found between main and embedded wh-clauses containing a definite NP as second NP (Experiment 1 and 7, respectively): the embedded clauses were disambiguated only after the second NP and following adverbial material; the main clause wh-questions, on the other hand, were disambiguated immediately after the first NP. Adverbial material following the second NP could therefore not have influenced the order preference starting at the point of disambiguation in the main clause experiment (Experiment 1).

2.4.4 Summary

In addition to the type of the NP and the manner of disambiguation, the length of the ambiguous region may affect order preferences. The longer the ambiguous region, the weaker the subject-object preference. It remains to be investigated to what extent linear distance per se, or the availability of other information within the region is crucial to this effect.

2.5 The relative strength of the sources of information

In sum, overall word order preferences in Dutch and German are determined by a number of factors, namely

• the syntactic bias for a subject-initial order;
• the discourse-related properties of the first NP:
  a definite first NP heavily favors a subject-initial reading; a \textit{wh}-phrase does not;
• the discourse-related properties of the second NP:
  a pronominal second NP biases towards a subject reading for itself, and, hence, an object-subject reading for the clause. This bias is weaker for non-pronominal second NPs;
• the manner of disambiguation:
  an object-subject reading is easier to obtain if the clause is disambiguated by case rather than number information; and
• the length of the ambiguous region and/or the information provided in this region (e.g. the presence of a second NP):
  in general, the longer the region (the more information), the weaker the subject-object bias.

These factors do not have an equally strong contribution to the resolution of word order ambiguities. Some factors or combinations of factors, are stronger than others. For instance, a pronoun in second position introduces an object-subject bias that is strong enough to override the syntactic subject-object bias if the first NP is a \textit{wh}-phrase (Experiments 3-6). However, the discourse-related properties of the pronoun are not strong enough to cause processing difficulties for subject-object clauses if the first NP is a definite NP (cf. the Lamers (1996) data). This suggests that a sentence-initial definite NP introduces a subject-object bias that, combined with the general syntactic bias for this order, is stronger than the object-subject bias introduced by a pronoun in second NP position.

Another example is the relative contribution of number and case disambiguation. As discussed in Section 2.1, the syntactically less preferred object-subject reading seems to be easier to construct when case rather than number information is used to disambiguate the clause. Nominative case on the second NP appears to be a stronger cue to trigger an object-subject reading than number mismatch between the verb and the first NP. However, the relative impact of the form of disambiguation also depends on other factors. Again, one of these is the nature of the first NP: disambiguation by case seems to be easier than disambiguation by number if the clause-initial NP is a \textit{wh}-phrase, but not if it is a definite NP. For \textit{wh}-clauses, a robust subject-object preference has been reported for clauses disambiguated by number (Experiment 1; Meng, 1995; Schlesewsky \textit{et al.}, to appear); but the subject-object preference is much less evident for clauses disambiguated by case information (Schlesewsky \textit{et al.}, to appear; Meng, 1995; Farke, 1994). If the first NP is a definite NP, however, the manner of disambiguation appears not to have much effect: a strong subject-object preference has been found for main clauses starting with a definite NP, both when case-marking (Hemforth, 1993; Lamers, 1996) or number information (Experiment 1; Frazier and Flores d’Arcais, 1989) is used to disambiguate the
clause. The facts thus suggest that the nature of the disambiguating information scarcely affects the strength of this preference.

Which order of subject and object is preferred, the strength of this preference and how this preference develops over time, thus depends on the interplay of various other factors which differ in their relative strengths.

3 Parsing models

The present data therefore suggest that the time course and strength of syntactic and discourse-related information on processing preferences is not fixed. This is in line with the apparently conflicting evidence provided by previous studies investigating the effects on non-syntactic information on ambiguity resolution (cf. Chapter 1, Section 3.3). Sentence processing theories must be able to account for these effects. Previous research on ambiguity resolution has been mainly directed at trying to distinguish syntax-first and interactive approaches to processing. Syntax-first models assume an initial syntactic stage of analysis -- an extreme version was represented by the Syntactic Hypothesis; interactive theories assume that all sorts of information is made use of immediately when available (cf. the Discourse Hypothesis). Strictly speaking, a syntax-first approach predicts the effect of non-syntactic information to be delayed, whereas interactive theories do not. However, there is no uncontroversial data supporting either approach. Rather than trying to show that non-syntactic information is used immediately or is delayed, research should be directed at specifying the factors that determine the strength of the processing preferences, and how the preferences develop over time. Theories should then be evaluated in terms of how the apparently conflicting data available at present is accounted for, and to what extent predictions can be generated and tested.

In this section, four current models on sentence processing will be discussed in the light of the present data on Dutch order ambiguities, namely (i) garden-path models (Frazier, 1979; 1987a; 1990a); (ii) referential theory (Crain and Steedman, 1985; Altmann and Steedman, 1988); (iii) linguistic tuning models (Mitchell, 1994; Mitchell, Cuetos, Corley and Brysbaert, 1995); (iv) constraint-based models (MacDonald, Pearlmutter and Seidenberg, 1994; Trueswell and Tanenhaus, 1994; Spivey-Knowlton and Tanenhaus, 1994). The first three approaches assume an initial syntax-based stage of processing, at least under some versions of the models; the fourth approach represents a more interactive view of sentence processing. Each of the four subsections below starts with a brief description of a model. Next, it will be sketched how the model in question may account for the general subject-object order preference in Dutch, the effect of the nature of the first and second NP on this preference, and the time course of these effects. Some problems for the models as initially formulated will be discussed, as well as possible extensions to deal with these problems.

