

# PRESUPPOSITIONS IN PROCESSING: A CASE STUDY OF GERMAN *auch* \*

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## Abstract

This paper presents two experimental studies investigating the processing of presupposed content. Both studies employ the German additive particle *auch* (*too*). In the first study, participants were given a questionnaire containing bi-clausal, ambiguous sentences with 'auch' in the second clause. The presupposition introduced by *auch* was only satisfied on one of the two readings of the sentence, and this reading corresponded to a syntactically dispreferred parse of the sentence. The prospect of having the *auch*-presupposition satisfied made participants choose this syntactically dispreferred reading more frequently than in a control condition. The second study used the self-paced-reading paradigm and compared the reading times on clauses containing *auch*, which differed in whether the presupposition of *auch* was satisfied or not. Participants read the clause more slowly when the presupposition was not satisfied. It is argued that the two studies show that presuppositions play an important role in online sentence comprehension and affect the choice of syntactic analysis. Some theoretical implications of these findings for semantic theory and dynamic accounts of presuppositions as well as for theories of semantic processing are discussed.

## 1 Introduction

The study of presuppositions has been an important topic in both the philosophy of language and in linguistic semantics and pragmatics, but only more recently has it become a topic investigated with psycholinguistic methods. However, a lot can be gained from such investigations, both with respect to theoretical issues in presupposition theory as well as with respect to our understanding of semantic processing. In the following, I present two experimental studies focusing on the German additive particle *auch* (*too*). I argue that the results from these studies indicate that presuppositions play an important role early on in sentence comprehension processes. This, together with seeing other relevant studies in the processing literature from the viewpoint of semantic theory, opens up the possibility of testing theoretical claims with psycholinguistic methods. One conclusion suggested by the results presented here is that something like contextual updates (in the sense of update semantics) are carried out below the sentence level in actual processing, namely at the level of DPs. In addition to these theoretical conclusions, some implications for a theory of semantic processing are also discussed.

The paper is organized as follows. In the following section, I provide some background on the issues relevant to the experiments, including my theoretical assumptions about presuppositions and a few remarks about existing work on semantic processing. Section 3 presents the two experimental studies that were carried out. Section 4 discusses implications of the experimental

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results for presupposition theory and theories of semantic processing. Section 5 provides a brief summary and a conclusion.

## 2 Background

One might start out the enterprise of investigating presuppositions in processing by wondering whether they matter at all in online sentence comprehension. After all, they are most commonly thought of as crucially relating to the context, and at least in the experimental settings typically used in psycholinguistic work, there is no realistic context. So it is at least possible that participants in experiments more or less ignore such context related information, especially if considerations relating to presuppositions are part of very late pragmatic processes in sentence comprehension that are more like conscious reasoning. If, on the other hand, the processor automatically made use of presupposed content, we would expect that participants would not be able to ignore it. In this case, the question becomes in what ways presuppositions can affect the parsing of incoming strings of linguistic expressions, and how quickly is their content accessible to the parser. Furthermore, we would want to know whether presuppositions interact with other factors known to be relevant in parsing, and if so in what ways. In order to address these issues in more detail, I will outline my theoretical assumptions and some of the previous findings on pragmatic processing.

From a theoretical viewpoint, we are, of course, especially interested in what implications experimental results might have for semantic and pragmatic theory. In connection with this it is interesting to note that most of the theoretical frameworks for the analysis of presuppositions share a procedural view of some sort which determines how presupposed content is integrated with the contextual information (although they don't make any explicit claims about actual processing). For concreteness, I will frame the discussion in this paper in terms of Heimian update semantics (Heim 1982, Heim 1983a, Heim 1983b). This is not to say that the results presented here could not be framed in other presupposition theories. In particular, they might just as well be viewed in terms of Discourse Representation Theory (Kamp 1981), which shares most of the features relevant for our purposes with update semantics.

Presuppositions have two crucial properties: first, they are something that is taken for granted by the discourse participants. Secondly, presupposed content behaves differently from asserted content in most embedded contexts. This is at the heart of what is usually referred to as the *projection problem* (for an overview, see von Stechow 2004, Beaver 1997). In update semantics, which can be viewed as a formal implementation of the accounts for presuppositional phenomena by Stalnaker and Karttunen (Stalnaker 1973, Stalnaker 1974, Karttunen 1973, Karttunen 1974), the aspect of being taken for granted is modeled by the common ground, which is the set of worlds in which all of the beliefs that the discourse participants knowingly share are true. A sentence can only be felicitously uttered when the presuppositions that come with uttering the sentence are entailed by the common ground. The behavior of presuppositions in embedded contexts is accounted for by the way that the common ground is updated when a new utterance is made in the discourse. Under certain circumstances, presupposition failure can be remedied by a process of accommodation (Lewis 1979), in which the common ground is adjusted in such a way that it does entail the presupposition at issue.

