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The Development of Argument Processing Mechanisms in German: An Electrophysiological Investigation with School-Aged Children and Adults

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Kerstin Leuckefeld
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Gutachter: Prof. Dr. Angela D. Friederici
Prof. Dr. Barbara Höhle

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Preface

In everyday conversation, it is essential to figure out 'who is doing what to whom'. If the relationship between the participants in a sentence is reversed, this may profoundly change its meaning. For instance, many more people will be affected if they hear that a servant killed the king, but the reversed action might even rank among the occupational risk at court. Also, it would be quite amazing to hear that Tom Cruise admires me (and has a picture of me hanging over his sofa), but no one would be surprised to hear that I admire a famous film star. Finally, it might have a serious effect on my neighbour's financial future if it turns out that he owes his ex-wife half a million dollars, and not vice versa.

Fortunately, our sentence processing mechanism allows us to quickly determine the relationship between the participants of a sentence. To this end, we rely on different linguistic cues that are analyzed at an astonishing speed. In German, for example, both the sequential ordering of the arguments and their morphological case marking indicate the participants' status. Crucially, case markings are much more informative with regard to the participants' relationship than the sequence of the arguments. Thus, a sentence like 'Den König erdolchte der Diener' ([the king]$_{accusative}$ poniarded [the servant]$_{nominative}$) may well indicate a day of national mourning if the case markings are taken seriously. Without overt case markings, for instance in a headline of a newspaper ('König erdolcht Diener'), the folk would rely on word order and continue mindlessly their daily business.

It is extremely unlikely that such highly specialized adult sentence processing mechanisms are 'innate'. Rather, they have to be learned and refined throughout infancy and childhood, and must be adjusted to the characteristics of the surrounding language. Up to now, only little is known about how children determine the relationship between two participants, and how their strategies change with age. In particular, the development of the underlying neural processes that change with increasing linguistic competence is still an open field.

The present thesis investigates how the on-line mechanisms of sentence processing develop during the early school years by means of event related brain potentials. Of specific interest is the nature of the representations built up on the

basis of word order and morphological case information in German. All previous studies examining this question employed behavioral paradigms that did not provide an insight into the processing stages at individual words in a sentence. However, a better understanding of the neurophysiological basis of the on-line processes will allow us to refine theories of language acquisition, especially concerning the transition to the adult processing system. Previous models of language acquisition primarily focused on how children start to use certain linguistic features, often neglecting later stages in language development.

This thesis is divided into two sections. The first section gives an overview of the theoretical background and of previous experimental data. First, the theoretical frame will be introduced in Chapter 1, with specific emphasis on the morpho-syntactic realization of hierarchical dependencies between the arguments of a sentence. Chapter 2 describes the method of event related brain potentials and its importance in research on language comprehension in children and adults. Chapters 3 and 4 present previous experimental data on sentence comprehension in adults and children, which are embedded into models of comprehension and acquisition. The research questions are formulated in Chapter 5. The second section of this thesis comprises five experiments on dative (Chapters 6 to 8) and accusative structures (Chapter 9) that were conducted with adults and children. Finally, the thesis closes with a discussion of the results (Chapter 10).

Chapter 1
Linguistic Foundations

1.1 Generalized Thematic Roles and the Thematic Hierarchy

Events typically involve one or more entities, which perform an action or which are somehow manipulated. For instance, the two sentences 'Martin strokes the dog' and 'Martin kicks the dog' clearly describe different events. Nevertheless, they have something in common. In both cases, 'Martin' is the one doing something, who actively and deliberately contributes to the action. The 'dog', on the other hand, is in both cases affected by the action – although either feeling comfortable or miserable.

Several theories have attempted to describe what distinguishes 'Martin' from the 'dog' in a semantic, or more precisely, in a thematic way. A classical assumption is that each argument in a sentence has a different thematic role (cf. Haegemann, 1994). Thus, in the case of 'kick', Martin bears the thematic role AGENT, and the dog bears the thematic role PATIENT. However, only in combination with the specific lexical verb information, the precise meaning of the arguments can be derived, Martin being the 'kicker', and the dog being the one 'kicked'. There are many further thematic roles, such as EXPERIENCER, THEME, GOAL, or LOCATION, each of which describes different thematic properties (cf. Haegemann, 1994).

The advantage of thematic roles is that they allow a generalization over many different verbs. In the present case, both the verb 'kick' and the verb 'stroke' involve an AGENT and a PATIENT role, despite the differences in verb meaning. In addition, both verbs have the same syntactic properties. For instance, both are transitive. Hence, on the basis of thematic roles different verb classes can be defined, including verbs that share thematic and syntactic properties. As such, the concept of thematic roles is a generalization that helps in mapping semantics onto syntax.

Over and above the notion of thematic roles, a further generalization is possible. Thematic roles can be subsumed under even more abstract labels, so-called

'generalized thematic roles' (Kibrik, 1985; Dowty, 1991; Van Valin & La Polla, 1997; Primus, 1999). Generalized thematic roles serve a more abstract thematic characterization of arguments than classical thematic roles do.

In terms of classical thematic roles, 'Martin' would be classified differently in sentences like 'Martin kicks the dog' and 'Martin likes the dog'. In the case of 'kick', Martin is the AGENT, as he is intentionally performing an action. However, in the case of 'like', Martin is the EXPERIENCER, as he is experiencing some psychological state. Above this level, generalized roles allow a further abstraction. They express the general relationship between Martin and the dog, highlighting that Martin is in both cases in a superior position with regard to the dog.

The present thesis is based on the theoretical frame developed by Primus (1999). She proposed three generalized roles, namely Proto-Agent, Proto-Patient, and Proto-Recipient. The properties of the three roles will be introduced with reference to example (1.1).

(1.1) Eve gave Adam an apple.

Proto-Agent. The Proto-Agent is thematically independent of other arguments. In other words, it is in a control relation. Ideally, the Proto-Agent acts deliberately, moves, and is animate. In (1.1) 'Eve' fulfils the Proto-Agent conditions. She is the one who deliberately initiates the action and who is thus independent of any other argument.

Proto-Patient. The Proto-Patient is thematically dependent on another argument. For instance, it may be causally affected by another participant of the event. In (1.1), the 'apple' fulfils the Proto-Patient condition. It is thematically dependent on 'Eve', as she moves it. In addition, it is dependent on 'Adam', as he will possess the apple in the end.

Proto-Recipient. The Proto-Recipient shares characteristics with the Proto-Patient and -Agent roles. The Proto-Patient-like characteristic is that it is dependent on another argument. In example (1.1) 'Adam' fulfils this condition. He is thematically dependent on 'Eve', as he receives the apple from her. The Proto-Agent like characteristic is that there is another argument dependent on

the Proto-Recipient. In (1.1), 'Adam' fulfils this condition, too. The 'apple' is dependent on him, as 'Adam' is the one who will finally possess it.

Crucially, Primus (1999) assumes that it is the relation of an argument to the other participants involved in the event that determines the generalized thematic role of that argument. The argument that is independent of any other participant is the Proto-Agent. The Proto-Patient is always dependent on another argument. The Proto-Recipient has an intermediate status. According to their degree of dependency, the generalized roles can be ordered in a universal hierarchy, the most independent role being ranked highest (cf. (1.2), whereby 'A $>_{them}$ B' indicates that 'A is thematically ranked higher than B').

(1.2) Thematic Hierarchy (Primus, 1999:55)
Proto-Agent $>_{them}$ Proto-Recipient $>_{them}$ Proto-Patient

1.2 Morphosyntactic Realization of Thematic Dependencies

What possibilities does the German language offer to encode thematic dependencies between the arguments of an event? Of course, the verb provides much of the information concerning the thematic properties of the arguments. In addition, the arguments themselves provide information about their thematic relationship, independently of the verb. This is quite important, given that in many sentences the crucial verb information only appears at the very end of a sentence (cf. (1.3)). Primus (1999) focuses on two functional aspects of linguistic information that encode thematic dependencies independently of the verb, namely morphological case marking and basic word order.

(1.3) Ich glaube, dass der Junge den Mann sieht.
I believe that [the boy]$_{\text{nominative (NOM)}}$ [the man]$_{\text{accusative (ACC)}}$ sees
'I believe that the boy sees the man'

1.2.1 Case Marking

Primus (1999) assumes a very close relationship between case marking and thematic relations. Her 'Principle of Morphosyntactic Expression of Thematic Information' states the following. The more Proto-Agent basic relations an argu-

ment accumulates, the more likely it is to bear the most unmarked case of a given language. The more Proto-Patient basic relations an argument accumulates, the more likely it is to bear the second most unmarked case (Primus, 1999).

The markedness of a given case is determined at least by the two following factors. First, it is determined by the complexity of morphophonological realization of individual cases. The less complex a case's realization, the less marked is this case. Second, it is determined by the subcategorization behavior of predicates. The more verbs exist that choose an individual case marker for one of their arguments, the less marked is this case. Both factors lead to a case hierarchy, with the most unmarked case being ranked highest (cf. (1.4), whereby 'A $>_{case}$ B' indicates that 'A is ranked higher than B in the case hierarchy').

(1.4) Case Hierarchy (Primus, 1999:18)
nominative/absolutive $>_{case}$ accusative/ergative $>_{case}$ dative $>_{case}$ others

According to the Principle of Morphosyntactic Expression of Thematic Information, a nominative-accusative language such as German will case mark Proto-Agents with nominative, and Proto-Patients with accusative. This case-marking pattern ensures maximal distinctness between the two arguments in terms of thematic properties (cf. Hopper & Thompson, 1980; Comrie, 1989). Hence, one argument is the Proto-Agent, the other one the Proto-Patient. In contrast, a dative marked argument always indicates a marked transitive relation in terms of thematic properties, since this case marking may be borne neither by ideal Proto-Agents nor by ideal Proto-Patients.

(1.5) Dem Kind gefallen die Blumen.
[to the child]$_{\text{dative (DAT), singular (SG)}}$ [appeal]$_{\text{plural (PL)}}$ [the flowers]$_{\text{NOM,PL}}$
'The flowers appeal to the child'

Moreover, the highest-ranking case determines verb agreement in German. Only a nominative marked argument agrees with the verb, irrespective of its basic structural position and its thematic role (Primus, 1999). For instance, in (1.5) 'the child' is thematically higher-ranking than 'the flowers', and 'the child' precedes 'the flowers' in basic word order (cf. also Table 1.1). Nevertheless, it is always the nominative case marked noun ('flowers') that agrees with the verb. Hence,

verb agreement is independent of the thematic status of the arguments and of their order.

In sum, morphological cases are ranked in a Case Hierarchy according to their markedness, which is closely related to the thematic properties of case marked arguments. However, only nominative marked arguments trigger verb agreement. Thus, agreement is not always a reliable cue with regard to the thematic status of the arguments.

1.2.2 Word Order

The arguments of a sentence are not only case marked but also sequentially ordered relative to each other. Canonical or unmarked word order is defined as the word order in a sentence that can be freely uttered in a neutral context, for instance as an answer to the question 'What happened?' (Siewierska, 1988). Primus (1999:136) states in her 'Principle of Structural Expression of Thematic Dependencies' that canonical word order patterns result from thematic dependencies. For instance, if an argument 'dog' is thematically dependent on a second argument 'boy', then 'boy' will be structurally superior to 'dog' in an unmarked sentence. An argument is structurally superior to another if it c-commands[1] it and/or if it precedes the other argument in linear word order. Thus, the thematically higher-ranking argument c-commands or precedes the lower ranking argument. This results in the following canonical word orders for transitive relations in German (cf. Table 1.1).

Crucially, dative markings occur both after and before the nominative marked argument. The latter involves so-called object-experiencer verbs like 'gefallen' (to appeal to so.). For instance, in example (c) of Table 1.1 the boy is the thematically higher ranked argument (Proto-Agent), namely the EXPERIENCER. The dog is the lower ranked STIMULUS (Proto-Patient). With dative object-experiencer verbs, the higher ranked argument exceptionally receives dative case, whereas the lower ranked argument is case marked by nominative. Nevertheless, the

[1] More specifically, structural superiority is defined in terms of 'asymmetric c-command'. Argument A c-commands argument B, iff (a) A and B do not dominate each other, and (b) the first branching node dominating A dominates B. The c-command is asymmetric if A c-commands B, but B does not c-command A (Haegemann, 1994).

higher ranked argument precedes the lower ranked one in canonical word order. By contrast, accusative marked arguments never outrank nominative marked arguments in transitive relations. Rather, all accusative-initial sentences are derived word orders (Fanselow, 2000; Wunderlich, 1997).

Table 1.1 Canonical word orders in German (cf. Fanselow, 2000).

canonical word orders	examples
(a) nominative-accusative	... dass der Junge den Hund sieht.
	... that [the boy]$_{NOM}$ sees [the dog]$_{ACC}$
(b) nominative-dative	... dass der Junge dem Hund folgt.
	... that [the boy]$_{NOM}$ follows [the dog]$_{DAT}$
(c) dative-nominative	... dass dem Jungen der Hund gefällt.
	... that [to the boy]$_{DAT}$ [the dog]$_{NOM}$ appeals
	'... that the dog appeals to the boy'

1.2.3 The Special Status of the Dative

Dative case has a special status in German, which fundamentally distinguishes it from accusative. As was already mentioned, only dative marked objects can precede the nominative in basic word order (cf. Table 1.1). In addition to this, there are several more differences. First, in transitive relations, dative marked objects are never as 'Patient-like' as accusative marked objects are. Consider (1.6) and (1.7) as examples. Whereas the accusative marked object in (1.6) passively undergoes the action, the dative marked object in (1.7) contributes in some way to the whole event, a phenomenon also known as co-agentivity (Wegener, 1985).

(1.6) Ich berühre dich.
[I]$_{NOM}$ touch [you]$_{ACC}$

(1.7) Ich helfe dir.
[I]$_{NOM}$ help [you]$_{DAT}$

Second, in ditransitive structures, there is always a clear thematic rule that decides which argument is marked by which case. For instance, in (1.8a) the object which is manipulated without having any control over the action ('the dog') is case marked by accusative. In contrast, the object which benefits from the action

('you') is case marked by dative. The dative marked object actively participates in the action and is thus thematically higher ranked than the accusative marked object (cf. (1.8b)). In terms of generalized thematic roles [to you]$_{DAT}$ is the Proto-Recipient, which is ranked higher than the Proto-Patient [the dog]$_{ACC}$. Hence, in a thematic sense, dative marked arguments occupy a medial position between nominative and accusative marked arguments (cf. Primus, 1999).

(1.8) a) Ich schenke dir den Hund.
[I]$_{NOM}$ give [to you]$_{DAT}$ [the dog]$_{ACC}$
'I give the dog to you.'

b) ich$_{NOM}$ >$_{them}$ dir$_{DAT}$ >$_{them}$ den Hund$_{ACC}$

Third, in transitive relations, dative marked objects may either have the thematic status of Proto-Patient as in (1.9), or of Proto-Agent, as in object-experiencer constructions like (1.10). Thus, the dative has a somehow twofold nature. Moreover, if the dative marked argument is the thematically higher ranked one, this results in an unmarked object-initial word order (cf. (1.10)).

(1.9) Der Junge dankt dem Bruder.
[the boy]$_{NOM}$ thanks [the brother]$_{DAT}$
boy >$_{them}$ brother

(1.10) Dem Jungen gefällt der Hund.
[to the boy]$_{DAT}$ appeals [the dog]$_{NOM}$
boy >$_{them}$ dog

Accusative marked arguments, in contrast, can almost never be thematically higher ranked than nominative-marked arguments. One exception is, for instance, the verb 'interessieren' (to intrigue so.) which is a 'real' accusative object-experiencer verb. In all other accusative object-experiencer constructions it is possible to ascribe Actor attributes to the nominative argument and to derive a causative meaning, for instance in 'Der Hund ängstigt mich' (the dog scares me) (e.g. Fanselow, 2000; for experimental evidence see Bornkessel, 2002; Scheepers, Hemforth, & Konieczny, 2000). In addition, real object-experiencer verbs cannot

be passivized ('Mir wurde gefallen' (I was appealed to) is ungrammatical), but accusative object-experiencer verbs can ('Ich wurde geängstigt' (I was frightened) is grammatical). The same is true for nominalization ('die Gefallung' (the appealing) is ungrammatical, but 'die Ängstigung' (the frightening) is grammatical) (Jackendoff, 1972).

In other words, the dative is able to mark both 'ends' of the thematic hierarchy: it may case mark the higher or the lower ranked argument. As a consequence, the nominative is forced to mark both ends, too (cf. (1.9), (1.10)). By contrast, accusative can only mark the lower end of the thematic hierarchy. A word order where an accusative marked object precedes a nominative marked one is always a non-canonical, marked order (see below).

Finally, datives behave differently to accusatives from a syntactic perspective. Under passivization dative 'survives' (cf. (1.11)) (Haegemann, 1994). Accusative, in contrast, is replaced by nominative (cf. (1.12)). Hence, the differences between passive structures with dative and accusative overtly demonstrate that the two cases have fundamentally different characteristics. Only with dative marked objects an overt morphological reflection of their thematic properties is preserved in passive sentences.

(1.11) Ich danke den Männern. – Den Männern wurde gedankt.
I thank [the men]$_{DAT}$ – [the men]$_{DAT}$ was thanked

(1.12) Ich sehe die Männer. – Die Männer wurden gesehen.
I see [the men]$_{ACC}$ – [the men]$_{NOM}$ were seen

Many accounts have attempted to offer explanations for the differences between dative and accusative verbs. One line of theories states that accusative is a 'structural case', which is assigned to the argument due to its syntactic position. As such, accusative is the default case. Dative on the other hand is a 'lexical' or 'inherent case', which is only assigned on the basis of the verb's lexical entry (cf. Haegemann, 1994). This distinction aims to account for the verb type difference in passivization. Dative survives passivization because it is lexically assigned. Accusative does not survive because passivized verbs cannot assign structural case, and the argument has to be moved into a position where nominative case can be (structurally) assigned.

Another line of theories considers dative verbs as intransitive. This assumption is found both in traditional Germanic linguistics (Helbig & Buscha, 1996; Helbig & Schenkel, 1991) as well as in recent theories (Van Valin & La Polla, 1997). The definition given by Helbig and Buscha (1996) states that only verbs assigning accusative are transitive verbs. All verbs that do not assign accusative (i.e. also all dative verbs) are intransitive. Thus, accusative verbs form a transitive class, and dative verbs form an intransitive class.

The theory of Van Valin and La Polla (1997) employs the notion of 'semantic macroroles'. Similar to the generalized thematic roles proposed by Primus (1999), semantic macroroles are a further abstraction of classical thematic roles. Crucially, Van Valin and La Polla only assume two macroroles, namely 'Actor' and 'Undergoer'. 'Actor and Undergoer are generalized semantic roles whose prototypes are the thematic relations AGENT and PATIENT' (Van Valin & La Polla, 1997:143). Transitive verbs assign two macroroles, namely Actor and Undergoer. In the unmarked case, Actor is assigned to the highest-ranking argument, and Undergoer is assigned to the lowest-ranking argument. In contrast, intransitive verbs only assign one macrorole, namely either Actor ('Laura dances') or Undergoer ('Laura suffers').

Within this account, the difference between accusative and dative verbs is explained in the following way. Accusative verbs have two macroroles. Nominative is assigned to the highest-ranking macrorole argument (Actor), and the other macrorole argument is assigned accusative ('$\text{Ich}_{\text{Actor}}$ sehe $\text{dich}_{\text{Undergoer}}$'; I see you). By contrast, dative verbs have only one macrorole. Nominative is assigned to the highest (only) macrorole argument, and the non-macrorole argument is assigned dative. Hence, German accusative verbs always assign two macroroles and are transitive. In contrast, dative verbs assign only one macrorole, and are thus intransitive.

Which of the two macroroles is assigned distinguishes dative active from dative object-experiencer verbs. A dative active verb assigns Actor to its subject, and no macrorole to its object ('$\text{Ich}_{\text{Actor}}$ danke dir'; I thank you). An object-experiencer verb assigns Undergoer to its subject, and no macrorole to its object ('$\text{Du}_{\text{Undergoer}}$ gefällst mir'; you appeal to me). Crucially, the assignment of Undergoer to the nominative argument is only possible, if no further macrorole (Actor) is present.

In addition, the macrorole account can explain the verb type related differences in passivization. The account states that only an argument with the Undergoer role can act as the nominative marked subject in passive constructions. This applies only to accusative verbs. By contrast, with dative active verbs the object does not bear the Undergoer role and thus does not fulfil the precondition. Hence, it remains case marked by dative. With dative object-experiencer verbs, no passivization is possible at all, as the Undergoer is linked to the subject function in active sentences.

Taken together, dative and accusative verbs differ in a number of thematic and syntactic aspects. They can be accounted for within several theoretical frames. Especially the macrorole theory developed by Van Valin and La Polla (1997) offers a distinction between accusative and dative verbs, and it can account for the distinction of active and object-experiencer verbs.

In sum, the arguments of a sentence are thematically hierarchized in order to express the relationship of the participants of an event. Such a basic ranking can be realized by means of case or by means of word order (although their functions are slightly different, cf. Primus, 1999), and is independent of specific lexical verb information. In addition, the two object cases of German (dative and accusative) differ from each other in several thematic and syntactic aspects.

Concerning the use of case and word order in sentence processing, recent experimental evidence led to a refined model on sentence processing. The following chapters will provide an overview of the method used (Chapter 2), previous experiments focusing on the processing of arguments, and the derived model (Chapter 3). Moreover, the role of case and word order in language acquisition during the development towards the adult sentence processing system will be described (Chapter 4).

Chapter 2
Neurophysiology of Language

In order to understand a sentence, the brain has to perform a number of processes to analyze the speech stream. Parts of these neural processes can be measured on the surface of the scalp as an electroencephalogram. The subsequent computation of so-called event related brain potentials provides an insight into language comprehension processes in real-time. The following chapter describes the methodology of event related brain potentials, and their significance in language processing research in adults and children.

2.1 Basics

2.1.1 The Electroencephalogram (EEG)

The first human electroencephalogram (EEG) was reported by Berger (1929). Initially, this method primarily served clinical diagnosis. During the last decades, the EEG has become increasingly important in cognitive brain research, because it can track the temporal characteristics of cognitive processes.

The EEG measures electrical brain activity by means of electrodes that are attached to the scalp. The activity of scalp electrodes is calculated relative to a given reference site where virtually no cortical activity is measured, for instance at the mastoids. The measurable current stems mainly from pyramidal cells of the neocortex. When excited, each pyramidal cell forms a dipole with the soma positive and the dendrites negative. This causes an extracellular flow of electric current between the apical dendrites and the soma. Due to their systematic vertical orientation towards the cortical surface, the cells produce an open field, such that the electrical potential can be recorded on the surface of the scalp. However, it takes a large population of neurons (10^3-10^4) to be synchronously active in order to produce measurable electrical potentials by means of EEG.

2.1.2 The Event Related Brain Potential (ERP)

Event related brain potentials (ERPs) are voltage changes in the EEG that are time-locked to a given stimulus (cf. Figure 2.1). ERPs are relatively small changes of maximally 10 microvolt (μV). They are superposed by much stronger voltage changes of the ongoing EEG at the size of 50 to 100 μV. In order to extract the ERP signal out of the noise of the spontaneous EEG, many stimuli of each respective type are presented. Afterwards, the EEG is averaged over all occurrences of one stimulus type at the time point of stimulus presentation. By means of averaging, incidental voltage changes that are not related to the presentation of the stimulus are eliminated. In order to diminish interindividual differences and to further enhance the signal-to-noise ratio, grand-averages are calculated over a group of participants (see Birbaumer & Schmidt, 1991; Kutas & Van Petten, 1994; Frisch, 2000).

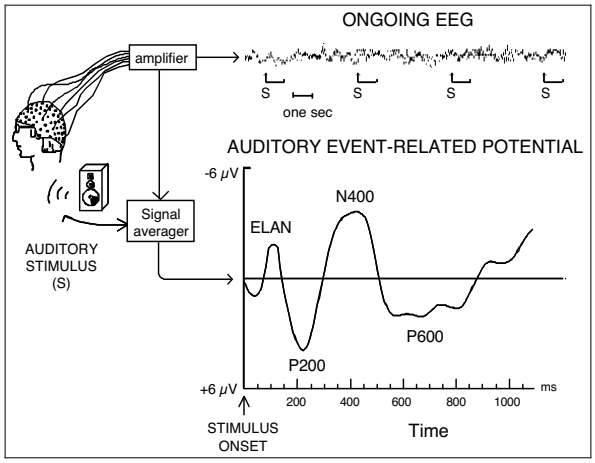

Figure 2.1 Measurement and computation of event related brain potentials (ERPs); schematic illustration, adapted after Coles and Rugg (1995).

ERPs have been successfully applied in language processing research. There are several advantages of this method in assessing questions of on-line sentence processing. First of all, the EEG is recorded continuously – during the presentation of a sentence for instance. Hence, ERPs can be calculated at any point of interest, covering the time point of a specific word's onset and the subsequent time range of its processing. Due to the high temporal resolution in the millisecond range and the close time locking to stimulus presentation, the EEG regis-

ters immediate changes in neural activity. Thus, it is able to track fast cognitive processes like language processing on-line.

ERPs can reveal the degree of difficulty in processing language stimuli of different experimental conditions. In addition, the specific characteristics of the ERP provide insight into the underlying processes involved. For instance, on the basis of the temporal ERP characteristics specific conclusions can be drawn about the detailed time course of processing different types of linguistic information. A further advantage of the EEG method is that no overt behavioral action of the participant is necessary, as brain activity is measured directly. Finally, due to its easy application this method is also well suited for testing children.