3.1 Garden-path models
Garden-path models (Frazier, 1979; 1987a; 1990a) are instances of syntax-first models: they assume an initial stage of analysis in which only syntactic information is used. In the case of structural ambiguity, an initial decision is made on the basis of non-probabilistic strategies that are sensitive to syntactic information only (e.g. Minimal Attachment, Chapter 1 Section 3.1; the Active Filler Strategy, Chapter 2 Section 4.1). Garden-path models are serial models: only one syntactic analysis is pursued at a time. Non-syntactic information (thematic, discourse and other information) is processed in other modules in parallel to, or following this initial syntactic stage. This non-syntactic information cannot directly influence the syntactic processes, however (cf. Clifton and Ferreira, 1989; Frazier, 1990a). The modules only have access to each other’s outputs. If the outputs of the syntactic and non-syntactic modules are in conflict, the syntactic analysis may be revised. The clash between the outputs of the modules, and the subsequent revision process may cause an increase in processing effort. Alternatively, post-syntactic modules evaluate the output of the syntactic module. This will also lead to an increase in reading times if the syntactic analysis is anomalous from a non-syntactic point of view. The extent of this increase depends on how easily the error can be detected (Fodor and Inoue, 1994) and/or the type of revisions that are required (e.g. Pritchett, 1991).

3.1.1 The general subject-object preference

Now let us see how the experimental results might be accounted for. In the initial syntactic stage, clause-initial NPs in Dutch are interpreted as the subject of the clause according to the strategies discussed in Chapter 2. Assuming a gap-filling strategy, the clause-initial NP is immediately linked to the subject position, as this is the quickest way to functionally integrate this NP (gap-filling strategies); according to structure-building approaches a subject-first analysis is constructed as this analysis involves the smallest number of phrasal nodes (Gorrell, 1996; to appear).

When number, case or other information is not compatible with the subject-initial analysis, the current structure has to be revised. These detection and revision processes lead to an increase in reading times, or a positivity in ERPs. The extent of processing difficulty depends on the ease of detection or revision. For reasons discussed in Section 2.1 revision may be easier when case rather than number information disambiguates the clause; and when the input contains two NPs rather than one NP at the point of disambiguation.

3.1.2 Wh-phases versus definite first NPs

The initial subject-object preference is thus based on strategies that are sensitive to structural configuration only. Recall that in Experiment 1, the subject-object preference was stronger when the main clause started with a definite NP rather than a wh-phrase. Furthermore, this effect was one word position delayed relative
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to the general subject-object preference. How can these results be accounted for in
a garden-path model?

The delayed effect of the nature of the first NP may result from the
modular architecture of the system. Under the assumption that the first syntactic
stage of parsing cannot be influenced by the properties of the NPs, the effect of
the first NP must be attributed to processes following this initial syntactic stage.
The effect of the nature of the first NP is therefore delayed relative to the general
subject-object preference.

The fact that the subject-object preference is stronger for declaratives
than for wh-questions may be attributed to three kinds of processes: error
recognition, reanalysis, and/or pragmatic evaluation procedures.

First, recognition of the intended object-subject reading may be easier
when the first NP is a wh-phrase than when it is a definite NP. Wh-phrases may
provide more morphological cues for the correct analysis: the presence of a wh-
word (or its abstract wh-features) may identify the wh-phrase as a filler (in the
gap-filling approaches), or as an NP that can easily occupy a position that is
different from the functional subject position (in structure building approaches).
Such cues are lacking when the first NP is a non-deictic definite NP. In this case,
it is hard or even impossible to figure out that the object-initial analysis is the one
intended. Repair of the error may therefore take longer in the object-subject
declaratives than in the object-subject wh-questions -- if the error can be
diagnosed and repaired at all.

Second, object-subject declaratives may be more difficult, not or not only
because it is harder to recognize the structure intended, but because the revision
of the initial subject-object structure requires more effort. Under certain syntactic
assumptions, object-subject declaratives involve more phrasal nodes than object-
subject wh-questions (cf. Chapter 2, Section 5.2.3). Hence, when the initial
subject-object analysis needs to be revised into an object-subject structure, more
structure has to be created in declaratives than in wh-questions. Under the
assumption that structure building is effortful, reanalysis is more difficult when
the first NP is a definite NP than when the first NP is a wh-phrase.

Third, the processing difficulty for object-subject declaratives may be
attributed to a discourse evaluation procedure. The object-subject declaratives used
in the experimental materials are pragmatically odd, since the appropriate
discourse cues and context are lacking. The additional increase in reading times
for this condition may thus be due to the detection of a pragmatic anomaly in a
post-syntactic stage of processing, and subsequent processes to overcome this
anomaly.

These three potential explanations are not mutually exclusive, however.
In fact repair, reanalysis and discourse evaluation processes may all contribute to
the increase in processing difficulty for object-initial declaratives.