Update semantics represents the meanings of sentences as context change potentials. More concretely, sentence meanings are understood as functions from contexts to contexts (where contexts are modeled either as sets of worlds or sets of pairs of worlds and assignment functions). One of the crucial issues in this type of theory is where or when context updates take place. Quite frequently the discussion in the literature focuses on the sentence or clause level, which seems intuitively plausible. However, in the full version of Heim's system, which in-

cludes assignment functions, updates also take place at the level of noun phrases (which are viewed as denoting atomic propositions). Furthermore, in order to account for certain facts concerning the behavior of presuppositions in embedded contexts, Heim (1983a) introduces the notions of local and global accommodation. As I will discuss in some more detail below, the issue of where updates take place is crucial for semantic processing viewed from the perspective of update semantics: if the processor is to make use of compositional semantic information, the way in which it can be used crucially depends on the point at which it has access to it.

Before turning to the discussion of the experiments, let me briefly review some existing work on presuppositions in processing. Most related work focuses on the presupposition of the definite article and follows the basic approach taken in the seminal study of Crain and Steedman (1985).<sup>1</sup> Looking at locally ambiguous sentences like the one in (1), they show that varying the discourse context (as in (2)) affects the way that the sentence is parsed.

- (1) The psychologist told the wife that he was having trouble with. . .
- a. . . her husband.
  - b. . . to leave her husband.
- (2)
- a. *Complement Inducing Context*  
A psychologist was counseling a married couple. One member of the pair was fighting with him but the other one was nice to him.
  - b. *Relative Inducing Context*  
A psychologist was counseling two married couples. One of the couples was fighting with him but the other one was nice to him.

In (1-a) the *that*-clause is interpreted as the complement of 'told', while in (1-b), it is a relative clause modifying *wife*. The latter reading is much harder to see due to a typical garden-path effect. The preceding contexts were varied in introducing either one or two couples, the idea being that if two couples are introduced, the definite description consisting of the noun only (*the wife*) cannot refer successfully, while the complex description consisting of the noun and the following *that*-clause analyzed as a relative clause does have a unique referent. The sentences were judged to be ungrammatical about 50 per cent of the time in a grammaticality judgment task when the context and the sentence did not match, but they were judged to be grammatical around 75 to 90 per cent of the time when the context matched. Crucially, even the garden-path in (1-b) was ameliorated by putting it in a matching context. This finding motivated Crain and Steedman to propose a principle of parsimony, which guides the selection between different syntactic parses in their parallel parsing architecture, so that the reading carrying the fewest unsatisfied presuppositions will be the preferred one. Similar techniques are used in more recent work (van Berkum, Brown and Hagoort 1999, van Berkum, Brown, Hagoort and Zwitserlood 2003). These studies all focus on definite descriptions and show effects of presuppositions indirectly in connection with structural parsing issues in particular parsing architectures. The studies presented here aim to broaden the range of triggers being studied and to look at effects of presuppositions in a more direct way. The experimental techniques used here contribute a new type of evidence for presupposition theory, where many hotly debated issues involve subtle intuitions. Furthermore, an attempt is made to integrate the experimental results into the theoretical discussion, in order to contribute to a theory of semantic processing informed by linguistic semantics.

<sup>1</sup>But recent work is becoming more diverse in terms of the presupposition triggers covered. See, for example, Chambers and Juan (2005) on *again* and for new work on pragmatic processing more generally (Noveck and Sperber 2004).

### 3 Two Experimental Studies on *auch*

How should we go about testing the potential effects of presuppositions in sentence processing? One of the standard techniques in psycholinguistics is to compare a normal or unproblematic form to a somehow deviant (or temporarily deviant seeming) form. This basic idea is applied to presuppositions in the two studies below in two ways: first, participants were shown ambiguous sentences containing *auch*, where one reading of the sentence satisfied the presupposition introduced by *auch*, whereas the other did not. The task, then, was to choose a paraphrase corresponding to the participants' understanding of the sentence. The second approach was to show unambiguous sentences with *auch* to the participants, which varied in whether the presupposition was satisfied or not. This study employed the self-paced-reading method, and participants simply had to read the sentences region by region and answer simple questions about them.

A few remarks are in order with respect to the particular choice of presupposition trigger made here. As mentioned above, the presuppositions introduced by many triggers can easily be accommodated. It certainly is a possibility to be considered that in an experimental setting participants are willing to accommodate just about any content, since the situation they are in is obviously artificial. Just compare this situation to reading an example sentence in a linguistics article. It might very well contain, say, a definite description. As a reader, there certainly is nothing odd about reading such a sentence, even if it is completely unclear and left open whether the relevant presuppositions are satisfied or not. The danger for an experimental inquiry into presuppositions in processing might be that they don't play any serious role at all, at least to the extent to which they can be accommodated without a problem. There are, however, a few presupposition triggers that are well-known to at least strongly resist accommodation (cf. Beaver and Zeevat to appear). One case in point is additive particles like *too* or German *auch*, which, roughly speaking, presuppose that there is another salient discourse entity of which the predicate in the sentence holds. If there is no such discourse entity, the utterance of the sentence will be infelicitous. This is illustrated by Kripke's famous example in (3-a) (Kripke 1991):

- (3) a. John is having dinner in New York tonight too.  
 b. Did you know that Bill is having dinner in New York tonight?