2.1.3 ERP Components

The course of an ERP curve is characterized by positive and negative deflections. These deflections are classified as components, which are defined by four parameters, namely polarity, latency, topography, and experimental manipulation (Donchin, Ritter, & McCallum, 1978). *Polarity* defines the orientation of a component. This is either positive or negative relative to a different experimental condition. *Latency* describes the temporal characteristics of a component. They comprise its onset, its duration, and the time point of its maximal amplitude (peak) relative to stimulus onset. *Topography* describes the spatial distribution of a component over the scalp. Finally, the *experimental manipulation* that influences the behavior of a component provides information about the mental function to which the component is related.

ERP components are usually named with respect to their polarity and time point of maximal amplitude. For instance, a negativity with a peak after 400 milliseconds (ms) is referred to as 'N400'. Some components are labeled after their topographical properties, as the 'Left Anterior Negativity', or with respect to the experimental manipulation to which they are related, like the 'Mismatch Negativity'.

2.2 Language-Related ERP Components

Over the past 20 years, ERPs have been successfully applied in language processing research. Several components specifically related to language processing have been identified. Below, the most robust language-related components will be introduced.

2.2.1 Left Anterior Negativities

ELAN (Early Left Anterior Negativity)

The earliest component related to sentence processing is the Early Left Anterior Negativity (ELAN), which is observable between approx. 150 and 300 ms after stimulus onset. It is a negative deflection, primarily occurring over left anterior electrode sites, which is usually followed by a later positivity (P600) (for an overview see Hahne & Friederici, 2002).

The ELAN was first reported by Neville, Nicol, Barss, Forster, and Garrett (1991) as a reaction to a word category violation in sentences such as (2.1a) in comparison to correct sentence structures such as (2.1b) (the star indicates the ungrammaticality of the structure, the word at which the effect is measurable is underlined). Subsequently, the ELAN could be replicated in a number of studies (e.g. Friederici, Pfeifer, & Hahne, 1993; Friederici, Hahne, & Mecklinger, 1996; Friederici, Steinhauer, & Frisch, 1999).

(2.1) a) *The scientist criticized Max's <u>of</u> proof the theorem.
b) The scientist criticized Max's proof <u>of</u> the theorem.

An ELAN effect was also elicited in ungrammatical sentences in which all content words were replaced by pronounceable pseudowords (Hahne & Jescheniak, 2001). In sum, the ELAN has been interpreted as a language specific component that reflects very early and highly automatic processes of word category identification (e.g. Friederici, 2002).

LAN (Left Anterior Negativity)

The second language related anterior negativity is the Left Anterior Negativity (LAN). It is a negative deflection with a fronto-central or frontal maximum, primarily over left electrode sites. The LAN emerges between 300 and 500 ms post-stimulus, and is usually followed by a later positivity (P600) (for an overview see Gunter, Friederici, & Schriefers, 2000; Friederici, 2002).

The LAN has mostly been reported following morphosyntactic violations, for example with violations of subject verb agreement (Osterhout & Mobley, 1995), case violations (Coulson, King, & Kutas, 1998), verb tense violations (Osterhout & Nicol, 1999), or gender violations (Gunter et al., 2000).

2.2.2 N400

The N400 is a component primarily associated with semantic processing. It is a negative deflection extending from 300 to 600 ms after stimulus onset, with a maximal peak at about 400 ms. In visual presentation, it generally has a broad distribution with a centro-parietal maximum. In auditory presentation the center of activation may shift towards more frontal electrode sites (for an overview see Kutas & Van Petten, 1994; Kutas & Federmeier, 2000). Moreover, the latency of auditorily elicited N400s varies as a function of the point of uniqueness at which a word can be unambiguously identified (Van Petten, Coulson, Rubin, Plante, & Parks, 1999; O'Rourke & Holcomb, 2002).

The N400 was first reported by Kutas and Hillyard (1980). They presented sentences ending in a semantically incongruous word such as in (2.2c) and compared them to semantically congruous words as in (2.2a). In comparison to congruous words, semantically incongruous words elicited an increased negativity. Subsequent research has shown that the N400 is tied more to semantic expectancy than to anomaly. The amplitude of the N400 proved to be inversely related to the predictability of a word in a given context. The better the fit between a word and its context, the smaller the amplitude of the N400.

(2.2) a) She called her husband at his office.
b) Captain Sheir wanted to stay with the sinking raft.
c) George was fired but he couldn't tell his fog.

Thus, the smallest N400 amplitude is elicited by words which are expected and supported by the preceding context, such as in (2.2a). Unexpected words, such as the final word in (2.2b) elicit a slightly larger N400 component. The largest N400 is elicited by words that are completely unexpected and do not fit into the given context at all (2.2c) (Kutas, Lindamood, & Hillyard, 1984; Holcomb & Neville, 1991). Most researchers agree that the N400 is bound to the semantic processing of a stimulus and thereby reflects lexical integration processes (Chwilla, Brown, & Hagoort, 1995; Bentin, Kutas, & Hillyard, 1993). During these processes, the meaning of a word or concept has to be integrated into the overall meaning representation of the preceding language input. The easier it can be integrated, the smaller the amplitude of the N400 (Hagoort, Brown, & Osterhout, 1999; Hahne & Friederici, 2002).

In addition to numerous studies reporting the N400 as a reflection of semantic or lexical processes, the N400 has also been reported as a reflection of reanalysis processes. Bornkessel, McElree, Schlesewsky, and Friederici (2004) reported an N400 for the dispreferred disambiguation towards a dative-initial reading. Thus, the N400 reflected a reanalysis of grammatical relations towards the dispreferred object-initial sentence structure (cf. Chapter 3). Moreover, an N400 was also reported for incorrect sentences with negative polarity items, such as '*An applicant who no member praised was ever admitted to the club' (Saddy, Drenhaus, & Frisch, 2004). Hence, the N400 is supposedly not only sensitive to lexico-semantic aspects of processing, but also to the analysis of certain grammatical relations.

2.2.3 P600

The P600 or Syntactic Positive Shift (SPS) is a component primarily associated with syntactic processing. It was first reported by Osterhout and Holcomb (1992), and by Hagoort, Brown, and Groothusen (1993). The P600 is a positive deflection which starts about 500 ms post-stimulus and lasts several hundred milliseconds. Its topographical maximum is located over parietal or centro-parietal electrode sites for both the visual and the auditory input modality (for an overview see Hagoort et al., 1999; Friederici, 2002).

The P600 component was first reported for locally ambiguous sentence structures such as 'The broker persuaded to sell the stock was sent to jail'. On the word disambiguating the sentence towards its dispreferred reading, the ERP is more positive going than in unambiguous sentences (Osterhout & Holcomb, 1992, 1993).

In the past decade, a large number of studies were conducted reporting a P600 effect for a variety of experimental manipulations. The P600 was elicited by phrase structure violations (Neville et al., 1991), subcategorization violations (Friederici & Frisch, 2000), and violations of subjacency (McKinnon & Osterhout, 1996). In addition, a P600 followed morphological violations, such as those of subject-verb agreement (Coulson et al., 1998), case violations (Frisch & Schlesewsky, 2001), verb tense violations (Gunter, Stowe, & Mulder, 1997), as well as violations of gender and number (Osterhout & Mobley, 1995). In the case of structural violation conditions, the P600 is preceded by an earlier negativity, such as the ELAN or the LAN (see above).

The ERP results of the past decade have led to the conclusion that the P600 reflects processes of structural reanalysis and repair (e.g. Friederici, 2002). The P600 varies in amplitude as a function of the cost of reprocessing (Osterhout, Holcomb, & Swinney, 1994). There are also reports about shifts in latency if the syntactic reanalysis is relatively easy ('P345'; cf. Chapter 3) (Mecklinger, Schriefers, Steinhauer, & Friederici, 1995). More generally speaking, the P600 may be regarded as a marker of syntactic integration difficulty (Kaan, Harris, Gibson, & Holcomb, 2000). This is further supported by experiments reporting a P600 on syntactically ambiguous items themselves (Frisch, Schlesewsky, Saddy, & Alpermann, 2002), and by a P600 elicited in sentences with a relatively high degree of syntactic complexity (Friederici, Hahne, & Saddy, 2002).

2.3 Developmental Aspects

2.3.1 Brain Development

During infancy and extending into late childhood, the neural structure of the brain undergoes important changes. These changes affect neurons, neural axons, dendrites, and synapses and comprise both growth as well as loss of nerval tissue (Neville & Bavelier, 2000; Kolb & Winshaw, 1996). The time period of such neural changes is presumably the time period during which environmental factors can have a major impact on cortical organization. Accordingly, neural changes are associated with so called 'sensitive periods', in which specific learning can optimally take place.

Crucially, brain areas differ with regard to their particular developmental time course. Thus, each area has its specific sensitive periods. Primary cortices develop well before higher association cortices. For example, in the primary visual cortex the adult structure is reached by the age of four, whereas brain development in the middle frontal gyrus takes place until the age of 20 (Huttenlocher & Dabholkar, 1997). The language related regions Broca's and Wernicke's area undergo major developmental changes between 5 and 11 years of age. In a longitudinal magnet resonance imaging (MRI) study Sowell et al. (2004) reported both increase and decrease of cortical thickness in these two areas.

Moreover, language related brain regions, like that of Broca's area were investigated in an anatomical post-mortem study. Amunts, Schleicher, Ditterich, and Zilles (2003) investigated the cytoarchitectonic structure of human brains of

3 months to 85 years of age. In adults, the language related brain regions BA45 and BA44 of Broca's area showed a hemispheric asymmetry, nerval tissue having a higher density in the left hemisphere. Crucially, children reached such an asymmetry at 5 years of age in BA45, but only at 11 years of age in BA44. The latter region has been shown to support syntactic processing, whereas BA45 is more involved in semantic processing, together with BA47 (Friederici, 2002).

Parallel to changes on the neural level, ERP characteristics change during development. Generally, latency and amplitude of ERPs decrease with increasing age. This is true for cognitive components like the N400 and P600 (see below), but also for early sensory components, which are related to the processing of the physical characteristics of a stimulus (e.g. Batty & Taylor, 2002; Onofrj, Thomas, Iacono, D'Andreamatteo, & Paci, 2001).

However, the interpretation of changes in latency and amplitude has remained quite speculative. Small latency changes might be explained by increasing myelination and thereby faster information conduction. Nevertheless, this could only account for changes of a few milliseconds, but not for changes in the 100 ms range (Onofrj et al., 2001). Rather, one might consider an increasing speed of information processing, possibly due to functional changes in the way the brain processes information (Fox, Schmidt, & Henderson, 2000). Similarly, decreasing amplitudes have often been associated with an increasing level of automation in information processing, possibly due to a decreasing number of neurons involved in the respective process (Batty & Taylor, 2002). During the last decades, ERPs have proven to be a valuable tool in investigating children's on-line sentence processing mechanisms. Results of previous studies will be reported in the following.

2.3.2 Left Anterior Negativities

There are only very few studies investigating the development of the anterior negativities LAN and ELAN. The development of the ELAN was investigated in German children. Hahne, Eckstein, and Friederici (2004) auditorily presented sentences including word category violations (cf. (2.3)) to children of 6 to 13 years of age.

(2.3) *Die Gans wurde im gefüttert.
'The goose was in the fed'

In the adult control group, these word category violations elicited an ELAN with a maximum on (left) frontal electrode sites. In children, the youngest group aged 6 showed no negativity at all. A negativity in the violation condition was first observable in 7-year-old children. With increasing age, it became more and more focused to frontal electrodes and gradually reduced in latency, demonstrating ELAN-like characteristics only at 13 years of age.

The development of the LAN was investigated by Lück, Hahne, and Clahsen (2001). They presented correct and incorrect German plural nouns auditorily in a sentence context to children of 6 to 12 years years of age, as exemplified in (2.4).

(2.4) Die meisten Jacken haben die praktischen Kapuzen/*Kapuzes
gegen den Regen.
'Most coats have handy hoods against the rain'

In the adult control group, incorrect plural nouns elicited a LAN with a maximum on left frontal electrodes. In children, a LAN-like negativity only slowly assumed shape. The youngest children with a mean age of 7 years and 1 month (7;1) showed a broadly distributed negativity for the incorrect condition. With 8;6 years, the negativity was reduced to frontal electrodes. Finally, with 11;6 years of age, the negativity selectively emerged over fronto-lateral electrode sites, resembling the adult LAN, albeit with a bilateral distribution.

Changes in these early language related components have been interpreted as a sign of ongoing development of the underlying processes of language comprehension. The late occurrence especially of the ELAN component suggests that the automatic structure building processes associated with it are neurally established at a quite late point in time, compared to language production abilities (Hahne et al., 2004). Interestingly, the anatomical study by Amunts et al. (2003) also suggested that syntactic processing mechanisms are fully developed at a later age than semantic processing mechanisms. As mentioned above, Amunts et al. reported that syntax related brain areas (BA44) reach a hemispheric asymmetry much later than areas related to semantic processing (BA45).

2.3.3 N400

The N400 effect seems already to be present in infants. The 'youngest' N400-like response was reported by Friedrich and Friederici (2004). Infants aged 1;7 showed more negative going ERPs for words that did not match simultaneously displayed pictures than for semantically matching stimuli.

The development of the N400 was investigated in detail by Holcomb, Coffey, and Neville (1992). They presented sentences with and without semantic violations auditorily (cf. (2.5)).

(2.5) Mother wears a ring on her finger/*school.

The participants' age ranged from 5 to 26. Semantic violations elicited an N400 effect in all age groups. With increasing age, the onset of the N400 decreased linearly from age 5 to 16, until reaching a steady level. Hemispherical asymmetries increased with age, with the N400 getting stronger over the right hemisphere. The component's distribution changed from a posterior-parietal to a more frontal maximum. Hahne et al. (2004) investigated auditory semantic processing in 6- to 13-year-old German children with sentences like (2.6).

(2.6) Die Gans/*Burg wurde gefüttert.
'The goose/*castle was fed'

The semantic violation elicited an N400 on the incorrect final verb in all age groups. Similar to Holcomb et al. (1992), the onset of the N400 decreased with increasing age. Increased N400 latencies in children have been reported for a variety of languages and stimuli, in visual and auditory modality (e.g. Juottonen, Revonsuo, & Lang, 1996; Neville, Coffey, Holcomb, & Tallal, 1993; Coch & Holcomb, 2003; Bonte & Blomert, 2004). Longer latencies of the N400 in children have been interpreted as a sign of slower information processing or a lower level of automation (Hahne et al., 2004; Juottonen et al., 1996).

With respect to the development of the N400 amplitude, Holcomb et al. (1992) reported a decrease of the N400 effect with increasing age. The authors suggested that the decrease in amplitude reflects a decreasing use of contextual information. The more skilled a language user gets, the less he is dependent on sentence context information. Thus, the increased N400 effect in children is the

result of the increased difficulty to integrate a word if it is not contextually supported.

By contrast, Hahne et al. (2004) reported only a very small N400 difference between semantically correct and incorrect conditions for the youngest age group. The older the children, the larger the N400 difference became. However, this initially small N400 effect was a result of the large N400 amplitude in the correct condition, which in turn decreased with increasing age. Hahne et al. suggested that the enhanced N400 amplitude in the correct condition reflects enhanced efforts to interpret even the correct sentences.

Up to now, the N400 component has only been investigated in connection with semantic processing. By contrast, no experiments have been conducted that investigated the development of a syntax related N400.

2.3.4 P600

The development of the P600 component was also investigated by Hahne et al. (2004). They presented sentences like (2.3) auditorily to children aged 6 to 13. In addition to the ELAN component, word category violations also elicited a late positivity (P600). In children, this positivity was already observable in the youngest group aged 6, although with a delayed onset. Again, the onset decreased with increasing age.

However, the amplitude of the P600 effect seemed to increase with age. The smaller P600 in the young children was due to a large positive going wave for the correct sentences. Kaan et al. (2000) ascribed the P600 to the difficulty of syntactic integration. Thus, young children may have high syntactic processing costs even for syntactically correct sentences. Interestingly, a similar pattern emerged for second language learners (Hahne & Friederici, 2001).

In sum, changes in neural structure take place well into the teenage years. Some language related components like the N400 or P600 are already observable in 5- to 6-year-old children. The early negativities ELAN and LAN emerge only at about 7 years of age. At first, they appear as broadly distributed negativities. During the following 4 or 5 years, they slowly converge on adult temporal and topographical characteristics. As for almost all ERP components, onset, latency, and amplitude of the language-related components decrease with increasing age. This is presumably due to functional changes in information processing, accompanied by an increasing level of automation.

Taken together, event related brain potentials are a valuable tool in language processing research. In particular, the high temporal resolution provides the opportunity to investigate sentence processing mechanisms 'on-line'. Moreover, ERPs revealed new insights into the development of language processing routines, that would be difficult to obtain with behavioral paradigms. The specific use of ERPs in the domain of argument processing and how ERP data formed the basis of sentence processing models will be introduced in the following chapter.

Chapter 3
Sentence Comprehension in Adults

Before turning to the acquisitional aspects and the development of sentence processing in children, evidence from adults will be reported first. Data on adults' sentence comprehension provide the necessary basis for the investigation of language acquisition. In the following sections, ERP data on the on-line processing of morphological case and word order will be described. The chapter closes with the presentation of two sentence processing models.

3.1 Case and Thematic Interpretation

In German, case has a twofold nature. First, it has formal syntactic properties. For instance, only nominative marked arguments trigger number agreement with the verb, irrespective of word order and thematic structure. Second, case has interpretive properties. As discussed in Chapter 1, both morphological cases and generalized semantic roles can be ranked in a hierarchy (Van Valin & La Polla, 1997; Kibrik, 1997; Primus, 1999). These hierarchies are in most cases parallelly ordered. Thus, a nominative marked argument of a given sentence will in most cases be thematically ranked in a high position. By contrast, an accusative marked argument will always be thematically ranked in a low position. Consequently, case markings can provide initial information about the thematic ranking of the arguments, even before the verb is encountered.

The role of case information in sentence processing was investigated by means of sentence structures which engender a higher degree of processing load, for example in sentences containing violations and in structures requiring reanalysis. For instance, the interrelation of case and thematic interpretation was investigated by Frisch and Schlesewsky (2001; submitted; Frisch, 2000). Besides correct sentences (cf. (3.1a)), they presented sentences in which both arguments were marked with identical case markings, namely nominative (cf. (3.1b)), accusative, or dative.

(3.1) a) Paul fragt sich, welcher Angler den Jäger gelobt hat.
Paul asks himself [which angler]$_{NOM}$ [the hunter]$_{ACC}$ commended has

b) *Paul fragt sich, welcher Angler der Jäger gelobt hat.
Paul asks himself [which angler]$_{NOM}$ [the hunter]$_{NOM}$ commended has

According to the assumption of case and role hierarchies, the nominative marked first nominal phrase (NP) in (3.1a) ('welcher Angler') would be ranked higher than the accusative case marked second NP ('den Jäger') in a case hierarchy. Parallelly, the 'angler' would be ranked higher than the 'hunter' in a thematic hierarchy. In contrast, in (3.1b), both the first and the second NP are case marked with nominative. Thus, in this case, a thematic ranking on the basis of case information is not possible, as both compete for the identical hierarchical position. This problem of thematic hierarchizing due to double case violations was reflected in an N400 followed by a P600. The N400 finding fits well with the usual connection of this component to semantic integration difficulties. The subsequent P600 might reflect additional later repair processes, or the 'syntactic aspect' of the violation.

However, if other information is available to the parser that might help to thematically hierarchize the arguments, a different ERP pattern emerges. One such type of information is that of animacy, which plays an important role in determining the agent of an action (MacWhinney, Bates, & Kliegl, 1984). Frisch and Schlesewsky (2001) presented both animate and inanimate arguments, as exemplified in (3.2).

(3.2) *Paul fragt sich, welcher Förster der Zweig gestreift hat.
Paul asked himself [which forester]$_{NOM,animate}$ [the twig]$_{NOM,inanimate}$ touched has

Again, both arguments of the subordinate clause are case marked with nominative. While one of the arguments is animate ('forester'), the other one is inanimate ('twig'). In this case, the double case violation elicited only a P600, but no N400. This result suggested that the factor animacy sufficed to resolve the thematic hierarchy problem, with the animate argument ranked higher than the inanimate. Nevertheless, there remains the formal problem of two consecutive nominative case markings. Both arguments compete for the single structural subject position.

This syntactic processing problem is reflected in the P600. Crucially, the range of helpful non-morphological information is restricted. For instance, general knowledge or context information does not lead to the establishment of a thematic hierarchy (Bornkessel, 2002).

In order to further investigate the process of thematic hierarchizing, Bornkessel, Schlesewsky, and Friederici (2002; 2003) took advantage of the difference between active and object-experiencer verbs. One vital characteristic of dative object-experiencer verbs is their unusual case assignment. Thus, the argument being higher ranked in the thematic hierarchy exceptionally receives dative case. By contrast, with canonical active verbs the higher ranked argument also receives the highest-ranking case, the nominative.

(3.3) Maria glaubt, dass der Priester dem Gärtner folgt.
Maria believes that [the priest]$_{NOM}$ [the gardener]$_{DAT}$ follows.
'Maria believes that the priest is following the gardener.'

(3.4) Maria glaubt, dass der Priester dem Gärtner auffällt.
Maria believes that [the priest]$_{NOM}$ [the gardener]$_{DAT}$ notices.
'Maria believes that the gardener notices the priest.'

Bornkessel et al. (2002; 2003) presented sentences in which the arguments were unambiguously case marked with nominative and dative. The sentence final verb was either a canonical active verb (cf. (3.3)) or a non-canonical object-experiencer verb (cf. (3.4)). As described above, the parser uses the morphological case information of the arguments to rank them thematically. Thus, the nominative marked 'priest' will be ranked higher than the dative marked 'gardener' (cf. (3.5)). If the sentence ends in an active verb ('folgt'), this ranking can be confirmed on the verb by its specific properties (cf. (3.6a)). However, if the parser arrives at an object-experiencer verb ('auffällt'), the verb specific information does not match with the previously established hierarchy. In this case, the hierarchy has to be rearranged, such that the dative marked argument is ranked higher than the nominative marked argument (cf. (3.6b)). In the ERP, this re-ranking was reflected in an early parietal positivity between 300 and 600 ms.

(3.5) der Priester dem Gärtner (...)
[the priest]$_{NOM}$ >$_{them}$ [the gardener]$_{DAT}$

(3.6) a) der Priester dem Gärtner folgt
[the priest]$_{NOM}$ >$_{them}$ [the gardener]$_{DAT}$

b) der Priester dem Gärtner auffällt
[the priest]$_{NOM}$ **<$_{them}$** [the gardener]$_{DAT}$

Crucially, the parser accomplishes the thematic ranking solely on the basis of the arguments' case markings (provided that the degree of animacy is held equal). The thematic hierarchizing took place independently of the arguments' word order. Thus, the thematic reanalysis effect on object-experiencer verbs was equally visible in subject- and object-initial sentences (Bornkessel et al., 2003).

Moreover, in sentences with ambiguous arguments no thematic hierarchy was established before encountering the verb. This was shown in an experiment conducted by Bornkessel et al. (2002), who presented sentences like (3.7) and (3.8).

(3.7) ..., dass Maria Sängerinnen folgt.
... that [Maria]$_{case\ ambiguous\ (AMB)}$ [singers]$_{AMB}$ [follow]$_{SG}$
'... that Maria is following singers'

(3.8) ..., dass Maria Sängerinnen auffällt.
... that [Maria]$_{AMB}$ [singers]$_{AMB}$ [notice]$_{SG}$
'... that singers notice Maria'

Again, the sentence final verb was either an active verb (cf. (3.7)) or an object-experiencer verb (cf. (3.8)). However, this time both arguments were completely ambiguous between nominative, dative, and accusative case. In contrast to (3.6b), no ERP effects were elicited on the object-experiencer verbs in (3.8). The absence of any ERP effects suggests that no thematic ranking was established before the verb was encountered. Consequently, no re-ranking had to be performed in the case of object-experiencer verbs. Thus, on the basis of the relative ordering of the arguments, no thematic hierarchy was established.

In contrast to German, there are languages without overt morphological case markings. In English, for instance, case is only very rarely overtly marked, namely on pronouns. Here, case is a direct reflection of the respective syntactic position. Hence, there is only one syntactic position for the subject, which is always assigned nominative case. Accordingly, there is only one syntactic position for the direct object, which is always assigned accusative case. As case is always bound to a specific syntactic position, it does not determine the thematic interpretation to the extent it does in German. Consequently, case violations in English reflect a syntactic problem rather than a thematic one. Coulson et al. (1998) presented sentences like *'The plane took we to paradise'. In comparison to correct sentences ('The plane took us to paradise') they found a LAN, followed by a P600 on the nominative marked pronoun 'we'. The LAN reflected the mismatch between a case and a structural position. No N400 was elicited, as no thematic processing is connected with the processing of case information in English.

To summarize, in German the parser uses unambiguous case information to establish a thematic hierarchy of the arguments of a sentence, even before the verb is encountered. If the initial ranking based on case information has to be restructured, as in the case of object-experiencer verbs, this is reflected in an early parietal positivity. In the case of two identical case marked arguments, this leads to a problem in thematically hierarchizing the arguments, which is reflected in an N400-P600 pattern.