3.1.3 Pronouns versus full definite second NPs
In the garden-path model as sketched above it is predicted that a case-marked subject pronoun in second position, or number mismatch between the verb and the first NP should lead to reanalysis of the initially proposed subject-object structure, causing an increase in processing times. However, when the second NP was a pronoun, however (Experiments 4 through 7), an increase in processing difficulty for the subject-object clauses relative to the object-subject clauses was seen. In a garden-path model, this result must be attributed to the operation of post-syntactic processes that evaluate the NPs in terms of their discourse properties.

Let us see how this works for clauses containing a case-ambiguous pronoun. Recall that in the jullie cases (Experiments 6 and 7) a non-significant subject-object preference was seen when the ambiguous region was fairly short, but an object-subject preference when the ambiguous region was rather long. This delayed effect falls out rather straightforwardly from the modular architecture of the processor. Initially, the syntactic module will assign a subject-interpretation to the wh-clause and an object interpretation to the pronoun jullie. This analysis leads to a pragmatic anomaly in the post-syntactic stage of processing, as pronouns are more likely to be topics and hence, expressed as subjects. This, in turn, triggers a syntactic revision process to change the subject-object analysis into an object-subject one. These feedback and reanalysis procedures require some time. If the ambiguous region is fairly short, a subject-object order will still be the preferred analysis when the disambiguating information comes in. However, if the ambiguous region is long enough, the initial syntactic analysis will have been changed into an object-subject representation before disambiguating information is encountered, leading to an increase in processing difficulty for subject-object clauses at the point of disambiguation. This is exactly the pattern obtained in the jullie conditions.

A potential problem for the account sketched above is that the object-subject preference was obtained immediately at or just after the point of disambiguation when the clause contained a case-marked pronoun in second position (Experiments 4 and 5). This quick object-subject preference is hard to explain if non-syntactic processes are inherently delayed as assumed above. Garden-path theories must therefore be extended with an account of the relative time course of non-syntactic influences. The rapid object-subject preference in the case-marked condition may be explained, for instance, by assuming that a nominative pronoun triggers a quick, effortless reanalysis of the initial subject-object structure (cf. Section 2.1), such that discourse-related information can have an apparently immediate influence on the order preference. This suggestion remains to be further specified and tested, however.

### 3.1.4 Remarks

Garden-path theories thus provide an explicit account of why a particular reading is preferred, why non-syntactic information is delayed, and why reanalysis is easier in one case than in the other. However, hardly any models of the garden-
path variety give a quantitative specification of the relative strengths of the various factors that influence ambiguity resolution. For instance, it is not clear to what extent disambiguation by case is easier than disambiguation by number; to what extent discourse-related information is delayed and how this depends on other factors; and to what extent specific discourse-related information (e.g. the object-subject preference triggered by a pronoun) is stronger or weaker than other sorts of information (e.g. the subject-object preference triggered by a main clause-initial definite NP, cf. Section 2.5). The lack of quantitative specifications makes it hard to infer predictions concerning the extent of the processing difficulty, and thus to empirically distinguish garden-path theories from other models.

3.2 Referential theory

Crain and Steedman (1985) and Altmann and Steedman (1988) propose the framework of a referential theory. Models of this kind share with the garden-path models their modular and rule-based nature. There is a separate stage of syntactic processing which is not affected by non-syntactic information. However, as opposed to garden-path models, referential theory models do not assume that syntactic analysis is serial; instead, several analyses compatible with the input are pursued in parallel. A choice among the alternative structures is made in a second, discourse stage of processing. Decision is based on discourse simplicity, as determined by principles such as the Principle of Parsimony (first proposed in Crain and Steedman, 1985). This principle states that the reading should be preferred which requires the least number of discourse inferences. This is another difference with garden-path models, which assume that ambiguity resolution is mainly driven by syntax-based economy principles such as Minimal Attachment or the Active Filler Strategy. In contrast to garden-path theories, discourse-related properties of the NPs may therefore play an important role in ambiguity resolution.

3.2.1 Wh-phrases versus definite first NPs

Let us now see how the processing of ambiguous sentences in Dutch may proceed according to a referential theory. First, the syntactic processor will assign both a subject-object and an object-subject analysis to the incoming clause. In the subsequent discourse stage, the analysis is chosen that is the most parsimonious from a discourse point of view. As discussed in Chapter 2, Section 5.2, object-initial declaratives impose more restrictions on the discourse than subject-initial declaratives. When the sentence is presented in isolation, a subject-object analysis is the most parsimonious in terms of discourse inferences. Referential theory thus provides a straightforward explanation for why object-initial declaratives are so hard.

A potential problem for a referential theory is that the subject-object preference for wh-questions cannot so readily be accounted for. Subject-initial and
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Object-initial wh-questions do not differ in terms of discourse inferences (cf. Chapter 2, Section 5.2.2). Hence, referential theory predicts no preference for either reading. This is in contrast with the preference for the subject-initial order found immediately after the wh-phrase in Experiment 1. Furthermore, in Experiment 1, the effect of the first NP became apparent one word position later than the subject-object preference. A solution to this problem is to rank the outputs of the syntactic stage such that the subject-object analysis is preferred. However, unless this ranking is based on discourse principles, this solution is in inconsistent with the original motivation of referential theory.