In an out of the blue context, the sentence in (3-a) is very odd, since there is no salient individual about whom it is already known in the discourse that they are having dinner in New York tonight. And even though it is completely uncontroversial that there are many people having dinner in New York every night, this presupposition failure cannot be remedied by accommodation. The utterance of (3-a) is only felicitous when there is some individual salient in the discourse that has the relevant property, e.g. in the context of (3-b). This type of presupposition trigger then lends itself to experimental investigation, as we have more control over whether presupposition failure takes place or not, without having to worry about the possibility of accommodation.

#### 3.1 Questionnaire Study on *auch*

##### 3.1.1 Methods and Materials

The basic strategy for the experimental items for the first study was to construct bi-clausal, ambiguous sentences consisting of a relative clause and a main clause. One of the readings is preferred based on well-known syntactic parsing preferences. The other reading was the one that satisfied the presupposition of *auch*, which appeared in the second clause. An example is given in (4):

- (4) Die Frau, die das Mädchen sah, hatte auch der Mann gesehen.  
The woman-N/A who-N/A the girl-N/A saw had also the man-N seen

'The woman that (saw the girl/ the girl saw) had also been seen by the man.'<sup>2</sup>

The relative clause is ambiguous due to the case-marking. In German, there is a strong and extremely well-studied parsing preference for interpreting such clauses as having a subject-object (SO) order (see, among many others, Hemforth 1993, Bader and Meng 1999, Schlesewsky, Fanselow, Kliegl and Krems 2000). In the main clause, the unambiguously nominative marked subject appears in final position. It is preceded by *auch*, which most naturally associates with the subject following it (*der Mann*), yielding the presupposition that someone else had seen the woman. This presupposition is not satisfied on the syntactically preferred interpretation (SO) of the relative clause. However, the syntactically dispreferred OS-reading of the relative clause (that the girl saw the woman) *does* satisfy this presupposition.

The task for the participants then was to choose a paraphrase that best matched their understanding of the sentence. The paraphrases for (4) would have been *The man and the girl saw the woman* and *The woman saw the girl and the man saw the woman*. This choice between paraphrases amounted to a choice between the syntactically preferred interpretation and the interpretation on which the presupposition of *auch* was satisfied. As a control condition, the same sentence was used but *auch* was replaced by *vorher* (*earlier*), which does not introduce any presupposition whose satisfaction depends on the interpretation of the relative clause. Two further conditions followed the same basic idea, but had the order of the clauses reversed, with *auch* appearing in the relative clause. An example is given in (5):

- (5) Die Frau sah das Mädchen, das auch den Mann gesehen hatte .  
The woman-N/A saw the girl-N/A who-N/A also the man-A seen had

'The woman saw the girl that had also seen the man.' or

'The woman was seen by the girl that had also seen the man.'

In this case, the matrix clause is ambiguous, and the relative clause contains *auch*. Note that this time the noun phrase *den Mann* (*the man*) in the relative clause is unambiguously marked accusative, so that the clause can only mean that the girl saw the woman. Also note that the first two noun phrases always were of distinct genders, so that there was no ambiguity with respect to which noun phrase the relative clause was modifying. As above, the ambiguous clause had a syntactic parsing preference for an SO-order, whereas the dispreferred OS-order satisfied the presupposition introduced by *auch* (that the girl saw someone else apart from the man). A control condition was again constructed by replacing *auch* by *vorher*.

The setup resulted in a 2 X 2 design, with the presence or absence of *auch* as the first factor and clause order as the second factor. For the questionnaire, 30 sentences were constructed with versions for each of the four conditions above (plus a fifth condition for an additional pilot, which is not discussed here). Five versions of the questionnaire were created, varying sentences across conditions, so that each list contained 6 sentences per condition, resulting in a fully counterbalanced design. The questionnaire was created in HTML and made available online. The sentences were followed by disambiguated paraphrases and participants were asked to choose the paraphrase that matched their understanding of the sentence or their preferred interpreta-

<sup>2</sup>N and A stand for nominative and accusative respectively. Here and below, the passive is only used in the English paraphrase to keep the word order similar to the German one. Note that the sentences given here as well as the ones given for the other study below are only used for illustration purposes and were not used in the actual studies. The complete materials used in the experiments reported in this paper are accessible online at <http://www.people.umass.edu/florian/materials.htm>.