3.2 The Processing of Word Order Information

The question how the human parser deals with word order information can best be investigated in languages with a free word order. English, for instance, would not be suited as it has a fixed word order, which determines the syntactic functions of the respective noun phrases. German, on the other hand, is a very good candidate, as the order of arguments can be manipulated independently of their syntactic function.

Due to this freedom in arranging the arguments of a sentence, German allows both subject- and object-initial sentences. The arguments of a sentence can be overtly case marked, with subjects receiving nominative and objects receiving accusative or dative case. Thus, a sentence initial object can be immediately identified if it is unambiguously case marked with accusative or dative, as was discussed in the preceding chapter. On the other hand, arguments may also remain case ambiguous, as in example (3.9).

(3.9) a) Welche Frau liebt den Mann?
[which woman]$_{AMB}$ loves [the man]$_{ACC}$

b) Welche Frau liebt der Mann?
[which woman]$_{AMB}$ loves [the man]$_{NOM}$

In (3.9) the first NP is ambiguous between nominative and accusative case. The disambiguation towards a subject- or object-initial reading occurs only on the following NP. If the latter is case marked with accusative, the preceding ambiguous NP must be the subject (cf. (3.9a)). If it is case marked with nominative, the ambiguous NP must be the object of the sentence (cf. (3.9b)). It is a very stable finding that the human parser has a strong preference to analyze initial ambiguous NPs like 'welche Frau' as the subject of a sentence, which leads to reanalysis effects in the case of sentences like (3.9b).

This subject-first preference has been shown in many behavioral studies, employing methods like self-paced reading, eye tracking, grammaticality judgments, or questionnaires. Different German sentence structures were investigated, like declarative sentences (e.g. Hemforth, 1993; Scheepers et al., 2000), wh-structures (Schlesewsky, Fanselow, Kliegl, & Krems, 2000), subordinate clauses (Bader & Meng, 1999), or relative clauses (Schriefers, Friederici, & Kühn, 1995). The subject-first preference persisted even in pseudo-word sentences (Röder et al., 2000).

The processing of word order information soon became the focus of ERP research, investigating the on-line processing mechanisms underlying the reanalysis processes associated with word order preferences. Experiments in this field have primarily been conducted in German. For instance, Mecklinger et al. (1995) presented sentences like (3.10).

(3.10) a) Das ist die Professorin, die$_i$ [t]$_i$ die Studentinnen gesucht hat.
this is the professor [that]$_{AMB}$ [the students]$_{AMB}$ sought [has]$_{singular\ (SG)}$
'This is the professor that has sought the students.'

(3.10) b) Das ist die Professorin, die$_i$ die Studentinnen [t]$_i$ gesucht haben.
this is the professor [that]$_{AMB}$ [the students]$_{AMB}$ sought [have]$_{plural\ (PL)}$
'This is the professor that the students have sought.'

Up to the finite verb, the sentences remained ambiguous between a subject- and an object-initial reading, as both the relative pronoun ('die') and the following NP ('die Studentinnen') were ambiguous between nominative and accusative. According to the subject-first preference the parser assigns nominative to the initial relative pronoun and accusative to the following NP. Thus, on the final auxiliary this analysis is either confirmed (cf. (3.10)) or disconfirmed (cf. (3.10b)). If it is disconfirmed, the parser has to reanalyze the structure towards the object-initial reading. In the ERP, this reanalysis was reflected in an early positivity on the auxiliary in (3.10b), which was labeled 'P345' (Mecklinger et al., 1995).

The P345 was first interpreted as a sign of relatively easy reanalysis compared to other syntactic reanalysis processes, which are usually reflected in a P600 component (Hagoort et al., 1999). In the case of object-initial relative clauses all the parser has to do is re-link the pronominal antecedent with a different trace position [t]. This might not be as costly as a complete reanalysis of the syntactic structure (cf. Friederici & Mecklinger, 1996). Alternatively, the P345 was interpreted as a sign of diagnosing syntactic violations, as opposed to structural reanalysis processes reflected in the P600 (Friederici, 1998; Friederici, Mecklinger, Spencer, Steinhauer, & Donchin, 2001).

Bornkessel et al. (2004) compared the processing of subject- and object-initial word orders employing different verb types, namely accusative and dative verbs. The subordinate sentences they presented were completely case ambiguous on the NPs (cf. (3.11), (3.12)). Both the proper name ('Maria') and the feminine plural NP ('Sängerinnen') were ambiguous between nominative, accusative, and dative case. The number marking of the sentence final verb disambiguated the sentence towards a subject-initial (cf. (3.11), (3.12)) or an object-initial reading (cf. (3.11b), (3.12b)). In addition, the verb either assigned accusative (cf. (3.11)) or dative case (cf. (3.12)).

(3.11) a) ... dass Maria Sängerinnen <u>besucht</u>
... that $[\text{Maria}]_{\text{AMB, SG}}$ $[\text{singers}]_{\text{AMB, PL}}$ $[\text{visits}]_{\text{SG, (ACC)}}$
'... that Maria visits singers'

b) ... dass Maria Sängerinnen <u>besuchen</u>
... that $[\text{Maria}]_{\text{AMB, SG}}$ $[\text{singers}]_{\text{AMB, PL}}$ $[\text{visit}]_{\text{PL, (ACC)}}$
'... that singers visit Maria'

(3.12) a) ... dass Maria Sängerinnen folgt
... that [Maria]$_{AMB, SG}$ [singers]$_{AMB, PL}$ [follows]$_{SG, (DAT)}$
'... that Maria follows singers'

b) ... dass Maria Sängerinnen folgen
... that [Maria]$_{AMB, SG}$ [singers]$_{AMB, PL}$ [follow]$_{PL, (DAT)}$
'... that singers follow Maria'

Interestingly, the disambiguation towards an object-initial word order elicited different ERP components, depending on verb type. With accusative verbs a P600 emerged, as it had in preceding experiments involving subordinate clauses (Friederici et al., 2001). The P600 could easily be interpreted as the reflection of syntactic reanalysis processes. Due to the subject-first preference the parser initially assigns 'subject' to the first argument and 'object' to the following noun. This assignment has to be reversed in the case of (3.11b). With accusative structures, this means that the parser has to restructure the whole syntactic tree. As no object-initial accusative structure can be base generated, the object must have been moved out of its base position. Thus, a new position above the subject has to be assumed for the fronted object, together with a trace filled base position. This syntactic reanalysis is reflected in the P600.

With dative verbs on the other hand, object-initial sentences elicited an N400. Bornkessel et al. (2004) interpreted the emergence of this component, which is usually related to semantic processing, in the following way. In contrast to accusative verbs, there are dative verbs that allow unmarked object-initial sentences, namely dative object-experiencer verbs (cf. Fanselow, 2000). By definition, unmarked word orders are not derived but base generated. Bornkessel et al. assumed that the parser makes use of this unmarked dative-nominative structure, even in the reanalysis of sentences with dative active verbs. In other words, the unmarked dative-nominative structure is 'overgeneralized' to all dative verbs. Thus, no movement and no additional structural positions have to be assumed for dative-initial structures. The reanalysis towards an object-initial reading can be thought of as a simple relabeling of the existing syntactic positions. This relabeling is supposed to be reflected in a reanalysis-N400.

Moreover, the ERP effects of word order differed between two types of dative verbs. Bornkessel et al. (2004) presented active and object-experiencer dative

verbs (cf. (3.12) and (3.13)). For both verb types, object-initial structures elicited a reanalysis-N400, as described above. However, the N400 was weaker in the object-experiencer verbs. Presumably, this reflected an easier reanalysis of object-initial sentences with object-experiencer verbs, as this is the unmarked word order for this verb type. Additionally, for object-experiencer verbs Bornkessel reported a LAN in subject-initial sentences (cf. (3.13)). The LAN probably reflected the mismatch between the syntactic (subject $>_{syn}$ object) and the thematic hierarchy (STIMULUS $<_{them}$ EXPERIENCER). By contrast, no principled mismatch is present in object-initial sentences, as this is the canonical word order for object-experiencer verbs.

(3.13) a) ... dass Maria Sängerinnen auffällt
... that [Maria]$_{AMB, SG}$ [singers]$_{AMB, PL}$ [notice]$_{SG, (DAT)}$
'... that singers notice Maria'

b) ... dass Maria Sängerinnen auffallen
... that [Maria]$_{AMB, SG}$ [singers]$_{AMB, PL}$ [notice]$_{PL, (DAT)}$
'... that Maria notices singers'

Crucially, word order information loses its importance for analysis if the arguments are unambiguously case marked. Bornkessel et al. (2003) presented unambiguous subject- and object-initial sentences like (3.14). Here, the ERPs on the sentence final verb did not differ between the two word orders. Thus, no reanalysis towards an object-initial reading was necessary on the verb in case marked sentences.

(3.14) a) ... dass der Gärtner den Jägern folgt.
... that [the gardener]$_{NOM}$ [the hunters]$_{DAT}$ [follows]$_{SG}$
'... that the gardener follows the hunters'

b) ... dass den Jägern der Gärtner folgt.
... that [the hunters]$_{DAT}$ [the gardener]$_{NOM}$ [follows]$_{SG}$
'... that the gardener follows the hunters'

In sum, the studies discussed above show that the arguments of a sentence are syntactically structured before the verb is encountered. In sentences with case ambiguous arguments, the parser analyzes the first argument as the subject. If the number marking of the sentence final verb disambiguates the sentence towards an object-initial structure, reanalysis has to take place. Reanalysis is associated with different ERP correlates depending on verb type (accusative or dative) and sentence structure (subordinate or relative clause). However, case information overrides word order information. Thus, the syntactic function of the arguments can be derived by the respective case marking, and no reanalysis processes are observable on the final verb.

3.3 Sentence Processing Models

Based on electrophysiological and functional imaging data, Friederici (1995; 1999; 2002) proposed a neurocognitive model of auditory sentence processing. According to the model, sentence processing passes through three distinct phases (after the input was phonologically analyzed) (Figure 3.1).

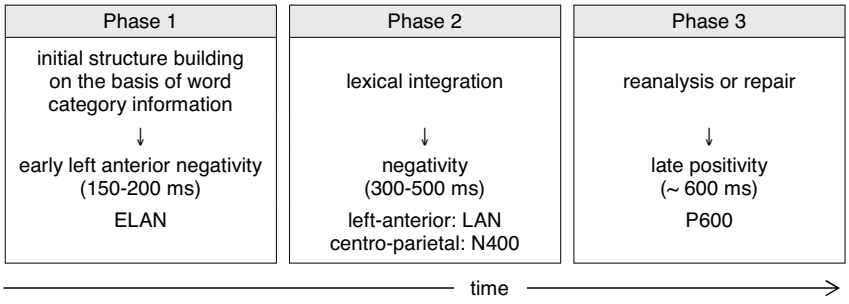

Figure 3.1 A neurocognitive model of sentence comprehension, after Friederici (1999).

Phase 1. During the first phase, the parser evaluates word category information to build an initial syntactic structure. This assumption is based on the ELAN effect, which is elicited by local phrase structure violations induced by word category errors.

Phase 2. In the second phase, lexical integration takes place. On the one hand, lexical-semantic information is processed. This is reflected in the N400 component, which is enhanced if semantic integration is difficult. On the other

hand, morpho-syntactic information is processed. This is reflected in the LAN component, which is enhanced if, for example, agreement errors are encountered.

Phase 3. During the last phase, the semantic and structural representations established in Phase 2 are mapped onto each other. This may require syntactic reanalysis in the case of dispreferred sentence structures, or repair in the case of ungrammatical sentences. Such processes are reflected in the P600 component.

This sentence processing model was extended in the Argument Dependency Model (ADM) (Bornkessel, 2002; Schlesewsky & Bornkessel, 2004; Bornkessel & Schlesewsky, to appear). The focal point of the ADM is the establishment of hierarchical dependencies between the arguments of a sentence. This is achieved during Phase 2 of Friederici's model. Essentially, the ADM assumes a subdivision of Phase 2 into two separate processing pathways for the establishment of hierarchical relations between arguments (Figure 3.2). One pathway establishes dependencies on the basis of morphological information, while the other establishes dependencies on the basis of positional information. Which of the two pathways determines sentence interpretation depends on the morphological case information on the arguments. The abstract representation that is derived via the respective pathway is language specific. In German, the parser applies the following procedure. If no unambiguous case information is available, syntactic dependencies are built on the basis of word order information. If the arguments are unambiguously case marked, thematic dependencies are built on the basis of case information, overriding word order information.

The necessary morphological analysis of the constituents is supposed to take place at the end of Phase 1 of the ADM. The results of the two pathways are integrated at the end of Phase 2. Lexical semantic information or general knowledge cannot influence the syntactic and thematic processing in Phase 2. Finally, a general mapping of all information types takes place in Phase 3. The two pathways of Phase 2 will be further described in the following.

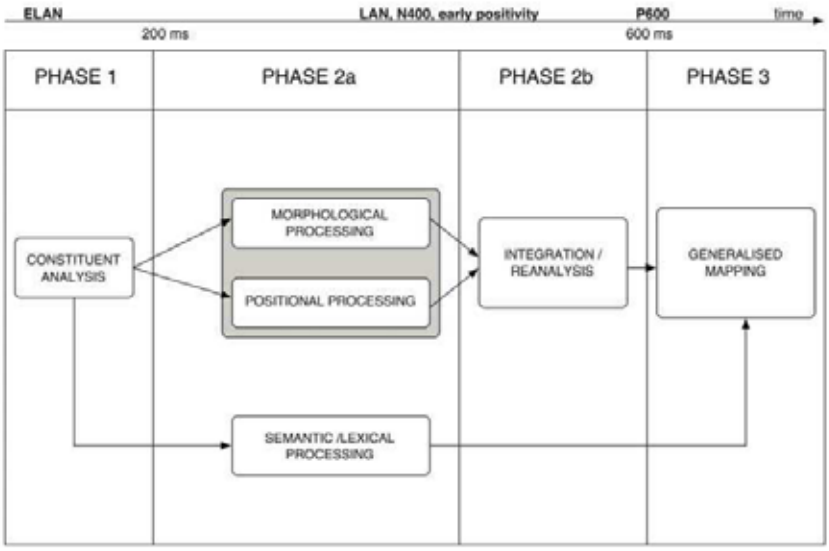

Figure 3.2 Argument Dependency Model (ADM) (Bornkessel & Schlesewsky, to appear).

Morphological Pathway

On the Morphological Pathway, the morphological case information on the arguments is evaluated. In German, morphological case information is used to establish the thematic relationship between the arguments of a sentence. Thus, a thematic hierarchy is built up, which determines the relative thematic ranking of two or more arguments. This is thought of in the sense of generalized thematic roles (Kibrik, 1997; Primus, 1999; Van Valin & La Polla, 1997). For instance, one argument receives the generalized role Proto-Agent and is thus ranked higher than the argument receiving the generalized role Proto-Patient. However, no specific role assignment (like GOAL or EXPERIENCER) takes place yet.

The basis of the thematic ranking is the morphological case marking of the arguments. Thus, an argument unambiguously case marked with nominative will be ranked higher than an argument case marked with accusative or dative. Importantly, this is independent of word order. Evidence in favor of the Morphological Pathway stems from ERP experiments involving active and object-experiencer verbs (Bornkessel et al., 2002; 2003). With active verbs, the thematic ranking that can be established via case markings works well. However, with dative object-experiencer verbs, the ranking has to be reversed. This reversal or reranking of the thematic hierarchy was reflected in an early positivity on sen-

tence final object-experiencer verbs, which was independent of word order. By contrast, no such positivity was observed in sentences with ambiguous arguments.

Positional Pathway

On the Positional Pathway, the sequential ordering of the arguments is evaluated. In German, positional information is used to establish the syntactic relationship between the arguments of a sentence. The Positional Pathway only determines the outcome of relational argument processing in Phase 2 if the arguments of a sentence are case ambiguous. Syntactic dependencies are established on the basis of word order information. Thus, the first ambiguous argument will be assigned the syntactic function 'subject', whereas the second ambiguous argument will be assigned 'object'.

Evidence in favor of the Positional Pathway stems from a number of behavioral studies reporting a strong subject-first preference in the processing of ambiguous arguments (e.g. Schriefers et al., 1995; Bader & Meng, 1999; Schlesewsky et al., 2000). In addition, ERP experiments provided evidence for the exclusive use of the Positional Pathway by ambiguous arguments. As reported above, Bornkessel et al. (2004) investigated the processing of subject- and object-initial sentences. Crucially, the disambiguation towards an object-initial structure was associated with higher processing costs only if the arguments were case ambiguous. This was reflected in an N400 for dative verbs, and in a P600 for accusative verbs. No such word order related effects emerged in the processing of sentences with unambiguously case marked arguments. Hence, only with case ambiguous arguments, word order is used to establish a syntactic representation.

In sum, sentence processing takes place in an incremental manner. Each incoming lexical item is integrated into the structure to the highest possible degree. The way the arguments of a sentence are interpreted depends on the degree of morphological informativeness. If the arguments are case ambiguous, their sequential ordering leads to a syntactic analysis, the first argument being analyzed as the subject of the sentence. However, if the arguments are unambiguously case marked, word order information is overridden. Morphological case information leads to a thematic interpretation of the arguments, such that they are ranked relatively to each other according to the case hierarchy.

Chapter 4
Sentence Comprehension in Children

Given the immense complexity of linguistic knowledge each native speaker has, and given the astonishing speed with which the complex speech signal is accurately processed, the question arises: How do we arrive at such highly specialized and efficient language processing mechanisms? Of particular interest in this thesis is the acquisition of the relationship between morphological case and thematic role information, as well as the role of word order in German sentence processing. In the following, previous behavioral experiments will be presented that investigated how children use case markings and word order in sentence comprehension. Moreover, selected language acquisition accounts on the acquisition and development of sentence processing mechanisms will be introduced.

4.1 Processing of Case Ambiguous Arguments

The role of word order information in children's interpretation of case ambiguous arguments was investigated in a number of studies. One of the first German studies was conducted by Mills (1977). She presented sentences with arguments that were completely ambiguous with regard to case. An example is sentence (4.1), in which both arguments are case ambiguous. Both 'the girl' as well as 'the woman' could possibly be the agents of the action.

(4.1) Das Mädchen trägt die Frau.
[the girl]$_{AMB}$ carries [the woman]$_{AMB}$
'The girl carries the woman' or 'The woman carries the girl'

Fifteen children at the age of 5;11 to 8;11 were asked to act out the experimental sentences by manipulating toys. In 90 % of all cases the children chose the initial argument as the agent of the action, and thus interpreted the ambiguous sentences as subject-initial structures. Hence, they behaved exactly as adults do (e.g. Schlesewsky et al., 2000).

Similarly, Lindner (2003) presented sentences in which the arguments were case ambiguous. In addition to word order, she manipulated the factors 'agreement' and 'animacy'. Thus, one of the two arguments or both were animate, and one of the two arguments or both agreed with the verb. For instance, in (4.2) the first noun is animate, the second noun is inanimate, and both agree with the verb. In (4.3), only the second noun agrees with the verb, and is thus the subject of the sentence.

(4.2) Die Katzen schubsen die Taschen.
[the cats]$_{AMB,PL,animate}$ [push]$_{PL}$ [the bags]$_{AMB,PL,inanimate}$
'The cats push the bags' or 'The bags push the cats'

(4.3) Die Katzen schubst die Ente.
[the cats]$_{AMB,PL,animate}$ [pushes]$_{SG}$ [the duck]$_{AMB,SG,animate}$
'The duck pushes the cats'

Eighty-four children between 2;8 and 9;6 years of age were asked to act out the experimental sentences. Sentence interpretation strategies changed with age. Three-year-old children chose animate arguments as Agents. Four- and five-year-old children primarily chose the initial argument. From the age of 6 on, subject verb agreement became more and more important. Nevertheless, object-initial sentences were still error-prone in 9-year-old children.

In addition to German, there are other languages that allow subject- and object-initial sentences, in which the arguments can be unambiguously case marked or remain ambiguous. This is the case for Polish and Hungarian, where research on children's sentence comprehension revealed a similar picture as in German. In case ambiguous sentences, 2;6- and 3;6-year-old Polish children clearly pursued a subject-first strategy (80 %) (Weist, 1983). In Hungarian children aged 2;0 to 6;0, this strategy was also present, although somewhat weaker (60 %) (MacWhinney, Pleh, & Bates, 1985).

Finally, in languages with a fixed word order and without morphological case marking, word order unsurprisingly strongly determines children's sentence interpretation. For instance, in English and Italian, children consistently relied on a subject-first strategy from the age of 2;6 to 3 onwards (Slobin & Bever, 1982; Bates et al., 1984; Thal & Flores, 2001).

To sum up, in languages with a fixed word order, like English or Italian, children clearly rely on a word order strategy for interpreting a sentence. But also in languages, which allow both subject- and object-initial sentences like German, Polish, or Hungarian, word order seems to be an important cue for the interpretation of a sentence. Preferably, the initial argument is interpreted as the agent of an action, given that no contrary morphological cue is available. Nevertheless, the present behavioral studies leave an important question unanswered: Do children primarily use word order to establish a syntactic representation of the sentence? Or do they immediately use word order to establish a thematic interpretation?

4.2 Processing of Case Marked Arguments

In spontaneous speech production, children start to produce articles at about 2 years of age. Nominative case markings are acquired before accusative and dative case markings. Overgeneralizations may occur, such that nominative is produced in contexts requiring accusative, and accusative is produced in contexts requiring dative. Case marking errors persist at least up to the age of 5 (Clahsen, 1984; Mills, 1985; Clahsen, Eisenbeiss, & Vainikka, 1994; Szagun, 2004). In addition, variable word ordering with the object preceding the subject is closely related to the ability to case mark the arguments (Clahsen, 1984; Meisel, 1986).

But how does morphological case information contribute to children's sentence processing? At what age does object case marking prevent children from analyzing the first argument as the subject of the sentence? Within the past three decades, several studies examined the role of case information in children's sentence interpretation. They investigated the processing of object-initial sentences and the degree to which morphological case marking of the object and/or the subject contributes to the correct understanding of the sentences.

One of the first experiments in this field was again conducted by Mills (1977). She presented subject- and object-initial sentences. In each sentence, either the first (cf. (4.4)) or the second NP (cf. (4.5)) was unambiguously case marked. The remaining NP was always case ambiguous. In a sentence-picture matching task children were asked to point to the picture corresponding to the sentence. In addition to the matching picture, a distractor picture was presented showing the reversed action.

(4.4) Den Hund sieht die Katze.
[the dog]$_{ACC}$ sees [the cat]$_{AMB}$
'The dog sees the cat'

(4.5) Das Mädchen ruft der Mann.
[the girl]$_{AMB}$ calls [the man]$_{NOM}$
'The man calls the girl'

Fifteen children aged 5;11 to 8;11 took part in the experiment. The results showed that children were much more error-prone when object-initial sentences were disambiguated on the final NP (cf. (4.5)). In these sentences, they pointed to the correct picture in 32 % of all cases, which is even below chance level. In contrast, if the accusative marked NP was at the beginning of the sentence (cf. (4.4)), 63 % of all reactions were correct. Thus, the probability of detecting the object-initial word order was higher, the earlier the unambiguous case marking appeared. However, even then performance was by no means perfect. Rather, it seems to be slightly above a chance level decision between the correct and the distractor picture. If the relevant information was presented at the end of the sentence, a general subject-first preference seemed to override case information.

Similar to Mills' study, Schaner-Wolles (1989) conducted a comprehension experiment with object-initial sentences. Either both arguments were unambiguously case marked (cf. (4.6)), or one of them was ambiguous (cf. (4.7), (4.8)). The task consisted in sentence-picture matching. Besides the correct picture, two distractors were presented. One showed the reversed action, and one showed only a single person performing the action.

(4.6) Den Vater fotografiert der Bub.
[the father]$_{ACC}$ takes a picture of [the boy]$_{NOM}$
'The boy takes a picture of the father'

(4.7) Den Vater frisiert das Mädchen.
[the father]$_{ACC}$ does the hair of [the girl]$_{AMB}$
'The girl does the hair of the father'

(4.8) Das Mädchen zwickt der Bub.
[the girl]$_{AMB}$ pinches [the boy]$_{NOM}$
'The boy pinches the girl'

Three age groups participated, comprising 9 children each at the ages of 3, 4, and 5, respectively. The results suggested that the accusative case markings could be used by the 5-year-old children, if the first argument was case marked. The 4-year-olds succeeded if the first and the second NP were case marked (cf. (4.6)). For the 3-year-olds, all conditions led to 50 % incorrect responses. Presumably, this reflected a chance level decision between the correct picture and the one with the reversed action. The most difficult sentences were those in which only the second NP was unambiguously case marked, as in (4.8). In this case, children of all ages performed on chance level. Nevertheless, the presence of an accusative marked argument in a sentence seemed to inhibit the exclusive use of a subject-first strategy. Otherwise higher error rates would have been expected.

In a further experiment, Lindner (2003) investigated the comprehension of subject- and object-initial sentences (cf. (4.9) and (4.10)). The arguments of a sentence were unambiguously case marked. In addition, the arguments were either animate or inanimate, and they did or did not agree with the verb.

(4.9) Der Frosch schubst den Storch.
[the frog]$_{NOM}$ pushes [the stork]$_{ACC}$
'The frog pushes the stork'

(4.10) Den Frosch schubst der Storch.
[the frog]$_{ACC}$ pushes [the stork]$_{NOM}$
'The frog pushes the stork'

Eighty-four children between 2;8 and 9;6 years were asked to act out the sentences. The dependent variable was the choice of the agent. The youngest children chose the agent of a sentence on the basis of animacy information, with animate entities being interpreted as actors. From the age of 4 years on, case information slowly became more and more important, with nominative marked arguments being chosen as actors. Finally, from the age of 6 on, case information in combination with subject-verb agreement information primarily determined sentence interpretation.