3.2.2 Pronouns versus full definite second NPs

Now let us turn to how a referential theory could account for the influence of the second NP. Again, the syntactic stage will assign both a subject-object and an object-subject analysis to the incoming clause at the wh-phrase. When the second NP is a pronoun, the object-subject analysis will be preferred for discourse reasons: a pronoun refers to highly salient, given information, which is generally encoded as the subject of the clause. If a non-pronominal NP in the clause is the subject instead of the pronoun, this may signal a shift of discourse focus (e.g. Grosz, Joshi and Weinstein, 1995; Brennan, 1995; Walker and Prince, 1996). An analysis in which the pronoun is the object of the clause thus involves more discourse inferences. An object-subject analysis therefore is the most parsimonious and, hence, preferred for wh-clauses containing a pronoun. This will lead to an increase in processing difficulty if a subject reading for a pronoun is not possible. However, no account is given of the difference in time course of the effects, depending on whether the pronoun is case-marked or not, and on the length of the ambiguous region. Hence, just like garden-path theories, referential theory must be extended with an account of the various factors that affect the amount and onset of processing difficulty.

Another potential problem for referential theory is the subject-object preference found for at least some instances of wh-clauses containing a definite second NP ( Experiment 7; Meng, in preparation). This problem has already been discussed for main clause wh-questions in the previous section.

3.2.3 Summarizing remarks

As opposed to garden-path models, referential theory attributes ambiguity resolution primarily to a discourse stage of parsing rather than to a syntactic stage. In such a framework, the impact of the nature of the NPs on word order preferences can be accounted for in a straightforward way. However, referential theory cannot readily account for all the data. First, additional assumptions must be made in order to account for the general subject-object preference in Dutch. One possibility is to assume that the alternative analyses proposed by the syntactic stage are ranked, with the subject-object analysis being the most preferred.
However, the inclusion of a syntactic decision criterion is at odds with the original motivation of referential theory. Second, the theory must be extended to account for the variation in the onset and strength of the order preference resulting from the manner and point of disambiguation.

3.3 Tuning

The linguistic tuning model (Mitchell, 1994; Mitchell, Cuetos, Corley and Brysbaert, 1995) is based on the assumption that in cases of ambiguity, the sentence processor prefers the analysis that is the most frequent in the language. If subsequent information in the input is incompatible with this analysis, either a more infrequent analysis is activated, or reanalysis takes place as described for garden-path models (Section 3.1.). Thus, in tuning models, ambiguity resolution is frequency-based rather than driven by non-probabilistic strategies as was the case in garden-path models.

One important question in tuning approaches concerns the "grain-size", that is, which information is initially abstracted away from when frequencies are tallied (cf. the discussion in Chapter 5; Mitchell et al., 1995). In some varieties of tuning (e.g. Mitchell, 1994) only coarse-grained distinctions are taken into account. In such models only phrasal categories such as NP and PP are relevant while calculating, for instance, the frequency of various modifier attachment possibilities. In other varieties of tuning, finer distinctions may be taken into consideration. For instance, frequencies may be stored separately for indefinite and definite NPs; or even separately for each individual noun.

Grain-size is related to the issue of whether non-syntactic information (thematic, discourse, etc) is used immediately or only later. Mitchell’s coarse-grained variety of tuning resembles garden-path theories in this respect: an initial structural stage of parsing is distinguished. In this stage, ambiguity is resolved without reference to the specific properties of the lexical items. Lexically specific and discourse information may influence the parsing process only at a later stage. If, on the other hand, tuning is more fine-grained and frequencies are tied to the separate lexical items, lexical properties such as subcategorization preferences of the verb and discourse-related properties of the NPs can be taken into account immediately.

Below I will discuss how both the coarse-grained model of Mitchell and finer grained models may account for the Dutch data.

3.3.1 Wh-phrases versus definite first NPs

Coarse-grained tuning models must be able to explain the subject-object preference found for Dutch main clauses by referring to the frequency of this order. Collapsing over clause types, the subject-object order is indeed the most frequent in Dutch (Chapter 2, Section 4.3). In cases of word order ambiguity, then, the parser will commit itself to a subject-object analysis. When
morphological or other information is incompatible with this solution, an increase in processing effort is expected. Since coarse-grained tuning models are not immediately sensitive to the distinction between \textit{wh}-phrases and definite NPs, the difference between \textit{wh}-questions and declaratives must be attributed to processes at later stages, as has been discussed for garden-path models (cf. Section 3.2).

Tuning models that assume a finer grain-size may take the nature of the NPs into consideration immediately. In such models, \textit{wh}-questions and declaratives can be considered distinct clause types in terms of frequency.\footnote{Data from English suggest that the parser must at least be sensitive to the $\pm$ \textit{wh} distinction: Merlo (1994) argues that a distinction must be made between $+$\textit{wh} and $-$\textit{wh} complementizers to explain the magnitude of the surprise effect when a verb that usually subcategorizes for a sentential complement, is immediately followed by an NP (Trueswell, Tanenhaus and Kello, 1993; Juliano and Tanenhaus, 1994).} The experimental results may then be accounted for in the following way. For both declaratives and \textit{wh}-questions the subject-initial order is the most frequent -- at least, when collapsing over all predicate types. For both clause types, then, the processor will analyze the first NP as the subject. This preference for a subject-initial interpretation is expected to be stronger for declaratives than for \textit{wh}-questions: the subject-initial order is relatively more frequent in declaratives compared to \textit{wh}-questions (cf. Nieuwborg, 1968; Chapter 2, Section 4.3). This is in accordance with the data. However, fine-grained tuning models do not readily account for the time course of the effect. The nature of the first NP did not immediately affect the order preference, but only one word position after the disambiguating verb. This is not expected if the processor is immediately sensitive to the nature of the NPs and the difference between declaratives and \textit{wh}-questions. Fine-grained tuning models must therefore be extended with an account of how the preferences develop over time.