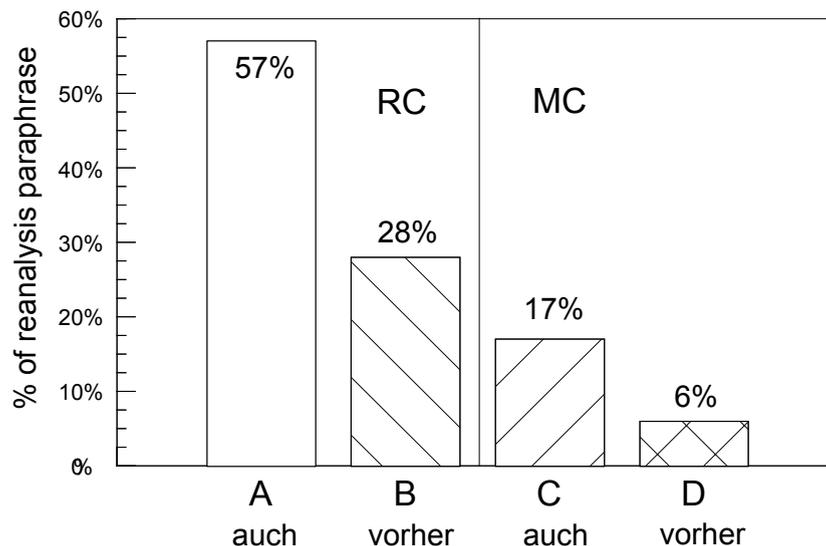


Figure 1: Percentage of OS-paraphrases per condition

tion of the sentence if more than one reading was possible. In addition to the experimental items, there were 3 items similar to the experimental ones, but preceded by a short text. Also, there were 20 unrelated filler items. Altogether, 90 native speakers of German completed the questionnaire.

### 3.1.2 Results

The results were analyzed with the percentage of the type of paraphrase chosen as the dependent variable, with the paraphrases corresponding to either the SO-order or the OS-order. The mean percentage of how often the OS-paraphrase was chosen is shown in Figure 3.1.2 for each condition.

The OS-interpretation was chosen more frequently in the *auch*-conditions (A and C) than in the corresponding control conditions with *vorher* (B and D). It was also chosen more frequently in general for the relative clause before matrix clause order (RC-MC) than in the matrix clause before relative clause order (MC-RC). A 2 x 2 ANOVA (*auch* vs. *vorher* and RC-MC vs. MC-RC) was performed. There was a main effect of *auch* ( $F_1(1, 89) = 112.3, p < .001, F_2(1, 29) = 277.2, p < .001$ ) and a main effect of clause type ( $F_1(1, 89) = 183.3, p < .001, F_2(1, 29) = 92.1, p < .001$ ). There also was an interaction between the two factors ( $F_1(1, 89) = 30.7, p < .001, F_2(1, 29) = 37.2, p < .001$ ). Two-tailed t-tests were carried out to test for simple effects of *auch* for the two types of clause orders. Both effects were significant (condition A vs. B:  $t_1(89) = 10.3, p < .001, t_2(29) = 13.2, p < .001$ , condition C vs. D:  $t_1(89) = 5.4, p < .001, t_2(29) = 7.3, p < .001$ ). This shows that the differences between the *auch* and *vorher* conditions are significant for each of the clause orders.

### 3.1.3 Discussion

The results from the questionnaire study clearly show that participants' choice of paraphrase is influenced by the presupposition introduced by *auch*. When it is present, as in conditions A and C, the otherwise dispreferred OS-paraphrase is chosen more frequently than when it is not, presumably because this order yields the *auch*-presupposition satisfied. This effect is present

and significant for both clause orders, but stronger in the RC-MC order. Altogether, the OS-paraphrase is chosen more frequently in the RC-MC order. This, together with the interaction, indicates that the effect of the presupposition interacts with other parsing factors.

One way of describing the process that readers might go through in reading these sentences is that they first commit themselves to an SO-interpretation of the ambiguous clause and then reanalyze that clause once they see that this renders the presupposition of *auch* satisfied. In the case of the ambiguous matrix clause, this reanalysis is most likely harder and involves at least one additional confounding factor: interpreting the clause initial DP as the object requires a special interpretation (e.g. as a topic), which is not supported by anything in the context. Therefore, it is altogether harder and less likely that participants will end up with the OS-interpretation for the MC-RC order, and the effect of the presupposition is smaller in the condition with this order. An interesting further result in the statistical analysis that was not mentioned above is that there was a learning effect reflected by a significant increase in the percentage of OS-paraphrases chosen for the MC-RC order in the second half of the questionnaire. For the RC-MC order, there was only a small numerical increase that was not significant. This supports the conclusion made above that it is harder to get the OS-order in the MC-RC order. Apparently, participants become more likely to choose the OS-interpretation after having been exposed to a number of these constructions and paraphrases for this clause order, whereas they start out at a fairly high level for the other clause order.

The interaction seen here between the effect of the presupposition and other parsing factors is a first indication that the issue of presupposition satisfaction plays a role in online processing, although we cannot draw any firm conclusions in this regard from an off-line questionnaire study. The study reported in the next section attempts to address this issue in a more direct way.