As mentioned above, there are further languages, which allow subject- and object-initial sentences and have morphological case markings. The use of morphological case markers in object-initial sentences was, for instance, investigated in Turkish, Serbo-Croatian, Polish, and Hungarian by means of the acting out paradigm. Turkish seems to be the language in which object-initial sentences are correctly understood at the youngest age, namely from 2;0 on (Slobin & Bever, 1982). Crucially, in Turkish sentence initial objects are always unambiguously case marked, as ambiguous NPs can never be moved (Kornfilt, 2003). In languages where also ambiguous arguments can be fronted, correct understanding of object-initial sentences is mastered at a later age. In Polish, children correctly understood object-initial sentences from the age of 2;6 onwards (Weist, 1983), in Hungarian from the age of 3;1 onwards (MacWhinney et al., 1985), and in Serbo-Croatian from 4;2 on (Slobin & Bever, 1982)[2].

To summarize, the ability of German children to use case information in sentence interpretation changes with age. From the age of about 5 or 6 years onwards case information becomes more and more important for determining the agent of an action, although there are still problems. This is concordant with data from Serbo-Croatian children. By contrast, in other languages like Turkish, Polish, or Hungarian, morphological case information is already reliably used at an earlier age.

However, several critical points have to be mentioned with regard to the presented studies on children's sentence comprehension. First, some of them comprised only a small number of participants, and/or a very small number of experimental items per condition (e.g. Mills, 1977; Schaner-Wolles, 1989), which diminishes the generalizability of the results. Second, in the experiments using a sentence-picture matching paradigm it has to be kept in mind that the procedure always offers a certain chance to pick out the right picture. Third, the large age range of some studies does not allow specific conclusions about developmental stages (e.g. Mills, 1977).

[2] Nevertheless, the result of Slobin & Bever (1982) has to be treated with attention. It comprises the understanding of sentences with unambiguously and ambiguously case marked arguments. Presumably, the bad performance of the Serbo-Croatian children was mainly due to object-initial sentences starting with an ambiguous argument, a condition which seems to be mastered only relatively late (Schaner-Wolles, 1989).

Moreover, it has to be pointed out that all the presented studies relied on behavioral paradigms, in which much time elapsed between the presentation of a sentence until the children chose a picture or acted it out with toys. In most cases, the experimental sentences were read out twice or even more times (e.g. Mills, 1977; Schaner-Wolles, 1989; Lindner, 2003). Thus, many cognitive processes comprising initial sentence comprehension, syntactic reanalysis processes, general cognitive and strategic decision processes had time to proceed before the children reacted. Consequently, these off-line measures do not allow a direct deduction of the initial mechanisms uniquely specialized for sentence processing, for they were obscured by a variety of later processes. Moreover, such later processes like conscious decision strategies might even be enhanced in the processing of ungrammatical sentences, like many of those presented by Lindner (2003) (e.g. *'Den Frosch der Klotz schubst' ([the frog]$_{ACC}$ [the block]$_{NOM}$ pushes) or *'Der Storch schubsen die Frösche' ([the stork]$_{NOM,SG}$ push$_{PL}$ [the frogs]$_{AMB,PL}$)).

In addition, the previously used off-line measures could not directly address questions regarding the nature of incremental sentence processing. Thus, nothing can be said about the specific structure which is built up and extended during the course of a sentence. More specifically, one does not know whether the children processed the arguments of a sentence independently of the verb, or whether the lexical information of the verb mainly determined structure building. Moreover, the specific type of abstract structure representation cannot be distinguished, namely whether the initial structure is thematic or syntactic in nature, or whether thematic and syntactic hierarchies are established in parallel.

Finally, in the German experiments, only accusative verbs were used. As laid out in the preceding chapters, sentences where the accusative precedes the nominative marked argument have a marked syntactic structure. At the same time, accusative case indicates that the respective argument has to be ranked low in a thematic hierarchy. Hence, it cannot be decided whether the interpretation of the presented object-initial sentences depended more on the establishment of syntactic or thematic dependencies.

4.3 Language Acquisition: The Theoretical Perspective

The acquisition of sentence processing mechanisms was described within several theoretical accounts. The following section will give a survey of acquisitional

theories that integrated the use of morphological case markings and word order by the language-learning child.

4.3.1 The Competition Model

Originally, the Competition Model was developed as a model of sentence comprehension (Bates & MacWhinney, 1982; MacWhinney et al., 1984). In addition, it also accounts for the development of children's sentence interpretation strategies (Bates et al., 1984). The core assumption of the Competition Model is that the listener uses linguistic cues in a probabilistic manner in order to derive the meaning of a sentence (for a recent overview see Year, 2003).

The probabilistic mechanism within the Competition Model is mainly modelled by the function of 'Cue Validity'. 'Cues' are the different linguistic information types, like morphological case markings, word order, or verb agreement. Each cue maps onto one or several functions, like for example 'object' or 'agent of an action'. The Cue Validity is determined by a combination of 'availability' and 'reliability'. A given cue is most valid if it is always available when the listener is in need of it (availability), and if it is never ambiguous (reliability) (MacWhinney et al., 1984).

For instance, in German, masculine singular nouns are case marked in a way that unambiguously distinguishes nominative from accusative (der_{NOM}/den_{ACC} Mann). According to MacWhinney et al. (1984), masculine nouns are case marked with nominative in about half of all German transitive sentences. Thus, the *availability* of this cue is 50 %. However, the article 'der' itself is ambiguous, as it also marks the feminine dative singular ('der Frau'), the feminine genitive singular ('der Frau'), and the feminine genitive plural ('der Frauen'). On the basis of text counts, the *reliability* of the article 'der' was estimated with about 65 % (MacWhinney et al., 1984).

Word order information on the other hand is always available, as arguments always have to be sequentially ordered. This means a high degree of availability of the cue word order (100 %). However, word order is ambiguous in German. Due to the flexibility in word order, the first argument is not always the subject or the agent of an action. This leads to a low degree of reliability of the cue word order.

In this manner, each possible linguistic cue can be assigned a specific degree of Cue Validity. The higher this degree, the more adults will rely on this cue in

sentence interpretation. However, in the absence of very valid cues, the listener will even attend to less valid cues, if they are the only ones available in the input. Of course, the validity of a specific cue depends on the respective language. In English for instance, overt morphological case markings are rare, such that they have a lower availability than in German. In language acquisition, children will use the most valid cues of their native language first. The lower the validity of a given cue, the later will this cue be used in sentence comprehension.

Concerning morphological case marking and word order, the Competition Model would predict the following for German. In the beginning, children will attend to the cue of word order, as this cue is always present in the input and is thus of high availability. The use of morphological case markings is predicted to be delayed, mainly due to their lower degree of availability. In other languages, for example in Turkish, case markings on definite NPs are of a higher availability and reliability. In particular, only case marked arguments can be moved out of their base position (Kornfilt, 2003). Thus, a reversed hierarchy as in the case of object-initial sentences is always indicated by unambiguous case markings. In consequence, case markings should be acquired at an earlier age in Turkish than in German. The predictions of the Competition Model were confirmed by behavioral experiments on sentence comprehension in different languages (e.g. Mills, 1977; Bates et al., 1984; Lindner, 2003; see above). However, there is no cross-linguistic evidence on children's on-line sentence comprehension mechanisms.

During the further course of development, the child must learn that in German, morphological case marking – albeit sometimes ambiguous – provides a much better cue to the thematic status of the arguments than word order does. Thus, in time a primary advantage of the higher availability of word order should become subordinate to the higher reliability of case markings (cf. MacWhinney, Leinbach, Taraban, & McDonald, 1989). Finally, the child must learn that morphological case cues can be directly mapped onto thematic relations, whereas case ambiguous arguments can only be syntactically analyzed on the basis of their word order (cf. ADM, Chapter 3). Thus, the cue 'der + masculine noun' very reliably maps onto nominative, which in turn reliably maps onto something like a generalized Proto-Agent role (Primus, 1999). By contrast, the cue 'first noun' is very unreliable with regard to thematic values. Thus, ambiguous items will not be analyzed thematically.

4.3.2 The Generalized Hierarchy Approach

The Generalized Hierarchy Approach proposed by Primus and Lindner (1994) serves to explain language specific properties, like word order preferences. In addition, it accounts for the development of children's sentence interpretation strategies. More specifically, the Generalized Hierarchy Approach draws upon three different relations, namely thematic, morphosyntactic case, and grammatical relations.

In any sentence, each argument has to be assigned a specific thematic relation (e.g. AGENT), a specific case relation (e.g. nominative), and a specific grammatical relation (e.g. subject). Crucially, all three types of relations are themselves hierarchically structured, which can be described in the form of a thematic, a case, and a grammatical hierarchy.

First, the thematic hierarchy within the Generalized Hierarchy Approach is similar to the one presented in Section 1.1. However, Primus and Lindner (1994) use the terms of specific thematic roles instead of generalized ones (cf. (4.11)).

(4.11) AGENT/EXPERIENCER $>_{them}$ RECIPIENT $>_{them}$ BENEFACTIVE
$>_{them}$ PATIENT/STIMULUS $>_{them}$ other roles

Second, the hierarchy of morphosyntactic case relations is the same as presented in Chapter 1, and is repeated in (4.12).

(4.12) nominative/absolutive $>_{case}$ accusative/ergative $>_{case}$ dative $>_{case}$ others

Finally, the hierarchy of grammatical relations ranks grammatical functions like subject and direct object in a hierarchical manner (cf. (4.13), whereby 'A $>_{gr}$ B' indicates that 'A is grammatically ranked higher than B').

(4.13) subject $>_{gr}$ direct object $>_{gr}$ indirect object
$>_{gr}$ other oblique arguments/modifiers

The crucial point is that 'there are no one to one relations between two relational concepts belonging to different hierarchies' (Primus & Lindner, 1994:188). For instance, it is not the case that the grammatical relation 'subject' is always related

to the thematic relation AGENT. Rather, all three relational hierarchies are independent of each other.

The interplay of the different hierarchies can be exemplified by basic word order. According to Primus and Lindner (1994) basic word order reflects the hierarchical relationship between two or more arguments. Thus, in any language, if an argument A is ranked higher than an argument B (A > B), A precedes B in basic word order. The hierarchy, on which A has to be ranked higher than B in order to determine basic word order is language specific. It may either be the thematic or the morphosyntactic hierarchy, thus $A >_{them} B$ or $A >_{case} B$.

In German, basic word order depends both on the thematic and on the morphosyntactic hierarchy. Thus, the first argument is the thematically higher-ranking argument, and/or the first argument is marked with the higher-ranking case. Both conditions apply for instance in the sentence 'Der Opa füttert den Vogel' ([the grandfather]$_{NOM}$ feeds [the bird]$_{ACC}$). Nevertheless, there are also exceptions to this rule. One of these exceptions are dative object-experiencer verbs. Consider for instance the sentence 'Dem Opa gefällt der Vogel' ([to the grandfather]$_{DAT}$ appeals [the bird]$_{NOM}$; 'The bird appeals to the grandfather'). Here, the lower ranked case (dative) precedes the higher ranked case (nominative). This exception is explained by giving a higher weight to the thematic ranking: in dative object-experiencer verbs, the thematically higher ranked argument (EXPERIENCER) precedes the lower ranked one (THEME). The explanation in terms of competing hierarchies can also account for the fact that the subject-first preference is less strong in object-experiencer verbs (Schlesewsky & Bornkessel, 2003; see also Chapter 1).

Crucially, the interplay of different hierarchies is also important in language acquisition. Specifically, Primus and Lindner (1994) state that children prefer cross-hierarchy correlations that are dominant in the native language. A cross-hierarchy correlation is for instance [AGENT = nominative = first argument]. Thus, an argument with the thematic role AGENT is case marked with nominative, and it is the initial argument of the sentence. In German, this cross-hierarchy correlation is dominant, that means, it is the most frequent correlation found in basic sentences.

In consequence, Primus and Lindner predict for German that children start with a word order strategy, the first argument being the AGENT. Nevertheless, the cross-hierarchy preference does not remain stable over time. Thus, in German,

children must gradually learn that the sentence initial position is in principle independent of the AGENT-nominative correlation. The predictions of the Generalized Hierarchy Approach were confirmed by behavioral sentence processing experiments with German children (Primus & Lindner, 1994) and also matched previous results from cross-linguistic data (e.g. Bates et al., 1984; see above). But again, there was no on-line evidence on the development of children's sentence processing mechanisms.

Taken together, sentence processing is characterized by the need to determine hierarchical dependencies between the arguments of a sentence. Crucially, there are three independent hierarchies, namely a thematic, a morphosyntactic, and a grammatical hierarchy. Each language primarily relies on one of these hierarchies to express the relationship between two arguments. During language acquisition children have to learn which hierarchy can mainly be relied upon. In addition, dominant cross-hierarchy relationships are preferred in the beginning of language acquisition. With increasing input, children learn that these cross-hierarchy relationships do not always apply. Nevertheless, Primus and Lindner (1994) do not give an explanation as to how the disentanglement of the hierarchies takes place in later language development, or how it might be triggered.

4.3.3 Bootstrapping Accounts

The fact that certain cross-hierarchy correlations are dominant in a language and are much more frequent than other correlations forms the core part of so called 'bootstrapping accounts'. The idea behind the notion of bootstrapping is that knowledge of one linguistic level, for instance semantics, is used as the starting point for inferring specific information of a second linguistic level, for instance syntax. Thus, in the present example semantics would serve as a 'bootstrap' to gain syntactic knowledge, a theory known as 'Semantic Bootstrapping'. On the other hand, an opposite theory was developed, in which syntax serves as a bootstrap to gain semantic knowledge. This theory is known as 'Syntactic Bootstrapping'. Crucially, both bootstrapping accounts rely on dominant cross-hierarchy correlations between the thematic and the grammatical level.

Semantic Bootstrapping presumes that children use semantics to infer syntactic knowledge (Pinker, 1984, 1996). This account is based on two basic assumptions. First, general cognitive abilities allow children to semantically (or rather thematically) analyze a given scene. For instance, if children observe a

scene where a girl pets a rabbit, the children are able to interpret the girl as the AGENT of the action and the rabbit as the PATIENT.

The second assumption is that of a canonical mapping between grammatical functions and thematic roles. In Pinker's theory, grammatical functions and thematic roles are represented on two separate tiers (cf. Figure 4.1). In each sentence, both tiers have to be linked or mapped onto each other. This mapping procedure is canonical as long as the links between the two tiers do not cross. If they do cross, the mapping is non-canonical. The 'Principle of Canonical Mapping' states that a canonical mapping is applied per default. Thus, in the above example children would link the AGENT (the girl) to the syntactic function 'subject', and the PATIENT (the rabbit) to the syntactic function 'object'.

syntactic tier (gramm. functions):	subject	object	oblique
thematic tier (thematic roles):	AGENT	THEME/PATIENT	GOAL/SOURCE /LOCATION

Figure 4.1 Representation of thematic roles and grammatical functions according to the Semantic Bootstrapping account (Pinker, 1996).

The Semantic Bootstrapping account tries to explain the way the syntactic properties of unknown verbs (e.g. 'to pet') can be inferred by means of the canonical mapping procedure. Correspondingly, the acquisition of non-canonical verbs will be hampered. This would be the case in German dative object-experiencer verbs, which require a non-canonical mapping of thematic roles onto grammatical functions. In order to learn such exceptional verbs, canonical mapping procedures must be overridden by 'direct learning from positive evidence' (Pinker, 1996).

Syntactic Bootstrapping presumes that children use syntax to infer semantic information (Landau & Gleitman, 1985; Gleitman, 1990; Kako & Wagner, 2001). More specifically, children are supposed to use the syntactic structure of an utterance to induce the meaning of a sentence or of an unknown verb. At the very least, the syntactic structure is thought to work as a zoom lens which narrows the range of possible interpretations.

For example consider a child observing a scene where a cat is running behind a mouse. At the same time, the child hears a sentence containing the unknown verb 'to zike'. Crucially, by observation alone the child cannot decide whether 'to zike' means something like 'to chase' or rather something like 'to flee'. The Syn-

tactic Bootstrapping account assumes that this conflict can be solved by the syntactic structure of the respective sentence. Thus, if the cat is the subject, as in 'The cat is ziking the mouse', then the new verb must mean 'to chase'. If however the mouse is the subject, as in 'The mouse is ziking the cat', then the new verb must mean 'to flee'. Behavioral experiments with similar sentences showed that children at the age of 3 and 4 years could make use of the syntactic structure to infer the verb meaning (Fisher, Hall, Rakowitz, & Gleitman, 1994). Nevertheless, this procedure only works in the case of regular cross-hierarchy relationships.

In sum, the strength of Syntactic and Semantic Bootstrapping accounts lies in the explanation of early verb learning by means of canonical cross-hierarchy mapping procedures. However, within both accounts it is difficult to explain how children disengage from canonical mappings in order to acquire non-canonical structures during later stages of language acquisition.

4.3.4 The Argument Dependency Model and Language Acquisition

In this section, previous language acquisition accounts, like the Competition Model and the Generalized Hierarchy Account will be extended, such that the development toward adult processing mechanisms as summarized in the ADM (Schlesewsky & Bornkessel, 2004) can be described. The specific focus will lie on the processing of German.

As introduced in Chapter 3, German offers two ways to establish hierarchical dependencies between arguments. Accordingly, in the sentence processing model ADM two pathways were proposed for the processing of arguments. First, a Morphological Pathway, which is used for establishing thematic dependencies on the basis of morphological case information. Second, a Positional Pathway, which is used for establishing syntactic dependencies on the basis of word order information, if no unambiguous case markings are available.

In comparison to other languages, German seems to be a particularly complicated case, a 'hybrid' language that needs the specialization of two independent pathways, which serve to establish two levels of meaning (Bornkessel & Schlesewsky, in preparation). Many other languages get by with a single processing strategy or pathway.

Now the question arises how the language-learning child arrives at the two distinct processing pathways that are necessary in German, or at a single pathway that may suffice in another language.

In language acquisition, the development towards the respective adult sentence processing mechanisms can be plausibly explained in the following way. At the very start of language acquisition, arguments are related to each other only on a single, primal hierarchy. Hence, the child's basic aim is to somehow determine a hierarchy between any two arguments, such that argument A is ranked higher than argument B (A > B). In the sense of the ADM this would mean that for such a primal hierarchy only one broad pathway is necessary for determining argument hierarchies.

Depending on the input language, this primal pathway must subsequently be specialized to focus on the specific type of information, on the basis of which arguments are hierarchically ranked. For instance, in English, children have to learn that the syntactic position of the arguments determines their thematic status. In other languages the children's parser must be attracted to morphological case markings. For instance, the Caucasian language Avar offers a large number of different morphological cases which reliably express distinct thematic properties (Blake, 2001). Thus, in Avar, morphological case markings provide the relevant cue for thematic analysis, whereas word order is much less informative.

This process of determining the relevant type of information which leads to a hierarchization of the arguments was also described by Primus and Lindner (1994). The search for the relevant and most reliable information type can be thought of in the sense of Cue Validity within the Competition Model (MacWhinney et al., 1984). Thus, in languages like English or Avar one single linguistic cue suffices for establishing a hierarchy.

In other languages, like German, the primal hierarchy must be split up into two distinct ones. In German, both word order and morphological case information are important for sentence interpretation. Word order is particularly important in sentences with ambiguously case marked arguments. By contrast, only unambiguous morphological case information directly contributes to the thematic interpretation of the arguments. Crucially, the syntactic and the thematic hierarchy are independent of each other and are not always organized in parallel (e.g. in the case of dative object-experiencer verbs). In terms of the ADM, in German the primal, broad pathway must be split up into a Positional Pathway, ranking

elements according to their syntactic status, and a Morphological Pathway, ranking elements according to their thematic status (cf. Chapter 3).

Before the separation into two independent hierarchies can take place, language learning children have to decide on which type of information they can preliminarily rely for establishing an A > B hierarchy. The most plausible option is that word order information is used as a starting point in German, as in every single sentence words are sequentially ordered. In contrast, unambiguous case markings occur less frequently. Moreover, case marked articles are often ambiguous, and they encode number and gender information, which makes it even more complicated to extract the specific case information. In terms of the Competition Model, word order has a much higher value of availability than morphological case markings (MacWhinney et al., 1984). If word order is used as a starting point, the first argument will be ranked higher than the second argument (argument 1 > argument 2). This is in accordance with behavioral experiments (e.g. Mills, 1977; Lindner, 2003).

As a consequence, in a single hierarchy, the first argument would be ranked higher in a number of ways, namely syntactically (subject $>_{gr}$ object), thematically (Actor $>_{them}$ Undergoer), and in terms of case (nominative $>_{case}$ accusative/dative). In other words, the primal hierarchy would allow a hierarchical representation like [subject = nominative = Actor] > [object = accusative/dative = Undergoer]. This parallel ordering of several information types according to one hierarchical position is similar to the concept of cross-hierarchy correlations within the Generalized Hierarchy Approach (Primus & Lindner, 1994), or regular syntax-semantics linking rules within Bootstrapping accounts (e.g. Pinker, 1996).

One single hierarchy would work very well in German, as long as only one object case like accusative is available. It would still work if the dative were analyzed as a mere allomorph of the accusative. Thus, under the assumption that German chooses between accusative and dative for object case marking 'by chance', one single hierarchy would suffice, which always ranks syntactic and thematic features in parallel.

However, the dative case has a special status in German, which fundamentally distinguishes it from the accusative (cf. Chapter 1). Crucially, these differences are an ideal candidate for triggering the split of the primal hierarchy into two separate ones. A short summary will recapitulate the important differences between dative and accusative, as described in Chapter 1. First, a dative marked

argument always contributes to the event (co-agentivity), while an accusative marked argument does not. Second, in ditransitive structures there are systematic thematic differences between dative and accusative marked objects. Thus, the higher ranked Proto-Recipient is case marked with dative, and the lower ranked Proto-Patient is always case marked with accusative. Third, in transitive structures, dative marked objects can occur at both ends of the thematic hierarchy, thus either as a Proto-Patient or as a Proto-Agent (as in object-experiencer constructions). Accusative marked arguments are always Proto-Patients. Fourth, only dative marked objects can precede the nominative in basic word order, accusative marked objects cannot. Fifth, only the dative case marking survives under passivization, accusative markings are replaced by nominative.

As soon as children recognize the distributional and syntactic differences between dative and accusative, the different thematic properties associated with them will become apparent. Only then, the establishment of thematic dependencies on the basis of case information will be possible. This amounts to recognizing that only case is a reliable cue for thematic structure marking. Hence, the Morphological Pathway will be set, acknowledging the distinct thematic properties associated with dative and accusative. Word order may still be used for determining a common syntactic and thematic hierarchy in the beginning. Hence, in the beginning the Positional Pathway might not yet be specialized to a pure syntactic strategy, but may also accomplish thematic interpretation, such that the subject is thematically ranked higher than the object.

Nevertheless, at some point it must become evident that the syntactic status of the arguments does not provide the same amount of thematic information as case markings do. More specifically, word order only allows an A > B ranking of the arguments. The three morphological cases however, do not fit into such a binary pattern. The reason is that the dative case has an intermediate thematic status between nominative and accusative and is not bound to one or the other endpoint of the thematic hierarchy. Consequently, word order and cases have to be treated separately, on two different hierarchies.

To sum up in terms of the ADM, the need to partition the primal pathway into two separate ones in German, namely a Morphological and a Positional Pathway, results from the distinct characteristics of the dative and the accusative case. In other words, 'even if there is a preference for a cross-hierarchy correlation at

some age level, this correlation does not remain stable over time' (Primus & Lindner, 1994:201).

Nevertheless, one would predict that, at the start, the Morphological Pathway would be inferior to the Positional Pathway, the former being installed only at a later point in time. The analysis of the distributional and thematic characteristics of dative and accusative must take some time and requires a large amount of input – especially because of the relatively low availability of unambiguous case markings. In the end, case information can be used independently of word order information for establishing a thematic hierarchy.

The age at which this final split into two separate, independent hierarchies is fully accomplished may be quite late in terms of language acquisition. Or, in the words of Tracy (1986): 'It seems that an actual functional division of labor between case morphology and word order takes much longer to develop than the child's spontaneous productions would have one believe' (Tracy, 1986:71).

Chapter 5
Research Questions

The aim of this dissertation was to contribute to the understanding of how argument-processing mechanisms develop during childhood. Previous behavioral studies provided a first impression as to children's off-line sentence processing strategies. However, conclusive evidence on children's on-line processing mechanisms is still missing, as is a detailed description of their abstract representations of argument hierarchies. In particular, the following questions are left open.

First question: How do German children arrive at independent abstract representations of thematic and syntactic argument dependencies? Many theories on language acquisition assume that in the beginning, children rely on cross-hierarchy correlations that are dominant in the native language (e.g. Primus & Lindner, 1994; MacWhinney et al., 1984). Thus, in German, children would start with the correlation [AGENT = nominative = first argument]. The question is, when and how children start to overcome these cross-hierarchy correlations, and how this influences on-line processing mechanisms.