One possible solution is to assume a serial processor. A serial, frequency-based processor will initially assign a subject interpretation to both definite NPs and \textit{wh}-phrases, since the subject-initial reading is the most frequent for both welke-questions and declaratives. When the number features of the verb are not compatible with this analysis, detection of the error will lead to a comparable increase in reaction times for both \textit{wh}-questions and declaratives. The difference between \textit{wh}-questions and declaratives only becomes apparent in a subsequent stage of repair when frequency information can be made use of to obtain the correct analysis. This may account for the delayed effect of the type of the first NP.
3.3.2 Pronouns versus full definite second NPs

Now let us turn to the effect of the second NP. In a coarse-grained tuning model, the object-subject preference found for embedded *wh*-clauses containing a pronoun must be due to a second, post-syntactic stage of processing. Initially, a subject-object analysis is preferred on the basis of the general frequency of this order (that is, collapsed over clause types). This analysis may be changed into an object-subject order in the same way as in the garden-path models described above. Just like the garden-path models, coarse-grained tuning models must be provided with an account of how the object-subject preference develops over time.

Now consider finer-grained models that are sensitive to the properties of the NPs. The order preferences for *wh*-clauses containing a definite NP appears to be somewhat problematic for such models. As has been shown in Chapter 5, the object-subject order is the most frequent for transitive *welke*-clauses, both for clauses containing a pronoun and for clauses containing a full definite NP as the second NP. According to a fine-grained model, the preferred analysis for such clauses should therefore be the one in which the object precedes the subject. This indeed corresponds to the experimental data for *wh*-clauses containing a pronoun. However, we have seen that the experimental and frequency data do not converge for *welke*-clauses containing a definite NP as second NP: the experimental data show a tendency for a subject-object preference, in spite of the fact that the object-subject order is more frequent for such clauses.

Possible solutions have already been discussed in Chapter 5. First, the relevant grain-size may be somewhat coarser, collapsing over several sorts of *wh*-phrases. Second, tuning may be even finer-grained such that the animacy and even the surrounding discourse is taken into consideration in storing and retrieving frequency information. It still remains an open question whether a single, fixed grain-size can be found such that frequencies match the experimental data. A third solution is to assume that the grain-size is not fixed, but that generalizations at various levels of abstraction play a role. Constraint-based models, to be considered below, are instances of such models.

3.3.3 Remarks

Coarse-grained tuning models of the Mitchell variety do not differ much from garden-path models with respect to the explanation of the present data. Both approaches attribute the subject-object preference to an initial, syntactic stage of processing; the nature of the NPs may affect the order preference only at a later stage. The difference between the two models concerns the explanation of the subject-object preference: garden-path models attribute this to the syntax of the language and the workings of syntax-based strategies; tuning models ascribe the subject-object preference to the frequency of this order in the language. However, just like garden-path models, coarse-grained tuning models must be extended with an account of the differences in onset and extent of processing difficulties.
According to some finer-grained tuning models, on the other hand, the parser may be immediately sensitive to the properties of the NPs. An advantage of fine-grained models is that differences in strength of the order preferences may potentially be accounted for, namely by taking frequency data into consideration. However, exactly which properties the processor is sensitive to in tallying and retrieving frequency information still has to be determined. Furthermore, an account is needed of how preferences develop over time (e.g. by assuming a serial processor as described above).

3.4 Constraint-based models

Constraint-based models (MacDonald, et al., 1994; Trueswell and Tanenhaus, 1994; Spivey-Knowlton and Tanenhaus, 1994) differ from the models discussed above in that no priority is in principle assigned to any particular type of information. Constraint-based models are interactive: all kinds of information, lexical, syntactic, discourse and other, can influence ambiguity resolution as soon as it is activated by the input. The possible solutions to the ambiguity are considered in parallel. Incoming words activate certain probabilistic constraints that bias one reading or the other. For instance, the resolution of the main clause/reduced relative ambiguity in English (e.g. the horse raced... ) can be considered to result from the competition among several constraints. One is related to the frequency in which the verb form is used in a particular reading. The form raced, for example, is ambiguous between a simple past form or a passive participle. The simple past reading is only compatible with a main clause verb interpretation, the participle reading is only compatible with a reduced relative interpretation of the ambiguity. However, the verb form raced occurs more frequently as a simple past form than as a passive participle. The verb form is thus biased towards a main clause interpretation. This verbal bias may be counteracted by other constraints. For example if there are two horses in the context, or if the focus operator only is used (as in only horses raced...), discourse constraints may bias a reduced relative interpretation (cf. Chapter 2, Section 5.1).

When a sentence is processed, the incoming words activate the constraints they are associated with. The activated constraints are combined and compete until a particular reading is preferred (or another decision criterion is reached). The various constraints need not contribute equally to the resolution of the ambiguity: some constraints may be more important and weigh more strongly than others. The strength of the bias provided by each constraint and the relative importance of the constraints may be determined by frequency of use.