## 3.2 Self-Paced-Reading Study on *auch*

### 3.2.1 Methods and Materials

The second study used the self-paced-reading method to investigate the effect of presuppositions on the time people spent reading the relevant parts of the experimental sentences. For this study, the basic strategy was to present unambiguous versions of the materials in the first study, which varied in whether the presupposition of *auch* was satisfied or not. Since the effect in the questionnaire was larger for the RC-MC order, sentences using this order were used for the online study. An example illustrating the setup of the experimental items is given in (6):<sup>3</sup>

- (6) a. Die Frau,/ die der Junge sah,/ hatte auch der Mann gesehen.  
The woman-N/A who-N/A the boy-N saw had also the man-N seen  
'The woman that the boy saw had also been seen by the man.'
- b. Die Frau,/ die den Jungen sah,/ hatte auch der Mann gesehen.  
The woman-N/A who-N/A the boy-A saw had also the man-N seen  
'The woman that saw the boy had also been seen by the man.'

In the sentence in (6-a), the noun phrase in the relative clause (*der Junge, the boy*) is unambiguously marked nominative, which results in the clause having OS-order and meaning that the boy saw the woman. The main clause contains *auch*, which (again assuming that it associates with *der Mann (the man)*) introduces the presupposition that someone else saw the woman. Given

<sup>3</sup>The character '/' indicates the section breaks between the parts of the sentence that were displayed at one time in the moving-windows display (this is described in more detail below).

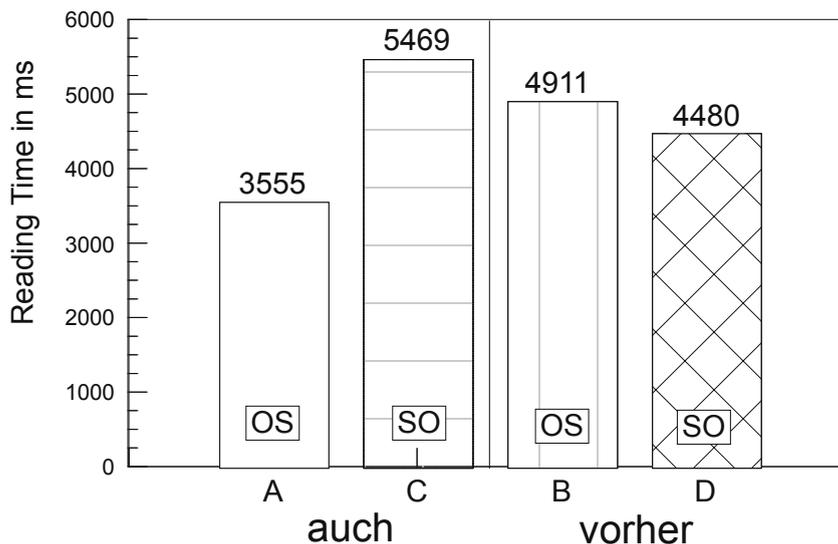


Figure 2: Reading time on final clause in ms

the meaning of the relative clause, this presupposition is satisfied. In (6-b), on the other hand, the noun phrase *den Jungen* (*the boy*) is unambiguously marked accusative, so that the clause has SO-order and can only be understood as the woman seeing the boy. The presupposition of the main clause is as in (6-a), and is therefore not satisfied by the relative clause.

As in the questionnaire study, control conditions were constructed by replacing *auch* with *vorher*. As in the first study, this resulted in a 2 x 2 design, again with the presence or absence of *auch* as the first factor and SO vs. OS-order as the second factor. The study included 24 sentences with versions in each of the four conditions. The sentences were counter-balanced across conditions in four lists. Participants only saw each sentence in one condition. The experiment was programmed using E-Prime software. The presentation order of the items was randomized. Sentences were presented using the moving-window technique. On the first screen, all characters were replaced by underscores. Participants had to press the space bar to see the first part of the sentence. When they pressed the space bar again, the first part was replaced by underscores, and the next part of the sentence was displayed. Reading times were recorded for each displayed phrase. After each sentence, a yes-no question about that sentence was presented, and participants had to push 's' to answer 'yes' and 'k' to answer 'no'. Both the responses and the response times were recorded. Apart from these experimental items, there were 72 items from unrelated experiments and 12 from a related experiment. Furthermore, there were 12 filler items. Subjects received instructions about the keys they had to press, and were told to only answer questions with 'yes' if this followed directly from the sentence in question. On average it took about 30 minutes to complete the experiment. 20 native speakers of German participated in the experiment.

### 3.2.2 Results

The measure of most interest was the reading times on the clause containing *auch* (or *vorher*). Their means are shown for each condition in Figure 3.2.2.

When *auch* was present (conditions A and C), the reading time in the OS condition (where the presupposition of *auch* was satisfied) was almost two seconds faster than in the SO-condition (where the presupposition was not satisfied). When *auch* was replaced by *vorher*, the SO con-

dition (D) had a small advantage over the OS condition (B). Interestingly, the *auch*-phrase was read almost 1.5 seconds faster than the *vorher* phrase in the OS-condition, but roughly one second slower in the SO-condition.