Second question: How do German children use word order in on-line sentence processing? Is the representation they infer from word order syntactic or thematic in nature? Theoretical accounts like the Competition Model predict that children use word order in sentence processing from the very start, because word order is a linguistic cue that is available in every single sentence (e.g. MacWhinney et al., 1984). Under the assumption that children start with regular cross-hierarchy correlations, one would predict that – unlike adults – especially young children use word order to establish a syntactic and a parallel thematic hierarchy of the arguments. Only at a later stage, children will be able to represent thematic and syntactic hierarchies separately. Crucially, this is the precondition for the establishment of a pure syntactic hierarchy on the basis of word order.

Third question: How do German children use morphological case markings in on-line sentence processing? Is the representation they infer from case markings thematic in nature, and is it independent of word order? Previous behavioral

studies indicated that around the age of 5 or 6, children start to use case information to infer the agent of an action, as they began to correctly act out object-initial sentences (e.g. Lindner, 2003). However, the automatic on-line processing of case information might still take several further years to reach adult-like routines (cf. also Hahne et al., 2004).

These questions were addressed in two series of ERP experiments that are presented in the second part of this thesis. The first series of experiments investigated the processing of auditorily presented dative sentences (cf. Chapters 6 to 8). In order to investigate the role of word order in argument processing, the experimental sentences were of subject- and object-initial structure. In order to investigate the role of morphological case markings, the arguments were either unambiguously case marked or case ambiguous. Moreover, besides canonical dative verbs the sentences also contained non-canonical object-experiencer verbs. As the latter require an inverse hierarchical representation, they allowed investigating processes of thematic reanalysis. The experiments were conducted with an adult control group and with children of two different age levels, namely 11 and 8 years of age. On the basis of the results on the processing of dative structures a second series of experiments was conducted with auditorily presented accusative sentences (cf. Chapter 9). The primary aim was to investigate whether 8-year-old children apply different sentence processing mechanisms in the analysis of accusative structures than in the analysis of dative structures.

Chapter 6
Experiment I: The Processing of Dative Structures in Adults

6.1 Introduction

Experiment I aimed to investigate adult sentence processing mechanisms in the auditory modality. On the one hand, the purpose was to verify the results of preceding visual experiments. Up to now, no ERP experiments have been conducted in the auditory modality that investigated the processing of word order and case marking. On the other hand, the adult participants in Experiment I served as a control group for the upcoming ERP experiments with children. Thus, stimuli and procedure were developed in a way suitable for school-aged children.

The specific purpose of Experiment I was to distinguish the ADM's Positional and Morphological Pathways by means of ERPs. In order to investigate the characteristics of the representation that is built up on the arguments of a sentence, auditory sentences were presented in which two arguments preceded the verb. In order to investigate the role of morphological case markings, the arguments were either unambiguously case marked or case ambiguous. Sentences with ambiguous arguments were disambiguated by number agreement on the verb. The role of word order was investigated by means of subject- and object-initial word orders.

In order to investigate mechanisms of thematic reanalysis, two different verb types were employed. First, active verbs were used that encode their arguments in a canonical way. In active verbs, the thematically higher-ranking argument also has the syntactically higher-ranking status 'subject'. Second, object-experiencer verbs were used that encode their arguments in a non-canonical way. In object-experiencer verbs, the thematically higher-ranking argument has the syntactically *lower*-ranking status 'object'.

On the basis of preceding visual experiments, the following ERP effects were predicted. First, case marked arguments were expected to be processed via the Morphological Pathway. If the case marking on the arguments is used for build-

ing a thematic hierarchy, this hierarchy has to be reversed when encountering non-canonical object-experiencer verbs. This reversal should be reflected in an early positivity on the verb. It should be independent of word order, because the thematic hierarchy is based solely on morphological case information (cf. Bornkessel et al., 2002; 2003). In sentences with ambiguous arguments, no thematic hierarchy should be established in advance to the verb. Thus, no early positivity was expected for object-experiencer verbs in ambiguous sentences.

Second, ambiguous arguments were expected to be processed via the Positional Pathway. Here, syntactic word order effects were predicted. Due to a strong preference for subject-initial structures, reanalysis effects were expected if the verb disambiguates the sentence towards an object-initial structure. This reanalysis was predicted to elicit an N400, independently of verb type. Reanalysis-N400 effects were reported for dative-initial structures, reflecting a relabeling of base generated positions (cf. Bornkessel et al., 2004). In addition, a LAN component was expected for subject-initial sentences with object-experiencer verbs, reflecting a mismatch between syntactic and thematic hierarchies (cf. Bornkessel et al., 2002).

6.2 Methods

6.2.1 Participants

Twenty-four adults (12 female) with a mean age of 24 years (range 20-27) participated in the experiment. All participants were right-handed (as assessed by an adapted German version of the Edinburgh Handedness Inventory, Oldfield, 1971), monolingual native speakers of German, and were healthy. The data of 3 further adults could not be evaluated due to technical problems and/or a missing second session. The mean interval between the first and the second session was 7 days (range 3-27 days). All participants received EUR 7 per hour.

6.2.2 Experimental Material and Design

6.2.2.1 Experimental Sentences

The experimental design was kept close to that of previous experiments in the visual modality (Bornkessel et al., 2002, 2003; Bornkessel et al., 2004), with the

main difference that presentation was auditory. In addition, as the experiment was designed to be conducted with children later on, stimulus material was selected according to a behavioral pretest to keep it appropriate for children. Only those verbs were included in the stimulus material which could be accurately defined by the majority of 41 children aged 6;10-10;10. Details of the material pretest and an overview of the final stimulus materials are given in Appendix A and C.

The stimulus material comprised a 2×2×2 factorial design with repeated measures of all three factors. The three factors were 'Case' of the NPs (unambiguous/ambiguous), 'Verb' (active/object-experiencer), and 'Order' (SO (subject before object) /OS (object before subject)). This resulted in 8 different experimental conditions (see Table 6.1). In order to avoid sentence final wrap-up processes (e.g. Frisch, 2000), the critical verb was kept in the middle of the sentence by continuing it with a matrix clause, for example 'hätte niemand gedacht' (as no one would have thought) or 'weiß doch jeder' (as everybody surely knows).

Table 6.1 Experimental conditions in Experiment I.

	case marked	**case ambiguous**
	active verbs	
SO	Dass der Ritter den Zwergen zuwinkt, ...	Dass Lena Piloten zuwinkt, ...
	that [the knight]$_{NOM}$ [the dwarfs]$_{DAT}$ [waves to]$_{SG}$	that [Lena]$_{AMB,SG}$ [pilots]$_{AMB,PL}$ [waves to]$_{SG}$
	'That the knight waves to the dwarfs, ...'	'That Lena waves to pilots, ...'
OS	Dass dem Ritter die Zwerge zuwinken, ...	Dass Lena Piloten zuwinken, ...
	that [the knight]$_{DAT}$ [the dwarfs]$_{NOM}$ [wave to]$_{PL}$	that [Lena]$_{AMB,SG}$ [pilots]$_{AMB,PL}$ [wave to]$_{PL}$
	'That the dwarfs wave to the knight, ...'	'That pilots wave to Lena, ...'
	object-experiencer verbs	
SO	Dass der Ritter den Zwergen gefällt, ...	Dass Lena Piloten gefällt, ...
	that [the knight]$_{NOM}$ [the dwarfs]$_{DAT}$ [appeal to]$_{SG}$	that [Lena]$_{AMB}$ [pilots]$_{AMB}$ [appeal to]$_{SG}$
	'That the knight appeals to the dwarfs'	'That Lena appeals to pilots, ...'
OS	Dass dem Ritter die Zwerge gefallen, ...	Dass Lena Piloten gefallen, ...
	that [the knight]$_{DAT}$ [the dwarfs]$_{NOM}$ [appeal to]$_{PL}$	that [Lena]$_{AMB,SG}$ [pilots]$_{AMB,PL}$ [appeal to]$_{PL}$
	'That the dwarfs appeal to the knight, ...'	'That pilots appeal to Lena, ...'

Ninety-six of these eight-tuples were created. Each noun and each proper noun were used twice, but never in the same combination. For each verb category, three different verbs were used as a result of the material-pretest. Each verb was used equally often. For each individual sentence, a counterpart was created by

reversing the NPs and putting the plural NP to the front. All nouns were human. Each sentence was semantically reversible, so that both nouns could be the logical agent of the action.

In sum, 768 different sentences served as stimulus material (96×8). The probability of the first noun being singular or plural was equal and counterbalanced across conditions. The stimulus set was divided into two subsets of equal structure and size (384). Due to the amount of experimental material, the experiment was conducted in two sessions. To this end, both subsets were split in two parts of 192 sentences. Each condition appeared equally often in both sessions. Identical noun-noun-verb combinations appeared twice per session. Additionally, each session was parted into six blocks of the same size. In each block, each condition appeared approximately equally often.

For each subset, two pseudo-randomized versions were created. No more than three sentences with the same property (Case, Verb, Order) followed in sequence. All in all, four different presentation lists were obtained. They were evenly applied to the participants, counterbalancing the gender of the participants.

All sentences were spoken condition by condition by a professional female speaker in a child directed manner. The stimulus material was first recorded on tape, and then digitized for further processing (44.1 kHz, 16 bit sample rate).

6.2.2.2 Task

The aim was to ensure that, in the course of the experiment, participants listened attentively to each sentence. To achieve this, each sentence was followed by a comprehension question that could be answered by "yes" or "no" (see Table 6.2). Hereby, questions where the correct response was "yes" were defined as 'true'. Questions where the correct response was "no" were defined as 'false'. True and false questions were equiprobable across conditions.

In false questions, either the first noun, the second noun or the verb was replaced by another one. As replacements, only nouns were chosen which were not part of the experimental material. As far as possible, phonologically similar words were chosen. Verbs were always replaced by an experimental verb of the other verb type. Another false question type consisted in the reversal of the thematic roles. Each question type (first noun, second noun, verb, reversal) appeared equally often and was counterbalanced across conditions.

Table 6.2 Structure of the questions following each experimental sentence.

sentence		Dass der Ritter den Zwergen dankt, ist wahr.	*That the knight thanks the dwarfs, is true.*
possible questions:		Stimmt es, dass ...	*Is it right that ...*
true		... der Ritter den Zwergen gedankt hat?	*... the knight thanked the dwarfs?*
false	1st NP	... der **Räuber** den Zwergen gedankt hat?	*... the **robber** thanked the dwarfs?*
	2nd NP	... der Ritter den **Zwillingen** gedankt hat?	*... the knight thanked the **twins**?*
	verb	... der Ritter den Zwergen **gefallen** hat?	*... the knight **appealed to** the dwarfs?*
	role-reversal	... **dem Ritter die Zwerge gedankt haben**?	*... **the dwarfs thanked the knight**?*

To reduce monotony, questions were formulated in different ways: either as an indirect question ('Stimmt es, dass', 'Glaubst Du, dass', 'Ist es wahr, dass'; Is it right that; Do you think that; Is it true that), or as a direct question ('Hat der Ritter ...'; Did the knight ...). The four different formulations were counterbalanced across the four question types.

In contrast to the experimental sentences, all questions were spoken by a male speaker. Thereby a quasi-natural dialogue between two persons was obtained. In addition, the two speakers could be easily differentiated by means of gender specific properties of voice. For obtaining a natural interrogative intonation, four types of stress patterns were used: In false questions, the replaced word was stressed (first noun, second noun, or verb) or the whole question (role-reversal). In true questions, all four intonation patterns were equiprobable.

The digitized sentences and questions were processed with CoolEdit 2000 (Syntrillium Software Corp.). Nine timestamps were inserted before and after the syntactic constituents. This allowed the analysis of the EEG data at sentence positions of interest, and the measurement of acoustic properties of the stimulus material (see Appendix D). To ensure a homogeneous presentation, the loudness of all sentences and questions was adjusted to a common level.

6.2.3 Procedure

In the course of the experimental session, participants were seated comfortably and held a response box on their lap. Visual stimuli were presented on a computer screen in front of the participant, at a distance of 130 cm. Auditory stimuli were presented via two loudspeakers next to the screen. A written instruction informed the participants of the experimental procedure. They were instructed to

listen carefully to the experimental sentences and the following question. A yes/no response was required after the question with emphasis on accuracy rather than speed.

Three training blocks preceded the experimental blocks. In the first training block, participants were introduced to the task (6 trials). The second block exemplified questions with thematic role reversal, as they were the most difficult ones (8 trials). In the third block, participants were instructed to keep their gaze at the fixation point and to avoid eye-blinks throughout its presentation (6 trials). By means of the three training blocks, children (and adults) could slowly get used to the experimental set-up and the various demands. Subsequently, all 192 trials were presented in six experimental blocks. Between the blocks, there was a break of at least three minutes. The entire experiment – including electrode preparation – lasted approximately three hours. The EEG measurement itself took about 1 hour and 15 minutes, depending on the length of the intervening breaks.

The time course of a trial was as follows (cf. Table 6.3). In the middle of the screen, a fixation point (star) was presented. It appeared 500 ms before the onset of the sentence and disappeared 200 ms after the offset of a sentence. All sentences and questions were presented auditorily. Each sentence was followed by a silent interval of 1500 ms. After this, the question was presented, followed by two smileys on the screen. One was presented on the left, the other one on the right. These two positions corresponded to the two buttons of the response box. One smiley was happy, representing the button for "yes". The other smiley was sad, representing the button for "no". The semantic values of the smileys helped the children to remember which button (left/right) corresponded to which answer (yes/no). The assignment of the left and right buttons to the answers "yes" and "no" was counterbalanced across randomizations, participants and gender of participants. During the next 4000 ms the participants had time to answer the question. Otherwise the program would continue automatically. Five hundred ms later a feedback was given for 800 ms. Each answer was followed by a feedback in the form of a comic picture (correct answer) or a simple point (false answer or time-out). After a stimulus free intertrial-interval of 1500 ms, the next sentence was presented.

Table 6.3 Trial scheme. ITI = inter trial interval.

event:	fixation point	sentence	pause	question	answer	pause	feedback	ITI
visual stimulus:	*	*			☺ ☹			
duration [ms]:	500	~ 5000	1500	~ 5000	< 4000	500	800	1500

6.2.4 Apparatus

EEG activity was recorded with Ag/AgCl electrodes mounted in an elastic cap (Electrocap International Inc.) from 21 scalp sites of the extended 10-20-system (cf. Figure 6.1). Electrode labeling was based on the standard nomenclature (Sharbrough et al., 1991). The ground electrode was placed at the position of AFZ. All scalp electrodes were referenced to the left mastoid (A1). The right mastoid was recorded as an additional channel. The vertical electrooculogram (EOG) was recorded from electrodes located above and below the right eye. The horizontal EOG was recorded from electrodes positioned at the outer canthus of each eye.

Electrode impedances were kept below 5 kOhm. The EEG was recorded continuously with a digitization rate of 250 Hz and was amplified with a bandpass from direct current to 40 Hz using a Twente Medical Systems amplifier. Stimulus presentation and recording of the behavioral data were performed by the ERTS software (Experimental Run Time System, V3.18, Beringer, 1993).

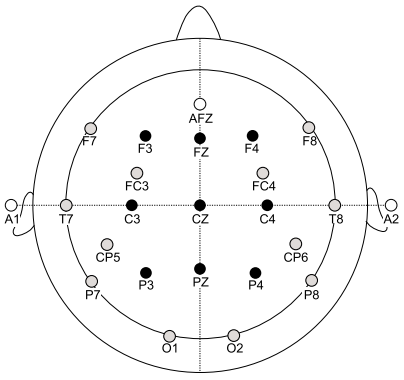

Figure 6.1 Electrode positions after Sharbrough et al. (1991). Circles filled with black: electrodes that entered statistical analyses; circles filled with grey: additional electrodes that were recorded; open circles: ground (AFZ) and referential electrode (A1).

6.2.5 Data Analysis

6.2.5.1 Behavioral Data

As the answers were given with a variable delay relative to the point in time at which a question turned out to be 'true' or 'false', reaction times were not evaluated. The analysis of the behavioral data was restricted to the error rate as a function of condition. The answers of the participants were classified as 'Correct' or 'Error'. Time-outs were classified half as Correct and half as Error, according to the chance level (cf. Snodgrass & Corwin, 1988). Errors per condition were calculated. Analyses of Variance (ANOVAs) with the two-level factors Case (unambiguous/ambiguous), Verb (active/object-experiencer) and Order (SO/OS) were calculated over group means. Results were interpreted as significant when reaching the alpha level $p < .05$ or $p < .01$, respectively.

6.2.5.2 ERP Data

The EEG data were analyzed by means of the evaluation software EEP 3.2 (Max Planck Institute of Cognitive Neuroscience). The EEG analysis comprised several steps. First, all data were bandpass filtered off-line (0.3-20 Hz). The lower boundary of the filter was chosen because the EEG data contained many slow drifts (especially the children's data). Nevertheless, slow ERP components like the P600 with a frequency of about 0.5 Hz would be preserved. The upper boundary was chosen to eliminate high-frequency noise (as for example caused by muscular activity), which lies outside the range of any ERP component. Second, the filtered data were automatically scanned for EOG artifacts (sliding window = 200 ms, threshold level: SD = 40 μV). Third, all epochs were manually checked for further extracerebral artifacts. All epochs containing artifacts were excluded from further analyses. All statistical analyses were computed on these artifact-free bandpass-filtered data. For graphical presentation only, the plots of the grand average ERPs were additionally smoothed with a 5 Hz low-pass filter.

ERP averages were calculated on the verb following the arguments ('critical verb'). As the verb was in the middle of the ongoing speech signal, there was no silent epoch or any other constant event to be defined in front of the critical verb. The epoch prior to the sentence was too far away from the onset of the verb. Thus, no condition-independent baseline window could be defined. To overcome

this difficulty, averaging took place with the raw EEG data. No baseline was calculated. This proceeding was justified because of the lower boundary of the bandpass filter. In consequence, the ERPs did not contain slow drifts that could have caused accidental differences between conditions (cf. Friederici, Wang, Herrmann, Maess, & Oertel, 2000).

Average ERPs were calculated per condition and participant from the onset of the critical verb to 2000 ms post onset. Only correctly answered trials entered the analysis. Subsequently, grand averages were calculated over all participants. To allow statistical analysis by means of ANOVAs 9 electrode positions were chosen (see Figure 6.1). They comprised 3 anterior (F3, FZ, F4), 3 central (C3, CZ, C4), and 3 posterior positions (P3, PZ, P4). The statistical design was composed of four factors with repeated measures. The factors Case (marked/ambiguous), Verb (active/object-experiencer), and Order (SO/OS) had two levels. The factor 'Region' had three levels (anterior/central/posterior).

For the sake of clarity, only main effects or interactions including the condition factors are reported. All effects with more than one degree of freedom in the numerator were adjusted for violations of sphericity according to the Greenhouse and Geisser formula (Greenhouse & Geisser, 1959). Results were interpreted as significant when reaching the alpha level $p < .05$ or $p < .01$, respectively.

6.3 Results

6.3.1 Behavioral Data

The error rates for all 8 conditions are shown in Figure 6.2. On average, 5 % of all questions were answered incorrectly. Case marked sentences revealed clear word order differences. With active verbs, subject-initial sentences elicited fewer errors. With object-experiencer verbs, however, object-initial sentences elicited fewer errors. In ambiguous sentences, there were differences in verb type, with active verbs eliciting fewer errors than object-experiencer verbs. These observations were supported by the statistical analyses reported below.

A global ANOVA of the error rates revealed a main effect of Verb ($F(1,23) = 32.87$, $p < .01$). Thus, conditions with active verbs were generally less error-prone (4 % errors) than conditions with object-experiencer verbs (6 % errors). In addition, a three-way interaction Case×Order×Verb emerged ($F(1,23) = 6.21$,

$p < .05$). This interaction was resolved by Case. Only for case marked sentences, there was an Order×Verb interaction ($F(1,23) = 14.44$, $p < .01$). Thus, in case marked sentences with active verbs, subject-first structures elicited significantly less errors (2.9 %) than object-initial structures (5.4 % errors) ($F(1,23) = 6.72$, $p < .05$). In contrast, with object-experiencer verbs, the pattern was reversed: here, subject-first sentences elicited significantly *more* errors (7 %) than object-initial sentences (3.7 % errors) ($F(1,23) = 9.90$, $p < .01$). Such a cross-over pattern did not emerge for the ambiguous sentences.

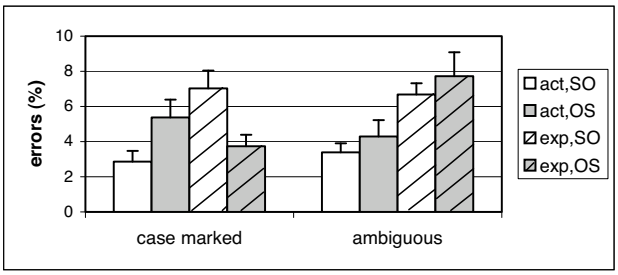

Figure 6.2 Behavioral data of adults in Experiment I. Error rates in % (+ standard error (s.e.)) for conditions with unambiguously case marked and case ambiguous arguments; act = active verbs, exp = object-experiencer verbs; SO = subject-initial, OS = object-initial conditions.

6.3.2 ERP Data

The ERPs elicited at the critical verb are shown in Figure 6.3 and Figure 6.4. The extended set of electrodes for all experiments is given in Appendix F. Three clear condition effects were observed. First, an early positivity occurred for object-experiencer verbs in case marked sentences, henceforth referred to as 'EPOS', standing for 'Early Positivity'. The EPOS was most pronounced on anterior electrode sites, lasting from 400-650 ms with a maximum around 590 ms (cf. Figure 6.3). Thereafter, a negativity (N400) occurred for all ambiguous object-initial sentences, although it seemed to be smaller for object-experiencer conditions. It was followed by a late positivity (P600) in ambiguous object-initial sentences with active verbs (cf. Figure 6.4). The N400 was most pronounced on centro-parietal electrode sites, lasting from 750-1000 ms with a maximum around 830 ms. The P600 was observable primarily on parietal electrode sites, lasting from 1200-1700 ms with a maximum around 1400 ms.

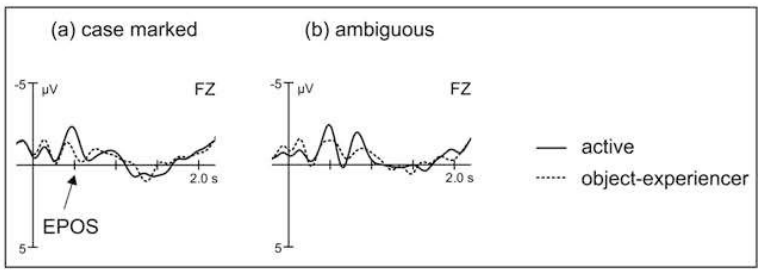

Figure 6.3 Grand average ERPs for dative object-experiencer vs. dative active verbs for adults in Experiment I. (a) shows the ERPs for unambiguously case marked arguments and (b) the ERPs for ambiguous arguments. The figure depicts the mid-frontal electrode FZ. In this and all following ERP figures verb onset is at the vertical bar, and negativity is plotted upwards.

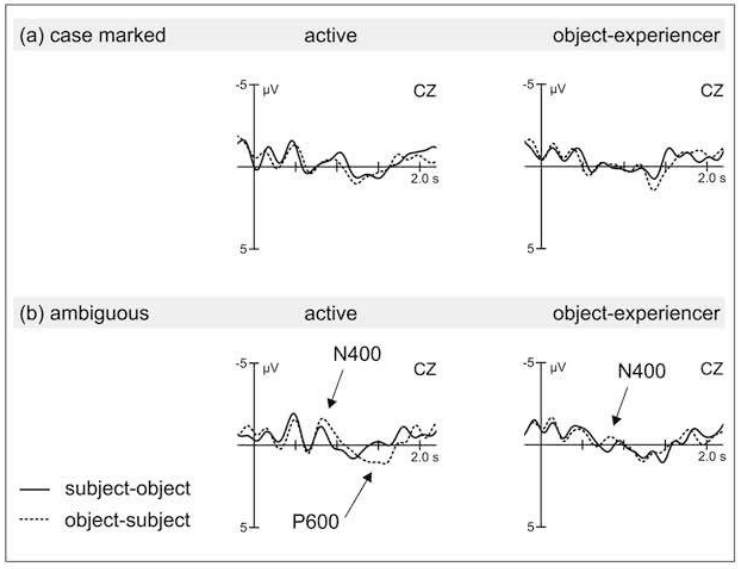

Figure 6.4 Grand average ERPs for dative verbs in object-initial vs. subject-initial sentences for adults in Experiment I. (a) shows the ERPs for unambiguously case marked arguments, and (b) shows the ERPs for ambiguous arguments, separately for active (left column) and object-experiencer verbs (right column). The figure depicts the mid-central electrode CZ.

These observations were supported by statistical analyses. To this end, time windows were chosen according to visual inspection of the grand averages, covering the time span in which the difference between two conditions was clearly visible on most electrode sites. The time windows were set at 400-650 ms for the EPOS, at 750-1000 ms for the N400, and finally at 1200-1700 ms for the P600.

EPOS (400-650 ms). In the time window of 400-650 ms, a global ANOVA yielded an interaction of Case×Verb ($F(1,23) = 7.06$, $p < .05$). The interaction was resolved by Case, resulting in a main effect of Verb only in case marked sentences ($F(1,23) = 13.49$, $p < .01$). Hence, a positivity occurred for object-experiencer verbs in case marked sentences, but not in ambiguous sentences. In addition, a three-way interaction Verb×Order×Region emerged ($F(2,46) = 4.41$, $p < .05$). This interaction was resolved by Region, but yielded no significant Verb×Order interaction within any Region.