When an incoming word strongly supports a reading that is different from the one that has been highly preferred up to that point, an increase in processing difficulty may result. This can have two potential causes. First, there might be a strong competition between constraints. Two biases are in strong competition when they are almost equally strong and each supports a different reading. It then takes some time before the difference in activation of the two
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readings is large enough for a particular outcome to be favored. This is reflected in an increase in reading time starting at the point at which the competing information comes in.

Second, an increase in processing difficulty may be caused by the inability to activate the correct reading. A particular reading may be so strongly preferred that incoming information cannot change this preference. In this case, the new input may be incompatible with the currently dominant analysis, but is too weak to activate the correct alternative reading. This, too, may lead to an increase in processing difficulty, as the constraints activated by the new input cannot be met (cf. Spivey-Knowlton, Hanna and Tanenhaus, 1996).

Constraint-based models are thus interactive, parallel, frequency-based models. In contrast to garden-path theories, processing difficulty is not due to reanalysis and repair processes, but to competition or the inability to activate the appropriate reading.

Now let us turn to the Dutch data. In a constraint-based approach, the Dutch word order preferences may be considered the result of the interplay of various constraints, among others, a syntactic bias for a subject-object interpretation, constraints tied to the nature of the NPs, constraints related to case-marking and number inflection (the manner of disambiguation), and information activated by the words in the ambiguous region. Each of these constraints biases a subject- or object-initial reading of the clause to a certain extent. Below, I will sketch how such a model could accomodate the present data.

3.4.1 The subject-object preference

In a constraint-based approach, the general subject-object preference in Dutch may be accounted for by a syntactic constraint favoring a subject interpretation of a clause-initial NP. The bias for the subject-initial order can be attributed to the frequency of this order: collapsed over all clause types, subject-initial clauses are far more frequent in Dutch than object-initial clauses (cf. Chapter 4.3).

On the basis of this syntactic constraint a subject-initial order is strongly favored, especially when only one NP has been encountered in the input. When case or number information forces an object-subject reading, an increase in processing effort is the result. This is probably due to the competition between the syntactic bias and morphological constraints, although it is also possible that the increase in processing difficulty results from the inability of the morphological constraints to inhibit the dominant subject-object order and activate the object-subject reading.

Note that the syntactic bias for a subject-initial order cannot be tied to a specific noun or to the thematic or other properties of the lexical verb. As has been illustrated in Chapter 2, the general subject-object preference for Dutch and German must be due to generalizations that abstract away from the specific properties of the NPs. Furthermore, the preference cannot be driven by the lexical verb, as subject-object preferences have been shown before the main verb. The
order constraint must therefore be represented independently of the specific lexical items. This means that there is a syntactic clausal representation that is either prestored and activated, or constructed during processing. A clause-initial NP activates the constraint just mentioned, and is linked (with a certain probability) to the subject position in this clausal representation.

The inclusion of a clausal representation may seem at odds with the underlying motivation of constraint-based modeling. Advocates of the constraint-based approach generally stress the lexical nature of ambiguity resolution in English. However, they do not deny the influence of syntactic constraints and biases, and the need of syntactic representations (MacDonald, Pearlmutter and Seidenberg, 1994). The inclusion of a syntactic constraint on the order of subject and object is therefore not incompatible with constraint-based approaches. However, how such syntactic representations are activated or constructed remains unspecified in most constraint-based models (cf. Frazier, 1995).

3.4.2 Wh-phases versus definite first NPs

Now let us see how constraint-based models may account for the difference between main clauses starting with a definite NP and main clauses starting with a wh-phrase. The influence of the first NP can be accounted for by independent constraints on sentence-initial definite NPs and wh-phrases. Sentence-initial definite NPs more frequently occur as subject than as object of the clause, whereas this difference is much smaller for the wh-clauses (cf. the Nieuwborg data cited in Chapter 2, footnote 9; and the frequency data in Chapter 5). A non-deictic, definite NP thus heavily supports a subject-object reading, whereas a wh-phrase does not. When the main clause is disambiguated towards an object-subject reading by case or number information, one would therefore expect less processing difficulty for the wh-clauses compared to the declaratives: either because there is less competition between the syntactic and the morphological constraints in the wh-questions than in the declaratives; or because the subject-object bias for declaratives is so strong that the correct object-subject reading cannot be activated, whereas it can in wh-questions.

In an interactive model, all information is made use of immediately when available. However, the data of Experiment 1 suggested that the nature of the first NP did not have an immediate effect on processing difficulty: although a subject-object preference was seen at the disambiguating auxiliary, the difference between wh-questions and declaratives only showed up at the next word position, the determiner of the second NP. How can this apparent delay be accounted for while maintaining the assumption that all information is immediately made use of in ambiguity resolution?

A possible explanation is the following. At the disambiguating auxiliary, the syntactic bias for a subject-initial order may be so strong that the nature of the first NP has hardly any effect. The overall subject-object bias will then be almost equally strong for wh-questions and declaratives at this point. However, the
information provided by the determiner following the disambiguating verb may weaken the syntactic bias for the subject-object order. The presence of a determiner is likely to signal the presence of a second NP. As has been discussed in the above (Section 2.4.2), an object-subject order is more likely when two NPs are available than when only one NP has been encountered. At the determiner of the second NP, the syntactic bias may therefore be weak enough for the nature of the first NP to exert more influence on the resolution process.  