A 2x2 ANOVA revealed an interaction between the two factors ( $F_1(1, 19) = 26.00, p < .001, F_2(1, 23) = 17.81, p < .001$ ). In addition, there was a main effect of order (SO vs. OS) ( $F_1(1, 19) = 11.58, p < .01, F_2(1, 23) = 7.88, p = .01$ ), which was dominated by the interaction. A number of t-tests were also carried out to test for simple effects of *auch* vs. *vorher* and OS vs. SO separately. The difference between conditions A and C was significant ( $t_1(19) = -6.49, p < .001, t_2(23) = -4.58, p < .001$ ), which shows that there was a simple effect of SO vs. OS-order in the *auch*-conditions. There also was a significant difference between A and B ( $t_1(19) = -4.72, p < .001, t_2(23) = -5.03, p < .001$ ), i.e. a simple effect of *auch* in the OS-order conditions. The difference between C and D was significant by subject and near significant by items ( $t_1(19) = 3.07, p < .01, t_2(23) = 1.96, p = .06$ ), but the difference between B and D was not significant ( $t_1(19) = -1.28, p = .22, t_2(23) = 1.25, p = .23$ ). In terms of the statistical analysis, then, the main results are the interaction between the two factors and the simple effect of order in the relative clause. The simple effect of *auch* in the OS-order conditions is of interest as well, but its interpretation is less clear as it could in principle be due to a lexical effect involving *auch* and *vorher*.

Taken together, these results show that the reading times in the *auch* conditions were strongly influenced by SO vs. OS order (corresponding to whether the presupposition is satisfied or not), while the reading times in the *vorher* conditions were only slightly influenced by this factor, and in the opposite direction.

As additional measures, the response times and the accuracy rates for the yes-no questions following the display of the sentence were also analyzed. There was a main effect of order, with the OS conditions having roughly an advantage of one second over the SO conditions. No other effects were significant. The accuracy rates differed only numerically, with an overall average of 78.5 per cent. The condition with the unsatisfied *auch* presupposition had the lowest accuracy rate (73.3 per cent).

### 3.2.3 Discussion

The results from the self-paced-reading study clearly show that the reading time on the final clause containing *auch* was substantially affected by whether the presupposition of *auch* was satisfied or not. This is not merely an effect of parallel order in the two clauses, as the effect was reversed in the *vorher* conditions, in which no relevant presupposition interfered.

The effect of the presupposition is rather large, at almost two seconds difference between conditions A and C. It is very likely that this is due, at least in part, to the similarity between the conditions, and the relatively demanding task of answering the yes-no questions that followed the display of the sentence. Almost all subjects reported that it was quite difficult to keep in mind who did what to whom amongst the three people talked about in each sentence. When the presupposition did not match the content of the relative clause, it must have been even harder to keep this information straight, and this may have caused rather substantial delays when reading the final part of the sentence. One particularly telling comment from one participant in this respect was that she thought there were a number of spelling mistakes in the sentences, especially with the case marking on the final DP (e.g. *der Mann* rather than *den Mann*). Apparently, the expectation raised by the presupposition of *auch* was so strong that the mismatch was perceived as a mistake.

The strong effect on the reading time suggests that the presupposed content is evaluated online,

which lends further support to the speculative conclusion that the results from the questionnaire study are based on online effects of presuppositions. This finding is consistent with previous studies on the presuppositions of definite descriptions that were mentioned above (e.g. Crain and Steedman 1985, van Berkum et al. 2003). An additional point of interest here is that the reading times for the clause containing *auch*, preceded by the relative clause that satisfied the *auch*-presupposition (condition A), were faster than the reading times for the same clause with *vorher* preceded by the same relative clause (condition B). Although the possibility that this is a lexical effect cannot be excluded at the moment, this difference could be taken to tell us something interesting about the role of presupposed content in natural language. The advantage of the *auch* condition might be that the presupposed content facilitates the integration of new content into the contextual representation by connecting new and old information.

These results of these studies have some interesting theoretical implications and may provide new approaches for empirical research on presuppositions. I turn to these points in the next two sections.

## 4 Theoretical Implications

Ideally, results from psycholinguistic studies can contribute to theory in two directions, which correspond to the following two questions: What do the results tell us about (the relevant part of) linguistic theory, and what can we learn from them with respect to processing theories? I will focus on the implications for semantic theory, which I turn to in the next subsection. A few brief remarks about related processing issues are made in the final part of this section.