N400 (750-1000 ms). In the time window of 750-1000 ms, a global ANOVA revealed an interaction of Case×Order ($F(1,23) = 7.06$, $p < .05$). The interaction was resolved by Case, resulting in a main effect of Order only for ambiguous sentences ($F(1,23) = 5.84$, $p < .05$). Thus, a negativity occurred on the verbs in ambiguous object-initial sentences, but not in case marked sentences. In addition, a four-way interaction Case×Verb×Order×Region emerged ($F(2,46) = 6.7$, $p < .05$), which could not be attributed to any systematic pattern when resolving it by Region.

Moreover, a three-way interaction Case×Verb×Region emerged ($F(1,23) = 4.32$, $p < .05$). The interaction was resolved by Region, yielding a Case×Verb interaction only in the posterior Region ($F(1,23) = 6.96$, $p < .05$). Resolving this interaction by Case, yielded a Verb effect only for ambiguous sentences ($F(1,23) = 4.59$, $p < .01$). Hence, in ambiguous sentences, active verbs elicited a posterior negativity in comparison to object-experiencer verbs.

P600 (1200-1700 ms). In the time window of 1200-1700 ms, a global ANOVA revealed an interaction of Case×Order×Verb ($F(1,23) = 11.73$, $p < .01$). The interaction was resolved by Case, resulting in an Order×Verb interaction only for ambiguous sentences ($F(1,23) = 5.57$, $p < .05$). This interaction was in turn resolved by Verb, yielding a main effect of Order only for active verbs ($F(1,23) = 11.88$, $p < .01$). Thus, a positivity occurred for ambiguous object-initial sentences with active verbs. In addition, a three-way interaction

Verb×Order×Region emerged ($F(2,46) = 6.12$, $p < .05$). However, resolving the interaction by Region revealed no Verb×Order interaction in any of the three regions.

6.4 Discussion

The three basic findings of Experiment I can be summarized as follows. First, object-experiencer verbs in case marked sentences elicited an early positivity (EPOS). Second, object-initial ambiguous sentences elicited an N400 on the disambiguating verb. Third, in the case of active verbs, the N400 was followed by a P600. The three different ERP effects will be discussed in the following.

EPOS

The first effect was an early positivity for object-experiencer verbs in comparison to active verbs, referred to here as 'EPOS'. The EPOS only emerged in case marked sentences. This confirmed the hypothesis based on previous visual experiments (Bornkessel et al., 2002; 2003). Bornkessel et al. interpreted the positivity as the reflection of a thematic reanalysis. When case marked arguments are processed, the parser immediately ranks them in a thematic hierarchy according to the specific case markings. At the verb, the thematic ranking can either be confirmed, as in the case of active verbs, or it must be reversed, as in the case of object-experiencer verbs. The EPOS is assumed to reflect this thematic re-ranking. In ambiguous sentences, no early thematic ranking is computed due to the lack of case information. Therefore no thematic reanalysis needs to take place, and no EPOS is elicited in case ambiguous sentences.

N400

The second effect was a negativity in ambiguous object-initial sentences as compared to subject-initial sentences. Although peaking not until 830 ms, it can be classified as an N400. It has to be kept in mind that the stimuli were presented auditorily, and thus unfolded over time. Case ambiguous sentences were only disambiguated towards subject- or object-initial word order by the number marking of the verb. This number marking was realized by a suffix, which could be unambiguously recognized about 470 ms after the onset of the verb (uniqueness point). Subtracting this time range from the peak after onset results in a peak after uniqueness point (cf. Van Petten et al., 1999; O'Rourke & Holcomb, 2002).

This peak after uniqueness point lies at approx. 360 ms, which falls into the typical time range for an auditorily evoked N400 (e.g. Connolly & Phillips, 1994; Salmon & Pratt, 2002). The centro-parietal topographical distribution is also typical for the auditorily elicited N400 (Friederici et al., 1993; Kutas & Van Petten, 1994).

The N400 appeared in all ambiguous sentences with object-initial word order, as was expected according to previous experiments in the visual modality (Bornkessel et al., 2004). The N400 effect in ambiguous sentences shows that in absence of any other evidence the parser first assumes a subject-initial structure. In the case of a disambiguation towards an object-initial structure, a reanalysis is required. Due to the existence of unmarked object-initial dative sentences, a 'relabeling' of the base generated syntactic positions suffices for reanalysis. This process of relabeling is assumed to be reflected in the reanalysis-N400.

In addition, a posterior N400 effect emerged for active verbs in comparison to object-experiencer verbs in ambiguous sentences. This effect was not predicted. Presumably, the N400 for active verbs can be attributed to the large N400 effect in object-initial sentences (Verb×Order interaction). On average, this may have led to more negative going ERPs for active verbs in comparison to object-experiencer verbs.

P600

The third effect was a late positivity, occurring in ambiguous object-initial sentences with active verbs in comparison to subject-initial sentences. Again, this component was delayed in time due to the late uniqueness point of the verb. The subtraction of the uniqueness point (470 ms) from the peak of the positivity (1400 ms) results in a peak after uniqueness point at approx. 930 ms. This time range together with the rather parietal distribution fits well with the interpretation of the positivity as a P600 (Friederici et al., 1996; Hagoort & Brown, 2000; Hahne, 2001).

The P600 was not expected from previous visual experiments (Bornkessel et al., 2004). Usually, this effect is associated with syntactic reanalysis processes (Friederici, 1995; Friederici et al., 1996), or increased difficulty in syntactic integration (Kaan et al., 2000). The latter interpretation may be compatible with the present finding. In the case of active verbs, the parser initially benefits from the fact that canonical dative-initial structures exist. Thus, a first attempt to reanalyze

the structure is reflected in the N400. This relational or case reanalysis does not change the already established syntactic representation. Rather, the parser only 'relabels' the existing syntactic positions. The subsequent P600 presumably reflected the reanalysis towards the non-canonical word order. This additional step of reanalysis is only necessary for active verbs, as they do not have an unmarked object-initial word order. Thus, additional effort is necessary. In contrast, object-experiencer verbs do have an unmarked object-initial word order, such that no further steps of reanalysis are necessary. The previous relational reanalysis suffices for this verb type.

Nevertheless, the question arises why the P600 did not appear in previous experiments with visual presentation (Bornkessel et al., 2004). One difference between visual and auditory presentation is that of prosodic information. Acoustic analyses of the present stimulus material comprising the course of fundamental frequency and duration of the phrases showed differences between the experimental conditions (see Appendix D). Most notably, the course of fundamental frequency differed between active and object-experiencer conditions. Differences started at the end of the second NP and were most prominent at the beginning of the verb. The differences amounted up to 33 Hz and can easily be perceived in the respective frequency range (cf. t'Hart, Collier, & Cohen, 1990). Thus, contrary to visual stimuli, auditory stimuli provided an additional cue for verb type. Presumably, prosodic information initiated the additional reanalysis process reflected in the P600. Whereas in visual presentation the parser is satisfied with the relational reanalysis, it receives additional cues in auditory presentation which highlight the inappropriateness of the relational reanalysis with active verbs.

Interestingly, a similar N400-P600 pattern was observed by Bornkessel (2002). She visually presented German sentences in which the dative verb preceded the arguments. The sentences had the structure adverb-verb-NP-NP. They were disambiguated on the second NP via case marking, leading to a subject-initial (cf. (6.1a)) or an object-initial structure (cf. (6.1b)). On the second NP, an N400 emerged for all object-initial sentences. In addition, in active verbs it was followed by a P600. This fits well with the finding that in the present auditory study the P600 occurred only for active verbs, too.

(6.1) a) Vielleicht droht/gefällt Stefan dem Regisseur.
perhaps threatens/pleases [Stefan]$_{AMB}$ [the director]$_{DAT}$
'Perhaps Stefan threatens/pleases the director'

b) Vielleicht droht/gefällt Stefan der Regisseur.
perhaps threatens/pleases [Stefan]$_{AMB}$ [the director]$_{NOM}$
'Perhaps the director threatens/pleases Stefan'

Crucially, the different sentence structures and the modality of presentation differ with regard to when which type of information becomes available. In sentences in which the verb precedes the arguments, the verb specific lexical-thematic information is available to the parser *before* the disambiguating region (cf. (6.2)). The same is true for the auditorily presented sentences of Experiment I. Due to the fact that the acoustic signal unfolds over time, verb class information becomes available *before* the disambiguating number information at the end of the verb (cf. (6.3)). In contrast, if the same verb-final sentences are presented visually word by word, both verb class and number information become available at the same point in time (cf. (6.4)). Crucially, if participants read a word, they do not proceed from left to right. Rather, they are able to perceive the word as a whole (Rayner & Pollatsek, 1989).

(6.2) *visual presentation, verb precedes the arguments:*
Vielleicht droht Stefan der Regisseur.
↳ active ↳ nominative (disambiguating)

(6.3) *auditory presentation, verb follows the arguments:*
dass Hannah Tennisspielerinnen zuwink -en
↳ active ↳ 3rd plural (disambiguating)

(6.4) *visual presentation, verb follows the arguments:*
dass Maria Sängerinnen zuwinken
↳ active
↳ 3rd plural (disambiguating)

In sum, if both types of information are available at the same time, only an N400 shows up for active verbs. If verb class information is available in advance, the N400 is followed by a P600. In the latter case, the parser first receives informa-

tion about the verb specific thematic properties. These properties specify whether the default subject-first assumption would be associated with a Proto-Agent > Proto-Patient sequence (active verbs) or with a Proto-Patient < Proto-Agent sequence (object-experiencer verbs). In the latter case, thematic structure can support reanalysis.

Due to missing case markings, the parser pursues a subject-first strategy, analyzing the first ambiguous argument as the subject, and the second ambiguous argument as the object. If the number information on the verb disambiguates the structure towards an object-initial word order, reanalysis must take place, which is reflected in the N400 effect for both dative verb types.

In object-experiencer verbs, this reanalysis is additionally supported by the previously activated Proto-Patient < Proto-Agent sequence, and the preference to obtain a reversal of it (cf. Chapter 1). By contrast, in active verbs no such support is given. The preactivated Proto-Agent > Proto-Patient template does not support the reanalysis towards an object-initial structure. Rather, the subject-first preference is reinforced. In consequence, the reanalysis towards the non-canonical word order requires additional effort, which is reflected in the subsequent P600 effect.

Finally, contrary to the visual precursor experiments no LAN effect emerged in the present experiment. Bornkessel et al. (2004) reported a LAN in subject-initial object-experiencer sentences compared to object-initial sentences (cf. Chapter 3). The LAN was interpreted as a reflection of the mismatch between syntactic and thematic hierarchies. In particular, there may be 'a brief processing advantage for an object-initial word order that derives from a preference for parallel thematic and syntactic dependencies' (Bornkessel et al., 2004).

Presumably, the LAN is dependent on the simultaneous processing of verb class and number information. As discussed above, only in the visual experiment verb class and number information were available at the same point in time (cf. (6.4)). By contrast, in auditory presentation verb class information was available before number information (cf. (6.3)). Probably, the simultaneous processing of thematic and word order information is critical for the elicitation of the LAN. If however the parser can cope with the two types of information in a serial way, no early mismatch effect is elicited. Accordingly, in the visual experiment in which the verb preceded the arguments, no LAN was elicited either (Bornkessel, 2002).

An alternative explanation why the LAN did not occur in the auditory experiment is that additional prosodic information was available. In the experimental sentences there were durational differences between word orders right from the beginning (cf. Appendix D). Specifically, phrases of object-initial sentences had a longer duration than those of subject-initial sentences. These prosodic cues may have given a slight hint to the parser with regard to word order. Hence, the mismatch between the two hierarchies was not as unexpected as it was in the visual experiments. This might be a further possibility why no LAN effect was elicited in the auditory experiment.

Conclusion

Taken together, Experiment I succeeded in replicating the basic findings from preceding visual experiments with regard to the processing of word order and case information by adults in the auditory modality. If unambiguous case markings were available, they were used for a thematic ranking of the arguments. More specifically, nominative marked arguments were ranked higher than dative marked arguments. If this ranking had to be reversed, as in the case of object-experiencer verbs, this was reflected in an early positivity (EPOS).

If no case markings were available, word order was used for determining syntactic dependencies. Thus, the first ambiguous argument was analyzed as the syntactic subject of a sentence. The disambiguation towards an object-initial structure led to an N400 effect, reflecting a relational reanalysis during which previously established syntactic positions are relabeled. In the case of active verbs a P600 effect followed, reflecting additional repair processes that are necessary in the reanalysis towards a non-canonical word order. In sum, the present findings are in accordance with the Argument Dependency Model: case marked arguments were processed via the Morphological Pathway, whereas ambiguous arguments were processed via the Positional Pathway.

Chapter 7
Experiment II: The Processing of Dative Structures in 11-Year-Old Children

7.1 Introduction

Experiment II investigated sentence processing mechanisms in children. The main question was which types of information children use in order to establish hierarchical dependencies between the arguments of a sentence. Thus, do children use morphological and positional information in the same way as adults? Do they distinguish between an abstract thematic and a syntactic hierarchical representation? Alternatively, children might put more weight on establishing syntactic dependencies and organizing thematic dependencies in parallel. The answer to these questions will shed more light on the issue of how sentence processing mechanisms develop during language acquisition.

Crucially, up to now no ERP experiments have been conducted which investigated children's use of word order and case marking during sentence processing. Thus, there are no data on children's on-line processing of positional and morphological information. Moreover, preceding behavioral experiments with children on word order and case marking exclusively examined transitive relations with accusative marked objects. However, as described in Chapter 1, in accusative sentences the syntactic and the thematic hierarchy are always organized in parallel. The advantage of dative verbs is that syntactic and thematic hierarchies can be disentangled. This makes it possible to distinguish whether children rank arguments on a syntactic or on a thematic hierarchy.

To this end, the identical experimental setup as in Experiment I was employed in Experiment II. Thus, subject- and object-initial sentences were presented auditorily. The arguments were either unambiguously case marked by nominative and dative, or they were case ambiguous. Two verb types were used. First active verbs, which require a parallel ranking of syntactic and thematic hierarchies. The second verb type were object-experiencer verbs, which require a cross over of syntactic and thematic hierarchies.

As this is the first ERP experiment investigating the use of word order and case marking in sentence processing with children, the age of 11 was chosen. At 11 years of age, components related to morphosyntactic processing seem to be fairly well established, and tend to be very similar to adults (Hahne et al., 2004; Lück et al., 2001). Furthermore, the cytoarchitectonic structure of important language serving neural areas (BA44) reaches adult characteristics around the age of 11 (Amunts et al., 2003; see also Sowell et al., 2004).

The predictions were the following. First, the full processing architecture may already be established in 11-year-old children. They may already have two distinct processing pathways, one syntactic and the other thematic in nature. In this case, exactly the same ERP components were expected as in adults in Experiment I. Thus, unambiguous morphological case markings should be used to establish a pure thematic ranking of the arguments. In the case of object-experiencer verbs, a thematic reanalysis should become necessary. This reanalysis should be reflected in an early positivity (EPOS). No word order related effects are expected with case marked arguments.

Assuming that the processing mechanisms are already fully established, case ambiguous arguments were expected to be syntactically ranked on the basis of word order, with the first argument being analyzed as the syntactic subject. If the sentence is disambiguated towards an object-initial structure, syntactic reanalysis effects were expected in the form of an N400. In active verbs, the reanalysis-N400 might be followed by a P600, reflecting reanalysis towards a non-canonical word order. No thematic reanalysis effects were expected with ambiguous arguments.

Alternatively, children's sentence processing mechanisms may not yet have reached adult-like state. For instance, not only case information but also positional information may lead to a thematic interpretation. Thus, in ambiguous sentences, the first argument would be ranked higher thematically than the second argument (argument 1 $>_{them}$ argument 2). If the sentence is disambiguated towards an object-initial structure, the thematic representation would have to be revised. This thematic revision should be reflected in an EPOS in object-initial ambiguous sentences.

Of special interest are sentences with conflicting information. Sentences with an initial dative marked object convey contradictory morphological (DAT < NOM) and positional information (argument 1 > argument 2). In order to hierar-

chize the arguments relative to each other, the parser must decide between positional and morphological cues. If the parser relies on morphological cues, then in dative-nominative sentences, the nominative marked argument should be ranked higher than the dative marked argument (DAT < NOM) – which corresponds to the adult strategy.

On the other hand, the parser may rely on positional cues. Thus, in an object-initial sentence, the first argument would be ranked higher than the second argument (DAT > NOM). Hence, word order would always determine the (thematic) hierarchization of the arguments. Crucially, this implies that a thematic reanalysis as reflected in the EPOS effect would be dependent on word order. Thus, an EPOS would be expected in object-initial sentences for active verbs, and in subject-initial sentences for object-experiencer verbs.

Finally, the question arose whether reanalysis differs between active and object-experiencer verbs at all. Thus, does the verb type influence the reanalysis process? If children have different abstract representations of the thematic properties of the two verb classes, and if they can access syntactic and thematic representations separately, the reanalyses processes were expected to differ between dative active and object-experiencer verbs. Nevertheless, this difference must not be identical to the adult ERP pattern.

7.2 Methods

7.2.1 Participants

Overall, 33 children participated in this study. The pre-condition for participation in the EEG experiment was sufficient knowledge of the experimental verbs. This was checked by means of word definitions and sentence production in a pretest which was conducted several days before the EEG sessions (cf. Appendix B). In addition, all children had to pass a test on subject verb agreement. In consequence, 6 children had to be excluded due to insufficient verb knowledge. Six further children had to be excluded from EEG analyses, either due to a missing session or due to performance on chance level in questions with role reversal (cf. Result part).

The final data analysis comprised 21 children (11 female) with a mean age of 11;6 years (range 10;11-12;0). All children were right-handed native speakers of German (as assessed by an adapted German version of the Edinburgh Handed-

ness Inventory, Oldfield, 1971). All children had normal hearing and were healthy. The mean distance between the first and the second session was 7 days (ranging from 2 to 21 days). All children received EUR 3.5 per hour and an individual present.

7.2.2 Experimental Material, Design, and Procedure

Experimental design and EEG recording were identical to Experiment I. The only difference in the procedure was that the children received a verbal instruction instead of a written one. First, their reading competence could not be estimated. Second, instructing them verbally allowed to deepen the experimenter-child relationship and to increase their motivation.

7.2.3 Data Analysis

The analysis of the behavioral data was identical to Experiment I. The EEG analysis was nearly identical to Experiment I. The only difference consisted in the compensation of typical eye movements by a regression algorithm. Otherwise too many trials would have to be rejected. In the case of multiple comparisons the alpha level was corrected according to a modified Bonferroni procedure (Keppel, 1991). Children answering on chance level (more than 45 % errors) in questions involving role reversal were excluded from the analyses.

7.3 Results

7.3.1 Behavioral Data

The error rates for all 8 conditions are shown in Figure 7.1. Both in case marked and in ambiguous sentences, subject-initial sentences with active verbs were the easiest to answer. In addition, the statistical analysis revealed that ambiguous sentences with active verbs elicited less errors than sentences with object-experiencer verbs. The statistical analyses are reported below.

Children answering on chance level (more than 45 % errors) in questions involving role reversal were excluded from the analyses. This was the case for 4 children. The remaining 21 children answered 16 % of all questions incorrectly.

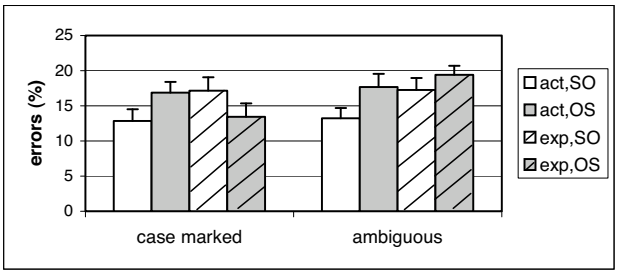

Figure 7.1 Behavioral data of 11-year-old children in Experiment II. Error rates in % (+ s.e.) for conditions with unambiguously case marked and case ambiguous arguments; act = active verbs, exp = object-experiencer verbs; SO = subject-initial, OS = object-initial conditions.

A global ANOVA of the error rates yielded a two-way interaction Order×Verb ($F(1,20) = 16.40$, $p < .01$). This interaction was resolved by Verb, yielding an Order effect only for active verbs ($F(1,20) = 28.50$, $p < .01$). Thus, subject-initial sentences were less error prone (13 % errors) than object-initial sentences (17.3 % errors), if containing an active verb. In addition, the ANOVA yielded a two-way interaction Case×Verb ($F(1,20) = 4.97$, $p < .05$). This interaction was resolved by Case, which resulted in a Verb effect for ambiguous sentences only ($F(1,20) = 14.00$, $p < .01$). Thus, in ambiguous sentences less errors occurred with active verbs (15.5 % errors) than with object-experiencer verbs (18.3 % errors).

7.3.2 ERP Data

The ERPs elicited at the critical verb are shown in Figure 7.2 to Figure 7.4. Three clear condition effects were observed. First, a centro-parietally distributed positivity occurred for object-experiencer verbs in case marked sentences (EPOS; cf. Figure 7.2). The EPOS lasted from 700-1100 ms with a maximum around 1000 ms, although on some posterior electrode sites the positivity seems to start earlier (cf. Appendix F). Second, a negativity (N400) emerged in ambiguous object-initial sentences with active verbs, being most pronounced over centro-parietal electrode sites (cf. Figure 7.3). The N400 lasted from 700-1100 ms with a maximum around 860 ms. Third, a positivity (P600) with a parietal maximum occurred. It lasted from 1200-1600 ms with a peak around 1400 ms. The P600 was most distinctive for object-initial active sentences. However, a small posi-

tivity was also visible for both object-experiencer conditions, compared to subject-initial active sentences, although it was not as large as in the object-initial active condition and peaked approx. 100 ms earlier (cf. Figure 7.4).

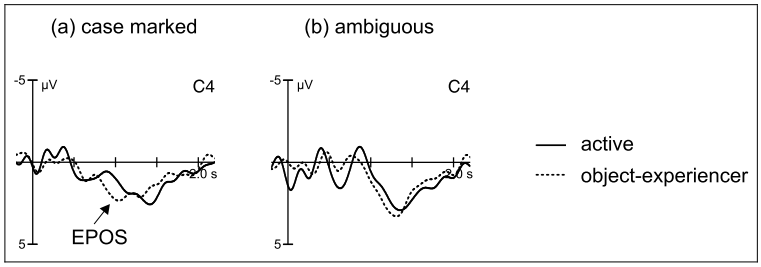

Figure 7.2 Grand average ERPs for dative object-experiencer vs. dative active verbs for 11-year-old children in Experiment II. (a) shows the ERPs for unambiguously case marked arguments and (b) for ambiguous arguments. The figure depicts the right-central electrode C4.

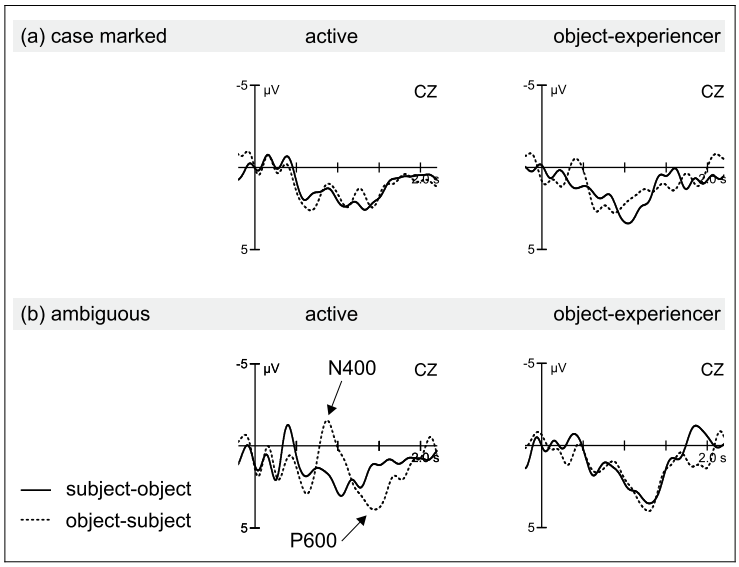

Figure 7.3 Grand average ERPs for dative verbs in object-initial vs. subject-initial sentences for 11-year-old children in Experiment II; (a) shows the ERPs for unambiguously case marked arguments, and (b) shows the ERPs for ambiguous arguments, separately for active (left column) and object-experiencer verbs (right column). The figure depicts the mid-central electrode CZ.

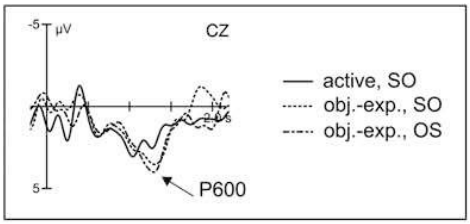

Figure 7.4 Grand average ERPs for ambiguous conditions for 11-year-old children in Experiment II, separately for active verbs in subject-initial sentences (solid line), and for object-experiencer verbs in subject-initial (dotted line) and object-initial sentences (dashed line). The figure depicts the mid-central electrode CZ.

These observations were supported by statistical analyses. To this end, time windows were chosen according to visual inspection of the grand averages, covering the time span in which the difference between two conditions was clearly visible on most electrode sites. Due to differences in the data, the time windows differed from the ones set in Experiment I. The time windows were set at 700-1100 ms for the EPOS and for the N400. A second time window was set at 1200-1600 ms for the P600.