3.4.3 Pronouns versus full definite second NPs

Let us now turn to the effect of the second NP. Constraint-based models might account for the influence of the type of the second NP by means of discourse-related constraints on the use of pronouns and definite NPs. Pronouns are heavily biased toward a subject interpretation on the basis of frequency. In the Nieuwborg (1968) study discussed in Chapter 2, Section 5.3.2, 89% of the personal pronouns appeared as the subject of the clause. If a pronoun is encountered as the second NP of an ambiguous clause it thus introduces a strong bias for an object-subject reading of the clause. This bias competes with the syntactic bias for the subject-object reading. Note that this pronominal object-subject bias must be based on a generalization that supercedes the specific lexical form of the pronoun: accusative pronouns such as *hem* (‘him’) never occur as the subject of the clause; nevertheless, it is assumed in this account of the data that they may activate the information that pronouns often occur as the subject of the clause.

For non-pronominal definite NPs, the percentage of subject uses is smaller (68% in the Nieuwborg study). This bias may have been too weak for a second definite NP to override the syntactically based subject-object preference. Additionally, a subject-object reading for sentences containing a definite second NP may have been supported by a constraint related to the discourse status of the NP referents. Recall that the experimental items always were presented in isolation. The definite NP in second position therefore always introduced a new entity into the discourse. Frequency data provided by Prince (1982) suggest that NPs that refer to entities that have already been mentioned in the discourse are more likely to be encoded as the subject than elements that introduce new entities. If constraint-based models also incorporate constraints related to the given/new status of the NP referents, the subject-object preference for clauses containing definite NPs in second position may even be enhanced.

Constraint-based models may thus account for the different order preferences for clauses containing pronominal and non-pronominal second NPs.

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3 The determiner of the second NP may thus have a comparable effect on ambiguity resolution as the presence of a *by*-phrase on the reduced relative/main verb ambiguity in English, cf. Spivey-Knowlton, Trueswell and Tanenhaus (1993); Tabossi, Spivey-Knowlton, McRae and Tanenhaus (1994).
But how can the differences between the various pronominal conditions be accounted for? The discourse-related information is available as soon as the pronoun is encountered in the input. The immediate object-subject preference found for *wh*-clauses containing a case-marked pronoun can thus be easily accounted for, at least, under the assumption that if the second NP accusative, the general pronominal object-subject bias strongly competes with the syntactic and morphological bias for the subject-object order, causing an immediate increase in processing difficulty for the subject-object condition.

Under the same assumptions, an immediate object-subject preference is expected for clauses containing non-case marked pronouns. This however is not clear: an object-subject preference for *wh*-clauses containing the pronoun *jullie* was only obtained when the ambiguous was fairly long (Experiment 6). In a constraint-based model, this delayed object-subject preference may be attributed to the categorial ambiguity of the pronominal form used. In addition to the personal pronoun interpretation (biasing the object-subject order), the possessive reading, and hence a definite NP reading of the second NP (Chapter 4, Section 4.4.3) may be activated as well. A subject reading for the second NP is not strongly biased as long as the possessive reading remains active. The longer the ambiguous region, the less likely the possessive reading becomes, and the stronger the bias for the object-subject reading. This may account for the (non-significant) tendency for a subject-object preference in the short conditions and the object-subject preference in the long conditions. More research and computational modeling is needed to see whether this explanation is tenable.

### 3.4.4 Remarks

In a constraint-based approach, the Dutch order preferences might be accounted for in terms of a competition between various constraints. As opposed to garden-path models, referential theory and coarse-grained tuning models, no separate, modular stages of processing are distinguished. Rather, processing is highly interactive: all kinds of information can influence order preferences when available. Which reading is preferred, the ease with which a certain reading is obtained, and how the preferences change over the course of the sentence is determined by the relative contribution of the various sources of information activated by the input.

Constraint-based approaches provide an inherently quantitative account of various sources of information on the resolution of word order ambiguities. The strengths and weights of the constraints can be estimated on the basis of frequency information and off-line completion data (for computational models, see e.g. Spivey-Knowlton, 1994; Spivey-Knowlton, Hanna and Tanenhaus, 1996). Unfortunately, data from frequency and completion studies are too sparse to construct a fully constrained computational model for the Dutch order preferences. Whether the current data can indeed be fully captured by a constraint-based model such as the one sketched above therefore remains a question for future research.
It should be noted, however, that although constraint-based models capture the fact that some sorts of information are more important than others, and that certain constraints bias a certain reading, they do not give an explicit account of why this should be so. Referring to frequency information only takes the explanation back one step: what one also wishes to know is whether there is a reason why certain options are more frequent than others. Constraint-based models, and frequency-based models in general, should therefore be provided with a (qualitative) theory about the constraints themselves.

3.5 Summary

In this section I have shown how several current theories of sentence processing might account for word order preferences in Dutch, the effects of the first and second NP, and the development of the preferences over time. Roughly put, the main differences among the models concern, first, whether the information introduced by the NPs is made use of immediately, or only somewhat later in the parsing process; and, second, whether preferences are based mainly on frequency information or on non-probabilistic strategies.