### 4.1 Implications for Semantic Theory

Let us take a closer look at the example sentences in order to understand what is going on in the processing study in slightly more refined semantic terms. The example sentence for condition A, where the presupposition of *auch* is satisfied by the relative clause, is repeated in (7):

- (7) a. Die Frau,/ die der Junge sah,/ hatte auch der Mann gesehen.  
 The woman-N/A who-N/A the boy-N saw had also the man-N seen  
 'The woman that the boy saw had also been seen by the man.'
- b. Presupposition of *auch* in general (Heim 1992)  
 $\Phi \text{ auch}_i [\alpha]_F$  presupposes  $x_i \neq \alpha \ \& \ \Phi(x_i)$
- c. Presupposition of *auch* in (a) (with focus on *der Mann*)  
 $\lambda x. \text{ see}(x, \text{woman}) \text{ auch} [\text{the man}]_F$  presupposes  
 $x_i \neq \text{the man} \ \& \ \text{see}(x_i, \text{woman})$

As the results from the self-paced-reading study show (and as is also intuitively clear), the relative clause satisfies the presupposition characterized in (7-c). As far as the processing perspective is concerned, it appears to be the case that this is something that takes place online, since the effect shows up in the reading time on the clause that contains the presupposition trigger. This suggests the conclusion that as one is reading the part of the sentence containing *auch*, one is aware of the content of the relative clause (of course, that also matches our intuitive sense of what happens when we read). When we look at processing in terms of update semantics, this is very interesting: to evaluate the presupposition of *auch* is to check whether the context entails it (and in the case of *auch*, something it also involves something like checking whether there is

an appropriate discourse referent having the relevant property). Since the the sentence is not at all problematic in any way (neither intuitively nor in terms of the reading time results), it seems to be the case that the content of the relative clause is already part of the context by the time the final part of the sentence, which contains the presupposition trigger *auch*, is semantically processed. In other words, it looks as if the context has been updated with the sentence initial DP, including the relative clause, by the time the rest of the matrix clause is interpreted and integrated into the context.

It is plausible to assume that if this is indeed what the processor is doing, the simplest assumption is that it does so by using the grammar (more on this issue below). If we think of context updates as only taking place on the level of a sentence or a full clause, we cannot explain how the initial DP can satisfy the presupposition: If we tried to apply the context change potential of the entire sentence to the neutral context, the update would fail, since the presupposition of *auch* is not satisfied in the initial context (and no repair would work, since the presupposition of *auch* cannot be accommodated). However, as I already mentioned in section 2, in the full version of update semantics of (Heim 1983b), contexts consist of sets of pairs of worlds and assignment functions and noun phrases denote atomic propositions and hence denote context change potentials of their own. The meaning of noun phrases is as in (8), with the difference between definite and indefinite ones being captured with the Novelty Condition in (8-b)<sup>4</sup>:

- (8) a. Let  $c$  be a context (here a set of assignment functions) and let  $p$  be an atomic formula, then, if defined:  

$$c + p = \{g : \text{DOM}(g) = \bigcup \text{Dom}(f) \text{ s.t. } f \in c \cup \{i : x_i \text{ occurs in } p\} \ \& \ g \text{ is an extension of one of the functions in } c \ \& \ g \text{ verifies } p \}$$
- b. The Novelty/Familiarity Condition  
 $c + p$  is only defined if for every  $NP_i$  that  $p$  contains,  
*if  $NP_i$  is definite, then  $x_i \in \text{Dom}(c)$ , and*  
*if  $NP_i$  is indefinite, then  $x_i \notin \text{Dom}(c)$ .*

With denotations such as these, the progression of updates for the sentences of condition A can proceed without a problem. First, the initial noun phrase is interpreted and its presupposition is evaluated with respect to the input context. It is not satisfied, but can be accommodated without a problem. Next, the rest of the matrix clause is interpreted, and the presupposition of *auch* is evaluated with respect to the local context. In this context it is satisfied, and the update can proceed smoothly. These steps are sketched in semi-formal terms in (9):

- (9) p: The woman  $x$  that the boy saw, q:  $x$  was also seen by the man
- a.  $c + p$  defined only if there is a unique woman that the boy saw
- b. after accommodation:  

$$c + p = \{g : g \text{ verifies } \text{woman}(x) \ \& \ \text{boy}(y) \ \& \ \text{see}(y)(x)\} = c'$$
- c.  $c' + q$  defined only if there is a  $z \neq$  the man in  $c'$  &  $\text{see}(z)(x)$   

$$c' + q = \{g : g \text{ verifies } \text{woman}(x) \ \& \ \text{boy}(y) \ \& \ \text{see}(y)(x) \ \& \ \text{man}(z) \ \& \ \text{see}(z)(x)\}$$

This contrasts with condition C, where the order in the relative clause has been switched around, so that even after the initial DP has become part of the context by the time the rest of the matrix clause is interpreted, the presupposition of *auch* is not satisfied, and there is no chance to accommodate it, since the presupposition of *auch* strongly resists accommodation. This problem is immediately present in processing, as reflected in the very slow reading times in that

<sup>4</sup>For simplicity, I restrict the formal representation of contexts to sets of assignment functions

condition.