N400 and EPOS (700-1100 ms). In the time window of 700-1000 ms, a global ANOVA yielded an interaction of Case×Order×Verb ($F(1,20) = 9.46$, $p < .01$). The interaction was resolved by Case. Only for ambiguous sentences, there was an interaction of Verb×Order ($F(1,20) = 7.55$, $p < .05$). It was resolved by Verb, yielding a main effect of Order only for active verbs ($F(1,20) = 10.39$, $p < .01$), but not for object-experiencer verbs. This reflected the N400 effect for object-initial sentences with active verbs.

For the analysis of the EPOS effect, the same time window was used as for the N400 effect. In order to exclude the influence of the strong N400 effect in ambiguous object-initial sentences with active verbs, this condition was removed from the statistical analysis of the EPOS effect. With the remaining seven conditions, an ANOVA was computed with the factors Case and Verb, which yielded a tendential interaction Case×Verb ($F(1,20) = 3.99$, $p < .06$)[3]. On the basis of this tendency and on the basis of the hypothesis of an EPOS emerging for object-experiencer verbs in case marked sentences, the statistical

[3] An ANOVA over all 8 conditions did not reveal a Case×Verb interaction ($F(1,20) < 1$).

analysis was resolved by Case. A main effect of Verb only emerged for case marked sentences ($F(1,20) = 4.93$, $p < .05$), which indicated the EPOS for object-experiencer verbs in comparison to active verbs.

P600 (1200-1600 ms). Finally, in the time window of 1200-1600 ms, a global ANOVA revealed an interaction of Case×Order×Verb ($F(1,20) = 6.58$, $p < .05$). The interaction was resolved by Case, yielding a Verb×Order interaction only for ambiguous conditions ($F(1,20) = 5.23$, $p < .05$). This interaction was resolved by Verb, and an additional contrast was computed.

Resolving the interaction by Verb resulted in an Order effect only for active verbs ($F(1,20) = 12.00$, $p < .01$, corrected for multiple comparisons). Thus, a positivity occurred for ambiguous object-initial structures with active verbs. Moreover, in order to verify that both ambiguous object-experiencer conditions were more positive than ambiguous subject-initial active conditions, an additional contrast was computed. The contrast compared the subject-initial active condition vs. (subject-initial object-experiencer + object-initial object-experiencer conditions)/2, which was significant ($F(1,20) = 7.23$, $p < .05$, corrected for multiple comparisons).

7.4 Discussion

The basic findings of Experiment II can be summarized as follows. First, object-experiencer verbs in case marked sentences elicited a positivity (EPOS). Second, ambiguous object-initial sentences with active verbs elicited a biphasic N400-P600 pattern. Third, in ambiguous sentences object-experiencer verbs always elicited a small P600 effect in comparison to subject-initial active structures. The different ERP effects will be discussed in the following.

EPOS

The first effect was a positivity for object-experiencer verbs in comparison to active verbs, which only emerged in case marked sentences. The positivity occurred in the same conditions as the 'EPOS' in adults in Experiment I, and was thus labeled accordingly. The fact that 11-year-old children exhibited an EPOS in case marked sentences leads to the conclusion that they used the case information on the arguments for establishing a thematic hierarchy. More specifically, nominative marked arguments were ranked higher thematically than dative marked arguments. The reranking of the arguments in the case of object-experiencer

verbs was reflected in the EPOS effect. Crucially, no such ranking took place in ambiguous sentences, which was indicated by the missing verb effect in these conditions. Thus, the children did not use word order information alone for a thematic ranking of the arguments.

Despite the similarities, there is also a difference in comparison to adults. The EPOS started about 300 ms later in children than in adults. Such increased latencies in children's ERPs were also reported for other language related components, such as the N400 (Holcomb et al., 1992; Juottonen et al., 1996; Hahne et al., 2004), and the P600 (Hahne et al., 2004). Generally, increased latencies have been interpreted as reflecting slower information processing (Fox et al., 2000). This interpretation can also be adopted here. The delayed onset of the EPOS in comparison to adults suggests that the children's parser does not yet work as fast as the adults' parser. Presumably, the (re)analysis mechanism is not yet as efficient as in adults, resulting in a later onset of computing the thematic structure.

N400 and P600

The second effect was a centro-parietal negativity in ambiguous object-initial sentences with active verbs. Both temporal and topographical characteristics were comparable to those of adults in Experiment I. The component was thus classified as an N400. The N400 was followed by the third component, a late centro-parietal positivity. The positivity was most prominent in ambiguous object-initial sentences with active verbs, but was also present for object-experiencer verbs in both word orders. Both temporal and topographical characteristics were comparable to those of adults in Experiment I. The component was thus classified as a P600.

It is very difficult to interpret the present data on the basis of the relabeling assumption (Bornkessel et al., 2004). Originally, Bornkessel et al. assumed that the N400 observed in the reanalysis of dative-initial sentences originated from the characteristics of object-experiencer verbs. Only object-experiencer verbs have a canonical dative-initial word order. It was assumed that this was somehow 'overgeneralized' to dative active verbs. Hence, all dative verbs benefit from the object-experiencers' basic word order, and the relabeling of existing syntactic positions suffices for reanalysis. Nevertheless, this interpretation does not fit with the present results of 11-year-old children. Crucially, only active verbs displayed an N400 effect, but object-experiencer verbs did not. This is not easily reconciled

with the assumption of an overgeneralization from object-experiencer to active verbs.

Alternatively, the reanalysis-N400 seen with dative verbs might be associated with their intransitive characteristics. As introduced in Chapter 1, a number of theories assume that dative verbs are intransitive. According to Van Valin and La Polla (1997), dative verbs assign only one macrorole to one of their two arguments (Actor or Undergoer). The other argument remains without a macrorole. Moreover, in German, only arguments with a macrorole can agree with the verb. Thus, in dative verbs the single macrorole is always assigned to the subject, but never to the object.

A short excursus shall exemplify how the adult sentence processing system might proceed during sentence processing within the macrorole account. If both arguments are ambiguous, the first argument is analyzed as the subject, due to the subject-first preference. When the parser arrives at the verb, its number information disambiguates the sentence towards a subject- or an object-initial structure. Simultaneously, the thematic interpretation sets in, according to the ADM. With active verbs, the macrorole Actor is assigned to the subject, with object-experiencer verbs the macrorole Undergoer is assigned to the subject (cf. Figure 7.5).

		subject-initial sentence	object-initial sentence
dative active in adults	subject-first preference:	S O	S O
	case assignment:	NOM DAT	DAT NOM
	macroroles:	Actor	Actor
dative object-experiencer in adults	subject-first preference:	S O	S O
	case assignment:	NOM DAT	DAT NOM
	macroroles:	Undg.	Undg.

Figure 7.5 Representation of dative active and dative object-experiencer constructions in adults, following the macrorole account of Van Valin and La Polla (1997).

Due to the general subject-first preference, dative verbs prefer the first argument in a sentence to be the subject, which bears the single macrorole. This preference is satisfied in subject-initial sentences, and the mapping of syntactic and thematic features is straightforward. However, in object-initial sentences, the preference is violated. The macrorole has to be associated with the dispreferred second argu-

ment. This process of dispreferred linking of a single macrorole is reflected in an N400 effect (cf. Bornkessel et al., 2004).

Crucially, the processing of sentences with dative verbs differs in comparison to sentences with accusative verbs. This difference can be explained easily on the basis of their different macrorole representations. In contrast to dative verbs, accusative verbs are always transitive and assign two macroroles: Actor and Undergoer. If a sentence is disambiguated towards the preferred subject-initial structure, the subject is assigned the highest-ranking macrorole Actor, and the object is assigned the macrorole Undergoer. Thus, the mapping of syntactic structure and thematic roles is straightforward, as the Actor precedes the Undergoer (cf. Figure 7.6).

		subject-initial sentence	object-initial sentence
accusative in adults	subject-first preference:	S O	S O
	case assignment:	NOM ACC	ACC NOM
	macroroles:	Actor > Undg.	Actor > Undg.

Figure 7.6 Representation of accusative constructions in adults, following the macrorole account of Van Valin and La Polla (1997).

By contrast, if the sentence is disambiguated towards an object-initial structure, the subject-first preference is violated. In addition, a cross-over assignment of the two generalized roles Actor and Undergoer is necessary. Crucially, the cross-over assignment of two macroroles in accusative verbs differs qualitatively from the dispreferred assignment of one macrorole in dative verbs. Presumably, this cross-over assignment is reflected in the P600 effect (e.g. Bornkessel et al., 2004).

Under the assumption that dative verbs only involve one thematic macrorole, the interpretation of the EPOS effect must be adapted. Originally, it was assumed that the EPOS reflects a reversal of the thematic hierarchy. However, if only one macrorole is assigned, there is no necessity to reverse a hierarchy between this role and another role. Most likely, the nominative marked argument is preferably assigned the Actor role. In object-experiencer verbs, this assignment has to be changed: the single macrorole Actor has to be changed to Undergoer. This change of macroroles is reflected in the EPOS effect.

Let us now return to the results of the 11-year-old children. Ambiguous object-initial sentences with dative active verbs elicited an N400 followed by a

P600, the same pattern as seen in adults in Experiment I. Like adults, the children obviously embarked on a subject-first strategy in ambiguous sentences, establishing a subject $>_{syn}$ object representation on the arguments. On the verb, number agreement information led to a reversal of the previously established representation towards an object-initial structure (object $<_{syn}$ subject). Presumably, 11-year-old children already have an abstract representation of dative active verbs as intransitive. Accordingly, the N400 reflects the assignment of the single macrorole Actor to the dispreferred second argument. As in adults, the reanalysis towards the non-canonical word order is reflected in the subsequent P600.

Crucially, the processing of sentences with object-experiencer verbs fundamentally differed between 11-year-old children and adults. Adults displayed an N400 effect for object-initial sentences, independently of verb type. In contrast, children displayed no N400 effect at all for object-experiencer verbs. Instead, object-experiencer verbs always elicited a P600 effect (in comparison to active verbs in subject-initial sentences). This pattern suggests that the children's processing of sentences with object-experiencer verbs differs qualitatively from sentences with active verbs. Independently of word order, object-experiencer verbs always confronted the children's parser with a problem.

According to the intransitivity account, the absence of the N400 in object-experiencer verbs may be explained as follows. If the N400 is closely bound to the intransitive representation of the respective verb, the missing N400 suggests that exactly this abstract representation of intransitivity is not yet available for the object-experiencer verbs. Rather, 11-year-old children seem to represent two macroroles for object-experiencer verbs (Actor and Undergoer). In this case, (re)analysis involves the (re)assignment of two macroroles (cf. Figure 7.7).

		subject-initial sentence	object-initial sentence
dative object-experiencer at 11 yrs.	subject-first preference:	S O	S O
	case assignment:	NOM DAT	DAT NOM
	macroroles:	Actor > Undg.	Actor > Undg.

Figure 7.7 Representation of dative object-experiencer constructions in 11-year-old children, folowing the macrorole account of Van Valin and La Polla (1997).

With the assumption of two macroroles for object-experiencer verbs, the parser will always run into problems. Verb specific information tells the parser that two macroroles are available. In subject-initial sentences, the subject-first preference

is satisfied. However, a cross-over assignment of the macroroles is necessary, as the higher ranked role Actor is exceptionally associated with the object, and the lower ranked Undergoer with the subject. If the sentence is disambiguated towards an object-initial structure, the subject-first preference is violated. Again, a cross-over assignment of two macroroles is necessary. In terms of the Generalized Hierarchy Approach (Primus & Lindner, 1994), one could say that the desired cross-hierarchy correlations are not given in object-experiencer verbs. Thus, in any case two macroroles have to be assigned in a crossover manner, a process that elicits the P600 effect.

In sum, the processing difficulties 11-year-old children exhibit with object-experiencer verbs are very similar to the adults' difficulties with accusative verbs. In terms of the macrorole account (Van Valin & La Polla, 1997), object-initial sentences with accusative verbs also require a cross-over assignment of two macroroles. As was argued, such a cross-over assignment is reflected in a P600 effect.

The assumption that the abstract representation of object-experiencer verbs is not yet as sophisticated as that of active verbs is supported by behavioral data. As a class, object-experiencer verbs seem to be acquired later than active verbs. Evidence for this was given in the material pretest, which showed that object-experiencer verbs were less familiar than active verbs (cf. Appendix A). The three object-experiencer verbs used in Experiment II were unfamiliar to approx. 29 % of the 7-year-old children, and to 17 % of the 9-year-old children. In contrast, the active verbs were unfamiliar to only 5 % of the 7-year-olds and to none of the 9-year-old children. In addition, 18 % of the 11-year-old children had to be excluded from Experiment II due to insufficient knowledge of the object-experiencer verbs, but none was excluded due to active verbs. This pattern suggests that the verb class of object-experiencer verbs tends to be acquired quite late during childhood.

Crucially, the assumption that 11-year-old children do not have an intransitive representation of object-experiencer verbs does not imply that they do not know the 'meaning' or the logical structure of those verbs. As the pretest of Experiment II had shown, all children participating in the EEG experiment were able to describe the meaning of all object-experiencer verbs. Thus, they already had a representation of the exceptional inverted [nominative-Undergoer < dative-Actor] scheme. Obviously, this representation led to the EPOS effect in case marked sentences, reflecting a thematic restructuring that was only necessary for

object-experiencer verbs, but not for active verbs. Nevertheless, the ERP pattern in case ambiguous sentences strongly suggests that the acquisition of the representation on the level of thematic macroroles is another step in language development. A more detailed discussion about the acquisition of object-experiencer verbs and their abstract representation will follow in Chapter 10 (General Discussion).

Conclusion

Experiment II clearly demonstrates that children at the age of 11 have two separate processing pathways at their disposal, namely a Morphological and a Positional Pathway. When processing unambiguously case marked arguments, the children used morphological case information for a thematic ranking of the arguments, which was independent of word order. Specifically, nominative marked arguments were ranked higher than dative marked arguments. If a revision of the thematic ranking became necessary, as was the case with object-experiencer verbs, this was reflected by a positivity (EPOS). Nevertheless, the thematic revision process was not yet as fast and efficient as in adults, resulting in a later onset of the EPOS. Alternatively, the EPOS may be interpreted as a macrorole change from Actor to Undergoer.

With ambiguous sentences, the interplay of the two distinct hierarchies became even more apparent. Ambiguous arguments were syntactically hierarchized on the basis of positional information, whereby the first argument was analyzed as the syntactic subject. In terms of the ADM, 11-year-old children use the Positional Pathway for processing case ambiguous arguments. The data suggest that active verbs already have an intransitive representation. Thus, the reanalysis towards an object-initial structure involved the re-assignment of the single macrorole Actor. As in adults, this re-assignment was reflected in an N400 followed by a P600.

The most striking effect emerged on object-experiencer verbs. Contrary to dative active verbs, 11-year-old children seem to have a transitive representation of dative object-experiencer verbs. Thus, two macroroles have to be assigned. Crucially, with object-experiencer verbs both subject- and object-initial sentence structures lead to a cross-over arrangement of the two macroroles. The processing costs of crossing macroroles were reflected in the P600 effect for all object-experiencer verbs, compared to active verbs in subject-initial sentences.

Chapter 8
Experiment III: The Processing of Dative Structures in 8-Year-Old Children

8.1 Introduction

Experiment III made one further step down on the age scale and investigated sentence processing mechanisms in children younger than 11 years of age. Experiment I and II showed that there are remarkable age related differences between 11-year-old children and adults. These differences mainly concerned the processing of sentences with ambiguous arguments.

The finding of Experiment II led to the question of what the previous developmental step looks like. Thus, which processing mechanisms do younger children apply? Do they already have two representational hierarchies at their disposal? And how do they use positional information for establishing dependencies between arguments? The answer to these questions would allow us to refine the theory about the development towards the adult sentence processing mechanisms.

In order to investigate how younger children use positional information for hierarchizing arguments, an ERP experiment was conducted, employing the ambiguous sentence conditions of Experiment I and II. Thus, ambiguous subject- and object-initial sentences were presented auditorily. Two different verb types, namely dative active and dative object-experiencer verbs were used. Concerning the age group, children between approx. 8;6 and 9;6 years of age were chosen. The age range was defined according to the behavioral pretest that had been conducted for selecting the stimulus material. The material pretest had shown that especially object-experiencer verbs are often unfamiliar to children younger than 9 years of age (cf. Appendix A).

The hypotheses were the following. First of all, there may be no developmental difference between 8- and 11-year-old children. In this case, exactly the same ERP pattern was expected as was exhibited by the 11-year-olds in Experiment II. Thus, object-initial sentences with active verbs should elicit an N400-P600

pattern. Object-experiencer verbs should elicit a P600 effect, independently of word order.

Alternatively, it might be the case that 8-year-old children do not yet have an intransitive representation of dative active verbs with only one thematic macrorole. If so, the reanalysis of object-initial sentences with active verbs should not elicit an N400 effect. Rather, one would expect only a P600 effect, as object-initial sentences with active verbs would require a cross-over assignment of two macroroles.

A third possibility is that there are no reanalysis differences between the two dative verb types. This might only be the case if thematic and syntactic properties are not represented independently of each other, namely on separate hierarchies that are mapped onto each other (cf. Chapter 7). With only one single hierarchy that encompasses thematic and syntactic properties, object-initial sentences would always require a cross-over representation, but subject-initial sentences would not. Independently of verb type, a cross-over assignment should elicit a P600 effect in object-initial sentences.

8.2 Methods

8.2.1 Participants

Overall, 34 children participated in this study. The pre-condition for participation in the EEG experiment was identical to that in Experiment II. In consequence, 7 children had to be excluded due to insufficient verb knowledge. Two further children were excluded on the basis of the agreement judgment test (cf. Appendix B). Finally, one child was excluded from EEG analyses because of premature disruption of the EEG session.

The final data analysis comprised 24 children (13 female) with a mean age of 8;11 years (range 8;3-9;7). All children were right-handed native speakers of German (as assessed by an adapted German version of the Edinburgh Handedness Inventory, Oldfield, 1971). All children had normal hearing and were healthy. They received an individual present and a gift coupon amounting to EUR 10.

8.2.2 Experimental Material, Design, and Procedure

The experimental design was identical to Experiments I and II, with the main difference that only ambiguous sentences were presented. Hence, Experiment III consisted of a 2×2 factorial design with repeated measures of the two factors 'Order' (SO/OS) and 'Verb' (active/object-experiencer). The procedure of the EEG recording was identical to Experiment II. However, due to the reduced stimulus material the experiment could be performed in a single session.

In sum, 384 different sentences served as stimulus material (96×4). The probability of the first noun being singular or plural was equal and counterbalanced across conditions. The stimulus set was divided into two subsets of equal structure and size (192). Each session was parted into six blocks of the same size. In each block, each condition appeared approximately equally often.

For each subset, two pseudo-randomized versions were created. No more than three sentences with the same property (Order and Verb) followed in sequence. Im sum, four different presentation lists were obtained. They were evenly applied to the participants, counterbalancing the gender of the participants.

8.2.3 Data Analysis

The analysis of the behavioral and the EEG data was identical to Experiment II. The only difference was in the statistical design. Due to the reduced design, the factor Case was irrelevant. As a consequence, the statistical design for the analysis of the behavioral data comprised the two-level factors Order (SO/OS) and Verb (active/object-experiencer). ANOVAs were calculated over group means. The statistical design for the EEG evaluation was composed of three factors with repeated measures. The factors Order (SO/OS) and Verb (active/object-experiencer) had two levels. The factor Region had three levels (anterior/central/posterior). Results were interpreted as significant when reaching the alpha level $p < .05$ or $p < .01$, respectively.

8.3 Results

8.3.1 Behavioral Data

The error rates for all 4 conditions are shown in Figure 8.1. On average, 25 % of all questions were answered incorrectly. Object-initial sentences were more error

prone (27 % errors) than subject-initial sentences (23 % errors). This observation was supported by statistical analysis. A global ANOVA of the error rates yielded a main effect of Order ($F(1,23) = 15.40$, $p < .01$).

In contrast to Experiment II, all 24 children were included in the final analysis. No child was excluded on the basis of percentage correct in the role reversal questions, as all children had equally high error rates of about 45 % in this condition.

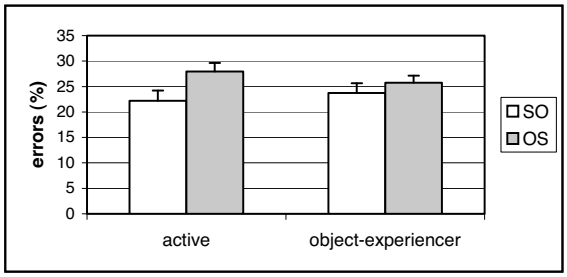

Figure 8.1 Behavioral data of 8-year-old children in Experiment III. Error rates (+ s.e.) for conditions with active and object-experiencer verbs; SO = subject-initial, OS = object-initial conditions.

8.3.2 ERP Data

The ERPs elicited at the critical verb are shown in Figure 8.2 and Figure 8.3. Three clear condition effects were observed. First, a broadly distributed negativity ('early N400') occurred for object-experiencer verbs in comparison to active verbs. It lasted from 400-600 ms and peaked at about 470 ms (cf. Figure 8.3). Second, a negativity (N400), followed by a positivity (P600) emerged in object-initial sentences in comparison to subject-initial sentences (cf. Figure 8.2). Both components were broadly distributed, but most pronounced over centro-parietal electrode sites. The N400 lasted from 750-1200 ms with a maximum around 890 ms. The P600 lasted from 1200-1700 ms with a maximum around 1300 ms.

These observations were supported by statistical analyses. To this end, time windows were chosen according to visual inspection of the grand averages, covering the time span in which the difference between two conditions was clearly visible on most electrode sites. The time windows were set at 400-600 ms for the 'early N400', at 750-1200 ms for the N400, and finally at 1200-1700 ms for the P600.

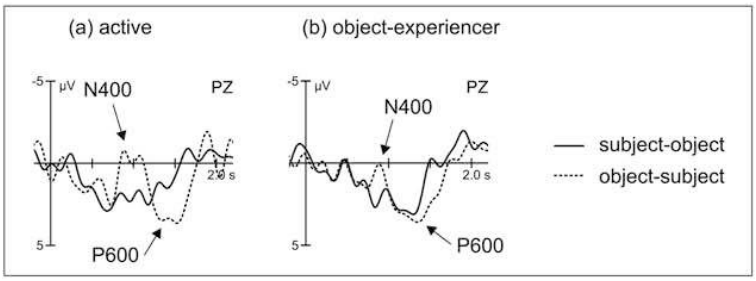

Figure 8.2 Grand average ERPs for dative verbs in object-initial vs. subject-initial sentences for 8-year-old children in Experiment III. (a) shows the ERPs for active verbs, and (b) for object-experiencer verbs. The figure depicts the mid-parietal electrode PZ.

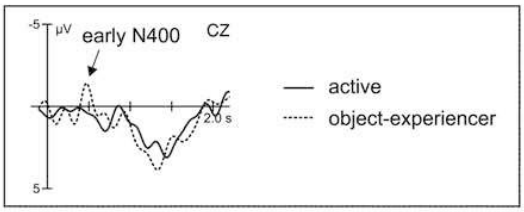

Figure 8.3 Grand average ERPs for dative object-experiencer vs. dative active verbs for 8-year-old children in Experiment III. The figure depicts the mid-central electrode CZ.

Early N400 (400-600 ms). In the time window of 400-600 ms, a global ANOVA revealed a main effect of Verb ($F(1,23) = 7.32$, $p < .05$), indicating a negativity for object-experiencer verbs in comparison to active verbs.

N400 (750-1200 ms). In the time window of 750-1200 ms, a global ANOVA yielded a main effect of Order ($F(1,23) = 11.22$, $p < .01$), which indicated a negativity for object-initial sentences in comparison to subject-initial sentences.

P600 (1200-1700 ms). In the time window of 1200-1700 ms, a global ANOVA revealed an interaction of Order×Region ($F(1,23) = 13.48$, $p < .01$). This interaction was resolved by Region, which yielded a main effect of Order only over central ($F(1,23) = 13.25$, $p < .01$) and parietal electrode sites ($F(1,23) = 26.74$, $p < .01$). Thus, a positivity occurred for object-initial sentences in comparison to subject-initial sentences that was centro-parietally distributed.

8.4 Discussion

The basic findings of Experiment III may be summarized as follows. First, object-experiencer verbs elicited a negativity ('early N400'). Second, all object-initial sentences elicited a biphasic N400-P600 pattern in comparison to subject-initial sentences. The different ERP effects will be discussed in the following.

Early N400

The first effect was a negativity for object-experiencer verbs in comparison to active verbs. Both the latency (400-600 ms) and the broad topographical distribution fit well with the interpretation as an auditorily elicited N400 (e.g. Friederici et al., 1993). At the respective point in time, the verb type could be recognized, but not yet the verb final number information. Thus, the effect is solely verb type related. Crucially, neither the 11-year-olds in Experiment II nor the adults in Experiment I had shown a comparable effect.

Generally, an enhanced N400 component is associated with an increased difficulty of lexical integration (e.g. Hagoort et al., 1999). In the present case, the N400 effect may thus be explained as reflecting an increased difficulty in processing object-experiencer verbs. This would fit well with the results of the material pretest (cf. Appendix A). The material pretest showed that object-experiencer verbs tend to be acquired quite late during childhood, as they were still unfamiliar to many of the 7- and 9-year-old children. As a consequence, the lexical entries of the object-experiencer verbs may not yet be as stable at 8 years of age as they are a few years later. Moreover, even at 11 years of age, object-experiencer verbs still seem to lack the adult intransitivity representation in terms of thematic macroroles, as was suggested by Experiment II. Hence, with 8-year-old children, object-experiencer verbs may require higher integration costs that are reflected in the early N400 effect.