According to garden-path theories a subject-object analysis is initially opted for on the basis of non-probabilistic syntactic strategies. Discourse-related properties of the NPs may influence the parsing process only at a later stage: they may facilitate reanalysis forced by number or case information, or trigger reanalysis before the point of syntactic disambiguation. Although some models of the garden-path variety provide a theory of why reanalysis is easier in some cases than in others (e.g. Pritchett, 1991; Fodor and Inoue, 1994), they do not give a quantitative specification of the way in which various factors influence processing difficulty.

According to the referential theory, order preferences are mainly driven by discourse related information. However, we have seen that without additional assumptions, the preference for a subject-initial order in *wh*-questions cannot be accounted for in such models. Furthermore, these models do not specify the interaction among syntactic, morphological and other information and their impact on processing difficulty.

Coarse-grained tuning models of the Mitchell variety differ from garden-path models in that the initial subject-object analysis is based on the frequency of this structure, rather than on rule-based strategies. In all other respects, coarse-grained tuning models resemble garden-path models: the specific properties of the NPs are made use of only at a later processing stage.

Finer-grained tuning models can be conceived of in which the nature of the NPs is taken into account immediately. However, it remains to be seen whether an appropriate grain-size can be found, such that the frequencies of the clause types correspond to on-line parsing preferences.

Finally, constraint-based models might account for word order preferences in Dutch in terms of the interplay of various probabilistic constraints,
syntactic and non-syntactic. In such models, the nature of the NPs is made use of as soon as it is available. To what extent the NPs can actually influence the order preferences depends on the availability of other information and the strength of the various constraints. The strength of the biases and the relative weights of the various constraints is mainly based on frequency of use.

The aim of the present discussion was to show how some current sentence processing theories may accommodate the various factors that influence the strength of order preferences and their change over time. Of the models discussed here, garden-path (or coarse-grain tuning) models and constraint-based models most readily account for the present results. Garden-path theories provide an explicit account of why some readings are easier to obtain than others and why non-syntactic information appears to be delayed in some cases. However such models must be extended with a quantitative theory of the various factors that influence the ease of obtaining a certain reading and the extent of the delay. Constraint-based theories, on the other hand, potentially provide exactly such a quantitative theory, but do not account for why some sources of information are more important than others -- unless frequency is an explanation in and of itself.

On the basis of the current data, no distinction can be made between syntax-first and interactive models. Future research should be aimed at constructing and testing quantitative models of processing, specifying which factors influence the strength and onset of processing difficulty. Only then can it be decided whether parsing preferences result from interactive frequency-based constraints as claimed by constraint-based theorists, or whether an initial, modular, non-probabilistic stage of syntactic parsing is still needed, as proponents of garden-path theories claim.

4 Conclusion

A number of clause types in Dutch and German are at least temporarily ambiguous between a subject-object and object-subject interpretation. Previous research has shown that speakers of either language have a preference to interpret such clauses as subject-initial. This preference has been shown to be fairly robust: a subject-object preference has been attested even when plausibility or contextual information biases an object-subject reading (Van Gompel, 1995; Schriefers et al., 1995; Mecklinger et al., 1995; Bayer and Marslen-Wilson, 1992).

The major finding of the present study is that the subject-object preference is not as strong as has previously been claimed. Various factors other than the syntactic bias appear to play a role in determining which order of subject and object is ultimately preferred and the ease with which a certain reading can be obtained. In particular, the results of the present experiments show that order preferences are influenced by the discourse-related properties of the NPs involved, even if sentences are presented in isolation. These properties can even override the syntactic bias and favor an object-subject reading of the clause. In addition,
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the manner and point of disambiguation appear to play a role in the ease of resolving the ambiguity.

The present findings suggest various modifications for sentence processing theories. All models of sentences processing must ultimately give an account of the various factors that determine order preferences. Only by providing a quantitative theory can strong predictions be made and the various sentence processing models be experimentally tested.

Future research should thus be aimed at further specifying the factors that influence word order preferences and their relative contributions over time. In the present work the effect of the type of the NP was studied using isolated sentences only. To further single out the effects of discourse-related biases, experiments should be conducted investigating the effect of the presence of an explicit NP referent in the preceding discourse. Other factors that may influence word order preferences and hence deserve extensive investigation, are for instance: animacy information and thematic fit (cf. Brouw, 1995); the distance between the wh-phrase and the clause it belongs to (‘Long distance extraction’: Frazier, 1990b; Jordens, 1991; Farke, 1994; Farke and Felix, 1994; Schlesewsky et al., to appear; De Vincenzi, 1996); prosodic information (Read et al., 1980) and individual differences in working memory capacity (Kaan and Stowe, 1995; Mecklinger et al., 1995; Friederici et al., 1996). Each of these factors has been shown to be relevant to the processing of other sorts of ambiguity (cf. e.g. Trueswell, Tanenhaus and Garnsey, 1994, for thematic fit; Clifton and Frazier, 1988, for long distance dependencies; Nagel, Shapiro, Tuller and Nawy, 1996, for prosody; and Just and Carpenter, 1992, for working memory). Results from on-line experiments should be combined with data from corpus studies and off-line completions to obtain a proper estimate of the relative strength of the various factors that play a role in the resolution of Dutch word order and other ambiguities. Only then can explicit predictions be made and the various sentence processing models tested.

Thus investigating the factors that play a role in ambiguity resolution and determining their relative contribution may ultimately lead to a better understanding of sentence processing and the cognitive mechanisms involved.