Although there is clear evidence here that the processor deals with presupposed content online, a word of caution is in order with respect to what conclusions we can draw about how the processor goes about this. The results from the self-paced reading study are not fully conclusive with respect to the issue of whether the processor employs incremental updates using Heimian atomic propositions ‘on the fly’, since we are looking at the reading times for the sentence final region. It is possible that the context sensitive part of interpretation (and perhaps the compositional semantic process altogether) takes place once the entire sentence has been presented (even though this seems intuitively implausible). The slow-down in the reading time on the final region certainly is consistent with that. But even if it were the case that the integration of the content of the sentence with the context takes place at the very end of the clause, the results here show that, at that point, the procedural steps it goes through must be very much like the ones sketched in (9).

Therefore the results of the experiments presented here contribute a new kind of evidence to the theoretical discussion. They show that the processor goes about interpreting a sentence in steps very much like those assumed by dynamic semantic theories. If we continue to assume that the processor does this by using the system supplied by the grammar, working out the details of a theory of semantic processing based on something like update semantics should make further experimentally testable predictions, which can help us to broaden the empirical foundation of semantic analyses of presuppositions. One possible follow-up to the current study would remedy the problem of the critical region being the final region by breaking up the regions into smaller chunks and by adding a continuation. This could be done by employing sentences such as the following:

(10) The woman/ who saw the boy/ also saw/ the man/ yesterday/ on her way to work.

In addition to these considerations about the online study, we should also note the relevance of the findings of the questionnaire study in this respect. Assuming a model of the syntactic parser that only pursues one structural analysis at the time, we find a remarkable amount of effort put into reanalysis of the relative clause that already had been previously parsed with an SO-order, which is revised in order to satisfy the presupposition. The fact that this revision is even considered indicates that the meaning of the relative clause is already accessible to the parser at the time it encounters the presupposition.

## 4.2 Implications for Processing Theories

Let us now turn to some considerations about what the results reported here mean for a theory of semantic processing. At this point, we aren’t anywhere close to having a realistic idea of how compositional semantic processing takes place. One central question, of course, is at what point the processor actually goes through steps of semantic composition and at what point the content of the currently processed linguistic unit is integrated with the information present in the context (which crucially should involve the evaluation of presuppositions with respect to that context). Modulo the caveat about the possible conclusions of the present studies concerning the issue of whether the processor goes through the steps of updating the context on the fly’ or whether it does so at a later point, a viable hypothesis can be constructed from what has been said here: Apart from the level of full clauses, where we obviously are dealing with propositional units, updates also take place at the level of noun phrases. This amounts to a straightforward extension of update semantics to the theory of processing. Whether or not this can be upheld, it is the simplest assumption that the processor makes use of the system supplied

by the grammar, and it has the advantage of making predictions that should, at least in principle, be experimentally testable. Hopefully, this will also enable us to investigate further theoretical issues in presupposition theory in new ways.

Apart from these issues related immediately to semantic processing, the studies might also contribute to more general architectural questions in processing theory, although I can only make some brief remarks about these here. Let me just mention one particularly interesting point, namely that the results from the questionnaire study are most likely problematic for a simple version of a parallel parsing architecture along the lines of the one proposed by Crain and Steedman (1985). The idea in this work is that when the processor deals with an ambiguous structure, it considers all possible structures at the same time, with some structures being filtered out by certain principles. One central principle that they assume to account for the data mentioned above in (1) is the principle of parsimony, which only keeps those interpretations that have the fewest presuppositions violated. One of the more intriguing aspects of the questionnaire study discussed here was the interaction of how often subjects would choose the syntactically dispreferred structure (to have the presupposition of *auch* satisfied) with the order the clauses appeared in (which affected whether the matrix clause or the relative clause was ambiguous). If people were considering both interpretations of the ambiguous clauses at the same time, and then would choose one of them based on which one has the fewest presupposition violations, we would expect that they would choose the reading on which the *auch*-presupposition is violated more often (in the MC-RC condition with *auch*, they chose it only 17 per cent of the time, and even in the RC-MC order condition, they chose it only 57 per cent of the time). Furthermore, we would not expect that the two clause orders would differ so drastically in this respect.

## 5 Conclusion

I have argued that the results from the studies reported here suggest that the processor has access to and makes use of presupposed content in online processing and employs something like context updates at the level of noun phrases. In a sense, this means taking the ‘dynamic’ aspect of dynamic semantics quite literally by claiming that the linguistic processor employs dynamic updates in the process of interpreting a sentence compositionally. Bringing our theoretical frameworks and processing theories closer together in this way has the advantage of being temptingly simple. Whether or not this turns out to be realistic in the long run, it should enable us to come up with straightforward predictions that we can test in further work. This opens up the possibility of extending the empirical foundation for work in theoretical semantics and of addressing central issues in presupposition theory that often involve disputes about the intuitive status of presupposed content. Investigating these issues in a more direct empirical way will make an important contribution to the theoretical discussion. Once we have a better understanding of what kind of effects related to presuppositions there are in processing, we can hope to address more sophisticated questions in presupposition theory (e.g. the issue of local and global accommodation) in new ways.

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