N400 and P600

The second effect was a broadly distributed negativity for object-initial sentences in comparison to subject-initial sentences. Both temporal and topographical characteristics were comparable to those of the adults in Experiment I and to those of the 11-year-olds in Experiment II. Consequently, the present effect was classified as an N400.

The N400 was immediately followed by a late centro-parietal positivity for object-initial sentences in comparison to subject-initial sentences. Both temporal and topographical characteristics were comparable to those of the adults in Experiment I and to those of the 11-year-olds in Experiment II. Hence, the effect was classified as a P600.

Crucially, the N400-P600 pattern emerged for all dative-initial sentences, independently of verb type. Thus, the disambiguation towards an object-initial structure was not influenced by the lexical properties of the verb. However, the uniformity of the word order effect with both verb types cannot be due to insufficient verb knowledge: all children knew the verb meanings, as had been ensured by verbal definitions in the behavioral pretest.

Table 8.1 Results of Experiments I-III. Overview of the ERP effects on the critical verb for ambiguous object-initial sentences compared to subject-initial sentences.

age group	word order effects: object- vs. subject-initial sentences with dative active		dative object-experiencer verbs	
adults	N400	P600	N400	
11 yrs.	N400	P600		(always P600 in comparison to subject-initial active structures)
8 yrs.	N400	P600	N400	P600

The developmental pattern of the ERP effects in the reanalysis of ambiguous object-initial sentences is summarized in Table 8.1. One aspect clearly stands out. Only 8-year-old children showed identical ERP effects for the reanalysis with active and object-experiencer verbs. This indicates that they applied the same reanalysis process with both verb types and did not differentiate between them. Thus, the lexical-thematic properties of object-experiencer verbs did not influence the reanalysis process. Rather, the disambiguation of ambiguous sentences towards an object-initial structure always involved the same type of reanalysis.

The observed pattern suggests that, contrary to the older age groups, 8-year-old children cannot yet deal with hierarchy mismatches. If 8-year-old children could access thematic properties independently of the syntactic structure, the reanalysis of ambiguous object-initial sentences should have elicited different ERP effects for active and object-experiencer verbs, respectively.

This may be closely related to underspecified lexical representations of object-experiencer verbs. The uniform N400-P600 pattern suggests that 8-year-old chil-

dren do not have an inverted hierarchical representation for object-experiencer verbs. As Experiment II had shown, crossed hierarchical representations would have led to word order independent processing difficulties for object-experiencer verbs in form of a P600. Moreover, Experiment II indicated that 11-year-old children have a transitive representation of object-experiencer verbs. This makes it very probable that 8-year-old children also represent object-experiencer verbs as transitive in terms of macroroles.

To sum up, in contrast to older children and adults, there is no evidence that 8-year-old children have two distinct hierarchies – namely a syntactic and a separate thematic hierarchy – at their disposal. Rather, the observed N400-P600 may be explained within one single hierarchy that can be established on a single processing pathway. In case ambiguous sentences, the first argument is interpreted as the higher-ranking one, both in a syntactic and in a thematic sense. Thus, a general hierarchy 'argument 1 > argument 2' is established. The first argument is analyzed as the [subject = Actor], and the second argument as the [object = Undergoer]. If the sentence is disambiguated towards an object-initial structure on the sentence final verb, a complex reanalysis becomes necessary, involving both the syntactic and the thematic representation. This is independent of verb type (cf. Figure 8.4).

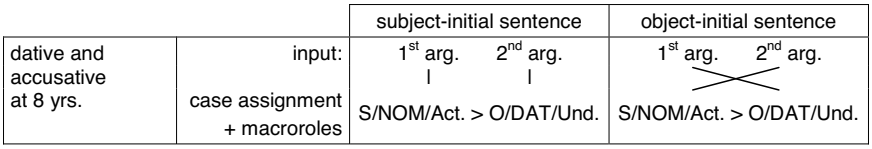

Figure 8.4 Representation of dative constructions in 8-year-old children.

Recall that adults process case ambiguous arguments via the Positional Pathway, and that they do not yet establish any thematic dependencies before the verb is encountered. A reanalysis towards an object-initial structure is accomplished by relabeling the already established syntactic nodes, which was reflected in an N400. Alternatively, reanalysis was interpreted as the reassignment of one macrorole.

Under the assumption of one general hierarchy for 8-year-old children, no separate representation of syntactic and thematic properties is possible. Therefore, a reanalysis always involves a restructuring of syntactic *and* thematic properties. The elicited ERP pattern may thus be interpreted as follows. The P600 effect presumably reflects the reanalysis towards the dispreferred object-initial

structure (e.g. Friederici et al., 2001) or a crossed macrorole assignment. The N400 effect may reflect the processing of the 'unexpected' number marking on the verb. Disambiguation was realized by number agreement of subject and verb. Due to the subject-first preference children expected the verb to agree with the first NP, which resulted in a mismatch in object-initial sentences (e.g. 'dass $Julia_{SG}$ $Lehrerinnen_{PL}$ $danken_{PL}$'). Hence, the N400 in 8-year-old children may not be specific to the processing of dative verbs and thus differ from the N400 effect seen in adults (who do not generally show such an effect for number mismatch).

The representation on a single hierarchical dimension might also be the source of the early N400 effect. If the arguments are syntactically and thematically ranked in advance of the verb (argument 1 > argument 2), object-experiencer verbs require a reversal of the thematic aspect of this ranking. In adults, such a thematic reversal is reflected in an EPOS effect (cf. Experiment I). However, with a single hierarchical representation, no separate reversal of the thematic properties is possible. Still, the parser realizes that with object-experiencer verbs argument 1 is no ideal Actor. This classification as an imperfect or 'degraded' Actor may be reflected in the early N400 effect (see also Schlesewsky & Frisch, submitted).

Conclusion

In summary, Experiment III shows that children at 8 years of age apply fundamentally different sentence processing strategies to 11-year-olds and adults. Independently of verb type, the reanalysis towards the dispreferred dative-initial structure was always reflected in an N400-P600 pattern. The missing influence of verb type on reanalysis suggests that 8-year-old children do not process syntactic and thematic information separately. Rather, the children seem to have only one processing pathway at their disposal. When processing case ambiguous arguments, the initial argument is ranked higher than the second one with regard to both syntactic and thematic properties. As a consequence, the reanalysis towards an object-initial structure elicits the same N400-P600 pattern with dative active and dative object-experiencer verbs. Moreover, the lexical integration of object-experiencer verbs seems to be generally more difficult for 8-year-old children, which was reflected in an early N400. Alternatively, the early N400 might reflect the inability to assign ideal Actor attributes to the first argument of object-experiencer verbs.

Chapter 9
Experiment IV: The Processing of Accusative Structures in Adults and 8-Year-Old Children

9.1 Introduction

The purpose of Experiment IV derived from the 8-year-olds' ERP effects in Experiment III. The results of Experiment III suggested that the N400-P600 pattern in ambiguous dative-initial sentences was not specific to the reanalysis of dative structures. Rather, it was assumed that 8-year-old children cannot yet process thematic and syntactic dependencies separately. If this interpretation were correct, one would predict that the reanalysis of any ambiguous object-initial sentence should elicit the same N400-P600 pattern, independently of the lexical properties of the respective verb. Adults, by contrast, apply different re-analysis mechanisms depending on the lexical verb properties. Specifically, the disambiguation towards an object-initial structure elicits an N400 with dative verbs, but a P600 with accusative verbs (cf. Bornkessel et al., 2004).

One central syntactic characteristic of accusative structures is that – contrary to dative – accusative-initial word orders are never unmarked. A typical way of modelling the distinction between unmarked and marked orders in generative syntactic approaches is to associate the former with base generation and the latter with some type of syntactic derivation, namely movement. Thus, accusative-initial orders are typically derived via movement of the accusative NP (cf. (9.1b); also see Chapter 1).

Accordingly, in sentence processing the reanalysis towards an accusative-initial word order always involves a reconstruction of the syntactic tree. In addition to the base generated positions, a further syntactic position has to be created for the moved accusative object (cf. (9.1a/b)). In contrast, no additional position has to be assumed for dative-initial sentences – at least under the

assumption of a generally available unmarked dative-nominative order (cf. Chapter 3).

(9.1) a) [dass [[$Maria_{subject}$ $Sängerinnen_{object}$ $besucht_{SG}$]]]
'that Maria visits singers'

b) [dass [$Maria_{obj.}$ [$Sängerinnen_{subject}$ t_{object} $besuchen_{PL}$]]]
'that singers visit Maria'

Alternatively, accusative verbs may be described as transitive verbs that assign two macroroles (Van Valin & La Polla, 1997). Thus, reanalysis towards an object-initial word order involves the reassignment of those two macroroles. As discussed in Chapter 7, such a cross-over reassignment of two macroroles differs from the reassignment of one single macrorole in the case of dative verbs.

The crucial question was whether 8-year-old children apply the same reanalysis mechanism for accusative as for dative sentences. To this end, an ERP experiment was conducted in which sentences with accusative verbs were presented auditorily. As in Experiments I-III, two arguments preceded the verb. In order to investigate the role of case markings, the arguments were either case marked with nominative and accusative, or they were case ambiguous. Sentences with ambiguous arguments were disambiguated by number agreement on the verb. The role of word order was investigated by presenting subject- and object-initial sentences.

Due to the absence of previous auditory ERP experiments on the processing of accusative-initial sentences, Experiment IV was also conducted with an adult control group. On the basis of preceding visual experiments (e.g. Friederici & Mecklinger, 1996; Friederici et al., 2001; Bornkessel et al., 2004), the following ERP effects were predicted for adults. The reanalysis of object-initial ambiguous sentences with accusative verbs was expected to elicit a P600 effect on the disambiguating verb. No word order effects were predicted for case marked conditions.

The hypotheses for 8-year-old children were the following. If the N400-P600 pattern exhibited in the reanalysis of dative-initial sentences is not dependent upon the specific characteristics of dative verbs, then the same N400-P600 pattern is expected in the reanalysis of sentences with accusative verbs in Ex-

periment IV. Alternatively, reanalysis mechanisms might differ between dative and accusative verbs. In this case, an adult-like P600 effect was predicted for the reanalysis of object-initial accusative sentences at the position of the verb.

9.2 Methods

9.2.1 Participants

Adults. The final data analysis comprised 23 adults (12 female) with a mean age of 24 years (range 18-30). Two further adults participated in the experiment, but had to be excluded from the analysis, because almost all trials were affected by artifacts. All participants were right-handed (as assessed by an adapted German version of the Edinburgh Handedness Inventory, Oldfield, 1971), monolingual native speakers of German, and were healthy. All participants received EUR 7 per hour.

Children. Overall, 32 children participated in this study. Three children had to be excluded from EEG analyses due to insufficient performance in the subject verb agreement task (more than 37 % errors). Two children were excluded from data analysis due to a premature disruption of the EEG session. Two further children were excluded due to performance on chance level in at least one experimental condition (more than 45 % errors).

The final data analysis comprised 25 children (12 female) with a mean age of 8;11 years (range 8;2-9;9). All children were right-handed native speakers of German (as assessed by an adapted German version of the Edinburgh Handedness Inventory, Oldfield, 1971). All children had normal hearing and were healthy. They received an individual present and a gift coupon amounting to EUR 10.

9.2.2 Experimental Material and Design

9.2.2.1 Experimental Sentences

The experimental design was kept close to Experiment I with the main difference that the dative verbs were replaced by verbs requiring accusative objects. Accordingly, case marking was changed from dative to accusative. An overview of the experimental stimuli is given in Appendix C.

The stimulus material comprised a 2×2 factorial design with repeated measures of the two factors 'Case' of the NPs (unambiguous/ambiguous) and 'Order' (SO/OS). This resulted in 4 different experimental conditions (see Table 9.1). The sentence structure was identical to Experiment I. All noun-noun combinations and the sentence continuations were identical to Experiment I. Only the verbs were replaced. Sixteen different verbs were chosen, which were presumably known by school-aged children.

Table 9.1 Experimental conditions in Experiment IV.

	case marked	**case ambiguous**
SO	Dass der Ritter die Zwerge besucht, ...	Dass Lena Piloten besucht, ...
	that [the knight]$_{NOM}$ [the dwarfs]$_{ACC}$ [visit]$_{SG}$	that [Lena]$_{AMB,SG}$ [pilots]$_{AMB,PL}$ [visits]$_{SG}$
	'That the knight visits the dwarfs, ...'	'That Lena visits pilots, ...'
OS	Dass den Ritter die Zwerge besuchen, ...	Dass Lena Piloten besuchen, ...
	that [the knight]$_{DAT}$ [the dwarfs]$_{NOM}$ [visit]$_{PL}$	that [Lena]$_{AMB,SG}$ [pilots]$_{AMB,PL}$ [visit]$_{PL}$
	'That the dwarfs visit the knight, ...'	'That pilots visit Lena, ...'

Ninety-six quadruples (i.e. 384 different sentences) were obtained as stimulus material. Each individual verb appeared three times in each condition. The probability of the first noun being singular or plural was equal and counterbalanced across conditions. The stimulus set was divided into two subsets of equal structure and size (192). Each subset was parted into six blocks of the same size. In each block, each condition appeared approximately equally often.

For each subset, two pseudo-randomized versions were created. No more than three sentences with the same property (Case and Order) followed in sequence. All in all, four different presentation lists were obtained. They were evenly applied to the participants, counterbalancing the gender of the participants.

All sentences were spoken condition by condition by the same professional female speaker as in Experiment I in a child directed manner. Processing and analysis of the acoustic stimuli was identical to Experiment I.

9.2.2.2 Task

Analogous to Experiment I, each sentence was followed by a comprehension question in order to ensure attentive listening. Question types and formulations were identical to Experiment I. Questions could be answered by "yes" or "no". In false questions, either the first noun, the second noun, or the verb was replaced

by another one. The replaced nouns were not part of the experimental material. Verbs were always replaced by another experimental verb. Finally, the thematic roles could be reversed. Each question type (first noun, second noun, verb, reversal) appeared equally often and was counterbalanced across conditions. All questions were spoken by a professional male speaker.

9.2.3 Procedure, Apparatus, and Data Analysis

Procedure, EEG recording, EEG data analysis, and the analysis of the behavioral measures were identical to Experiments I and III, respectively. The statistical design for the analysis of the behavioral data consisted of the two-level factors Case (unambiguous/ambiguous) and Order (SO/OS). ANOVAs were calculated over group means. The statistical design for the EEG evaluation was composed of three factors with repeated measures. The factors Case (unambiguous/ambiguous) and Order (SO/OS) had two levels. The factor Region had three levels (anterior/central/posterior). Results were interpreted as significant when reaching the alpha level $p < .05$ or $p < .01$, respectively.

9.3 Results

9.3.1 Adults

9.3.1.1 Behavioral Data

The error rates for all 4 conditions are shown in Figure 9.1. On average, 6 % of all questions were answered incorrectly.

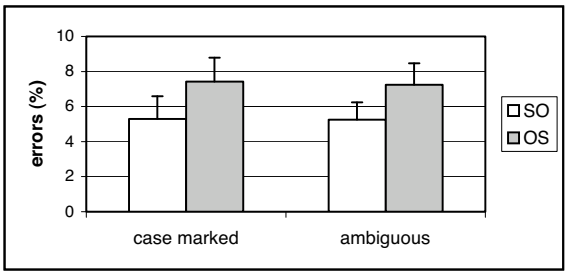

Figure 9.1 Behavioral data of adults in Experiment IV. Errors in % (+ s.e.) for conditions with unambiguously case marked and case ambiguous arguments. SO = subject-initial, OS = object-initial conditions.

Object-initial sentences were more error prone (7.6 % errors) than subject-initial sentences (5.2 % errors). This observation was supported by statistical analysis. A global ANOVA of the error rates yielded a main effect of Order ($F(1,22) = 7.12$, $p < .05$).

9.3.1.2 ERP Data

The ERPs elicited at the critical verb are shown in Figure 9.2. Two clear condition effects were observed. For ambiguous object-initial structures compared to subject-initial structures, a centro-parietally distributed negativity (N400) occurred. The N400 lasted from 500-1000 ms with a maximum around 740 ms. It was followed by a centro-parietally distributed positivity (P600), which lasted from 1000-1600 ms with a maximum around 1350 ms.

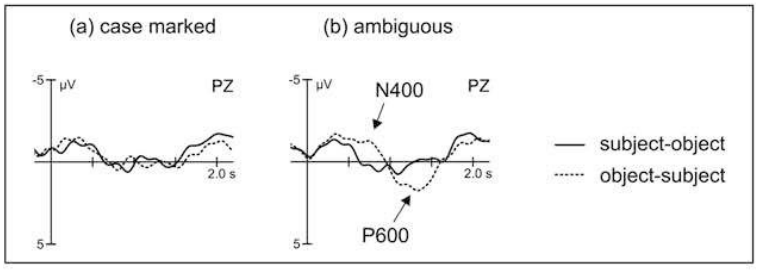

Figure 9.2 Grand average ERPs for accusative verbs in object-initial vs. subject-initial sentences for adults in Experiment IV. (a) shows the ERPs for conditions with unambiguously case marked arguments and (b) for conditions with ambiguous arguments. The figure depicts the mid-parietal electrode PZ.

These observations were supported by statistical analyses. To this end, time windows were chosen according to visual inspection of the grand averages, covering the time span in which the difference between two conditions was clearly visible on most electrode sites. Time windows were set at 500-1000 ms for the N400, and at 1000-1600 ms for the P600.

N400 (500-1000 ms). In the time window of 500-1000 ms, a global ANOVA yielded an interaction Case×Order×Region ($F(2,44) = 7.71$, $p < .01$). The interaction was resolved by Case, resulting in an Order×Region interaction only for the ambiguous conditions ($F(2,44) = 11.96$, $p < .01$). Resolving this inter-

action by Region yielded an Order effect only over central ($F(1,22) = 7.94$, $p < .01$) and parietal electrode sites ($F(1,22) = 27.30$, $p < .01$). Thus, a centro-parietally distributed negativity occurred for ambiguous object-initial sentences in comparison to ambiguous subject-initial sentences.

P600 (1000-1600 ms). In the time window of 1000-1600 ms, a global ANOVA revealed an interaction of Case×Order×Region ($F(2,44) = 22.93$, $p < .01$). The interaction was resolved by Case, which yielded an interaction Order×Region only for the ambiguous conditions ($F(2,44) = 21.16$, $p < .01$). Resolving this interaction by Region yielded an Order effect only over central ($F(1,22) = 6.00$, $p < .05$) and parietal electrode sites ($F(1,22) = 17.63$, $p < .01$). Hence, a centro-parietally distributed positivity occurred for ambiguous object-initial sentences in comparison to ambiguous subject-initial sentences.

9.3.2 Children

9.3.2.1 Behavioral Data

The error rates for all 4 conditions are shown in Figure 9.3. Two children were on chance level within one or more conditions. They were excluded from the entire analysis. The remaining 25 children answered 17 % of all questions incorrectly. With case marked arguments, object-initial word sentences were more error prone (21 % errors) than subject-initial sentences (13 % errors). With ambiguous arguments, the same tendency is present, although not as prominent (19 % vs. 17 % errors).

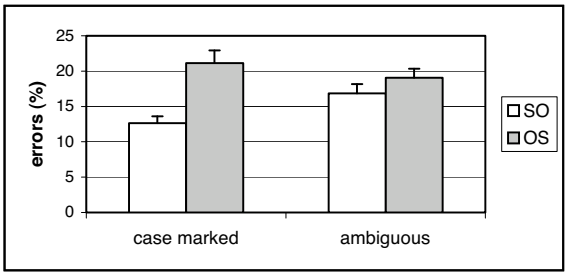

Figure 9.3 Behavioral data of 8-year-old children in Experiment IV. Error rates (+ s.e.) for conditions with unambiguously case marked and case ambiguous arguments. SO = subject-initial; OS = object-initial conditions.

These observations were confirmed by statistical analyses. A global ANOVA of the error rates yielded a two-way interaction of Case×Order ($F(1,24) = 15.90$, $p < .01$). The interaction was resolved by Case. A main effect of Order only emerged for the case marked conditions ($F(1,25) = 30.31$, $p < .01$).

9.3.2.2 ERP Data

The ERPs elicited at the critical verb are shown in Figure 9.4. Two clear condition effects were observed in ambiguous object-initial sentences. The first effect was a centro-parietally distributed negativity (N400). The N400 lasted from 600-1200 ms with a maximum around 880 ms. The second effect was a positivity (P600) that was most prominent over parietal electrode sites. The P600 lasted from 1300-1800 ms and peaked at approx. 1500 ms. In addition, between 250 and 500 ms the ERPs in subject-initial conditions were more negative going than in object-initial conditions.

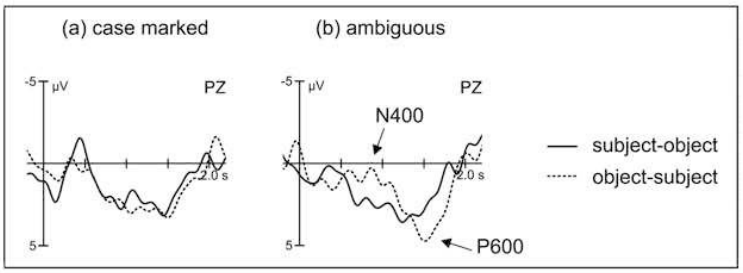

Figure 9.4 Grand average ERPs for accusative verbs in object-initial vs. subject-initial sentences for 8-year-old children in Experiment IV. (a) shows the ERPs for conditions with unambiguously case marked arguments and (b) for conditions with ambiguous arguments. The figure depicts the mid-parietal electrode PZ.

These observations were supported by statistical analyses. To this end, time windows were chosen according to visual inspection of the grand averages, covering the time span in which the difference between two conditions was clearly visible on most electrode sites. The time windows were set at 250-500 ms for the early negativity, at 600-1200 ms for the N400, and at 1300-1800 ms for the P600.

Early effect (250-500 ms). In the time window of 250-500 ms, a global ANOVA resulted in a main effect of Order ($F(1,24) = 5.14$, $p < .05$). ERPs in subject-initial conditions were more negative going than in object-initial conditions.

N400 (600-1200 ms). In the time window of 600-1200 ms, a global ANOVA yielded a three-way interaction Case×Order×Region ($F(2,48) = 10.35$, $p < .01$). The interaction was resolved by Case, which resulted in an Order×Region interaction for ambiguous conditions ($F(2,48) = 6.17$, $p < .05$). This interaction was in turn resolved by Region, yielding an Order effect only over central ($F(1,24) = 10.32$, $p < .01$) and parietal electrode sites ($F(1,24) = 9.97$, $p < .01$). Thus, a centro-parietal negativity emerged for ambiguous object-initial sentences compared to subject-initial sentences. In addition, there was an Order×Region interaction for case marked conditions ($F(2,48) = 4.37$, $p < .05$). However, resolving the interaction by Region did not yield an Order effect within any region.

P600 (1300-1800 ms). In the time window of 1300-1800 ms, a global ANOVA revealed a three-way interaction Case×Order×Region ($F(2,48) = 4.84$, $p < .05$). The interaction was resolved by Case, which yielded an interaction Order×Region only for ambiguous sentences ($F(2,48) = 6.67$, $p < .01$). This interaction was resolved by Region. An Order effect only emerged over parietal electrode sites ($F(1,24) = 6.19$, $p < .05$). Hence, a parietally distributed negativity occurred for ambiguous object-initial sentences compared to subject-initial sentences.

9.4 Discussion

The findings of Experiment IV may be summarized as follows. In object-initial sentences with ambiguous arguments a clear ERP pattern emerged for adults and children, namely an N400 followed by a P600 effect. For unambiguously case marked sentences, this N400-P600 pattern was not observed. As in Experiment I, the reason for the late onset of the components is the late uniqueness-point with the number information becoming available only at the end of the verb (approx. at 500 ms).

Adults

The emergence of an N400 effect in adults was completely unexpected. The unforeseen adult ERP pattern will thus be discussed first. Preceding visual experiments with comparable syntactic structures (Bornkessel et al., 2004) and all other previous studies examining the reanalysis of accusative-initial structures reported only a P600 effect (e.g. Friederici & Mecklinger, 1996; Friederici et al., 2001). The P600 was interpreted as reflecting the reanalysis towards a non-canonical word order, which requires a restructuring of the syntactic tree. In terms of the macrorole approach of Van Valin and La Polla (1997) the P600 may also be interpreted as reflecting the cross-over assignment of two generalized roles (cf. Chapter 7).

There are several possibilities as to how this modality dependent difference in the ERP pattern may be explained. First of all, the N400-P600 pattern seen in the grand average might be composed of an N400 effect displayed by one group and a P600 effect displayed by another group of participants. Such individual differences were for instance observed by Osterhout (1997) in visually presented sentences with a syntactic violation. However, in Experiment IV each single participant showed a negativity followed by a positivity in ambiguous object-initial compared to subject-initial conditions. Thus, the N400-P600 pattern is stable over all participants and cannot be attributed to individual differences.

An alternative possibility is suggested by Roehm (2004). He compared the physical properties of syntax related N400 and P600 effects by examining their frequency characteristics. To this end, Roehm reanalyzed the N400 in dative-initial sentences reported by Bornkessel et al. (2004), and the P600 elicited by ungrammatical double nominative constructions reported by Frisch and Schlesewsky (2001) (cf. Section 3.1). The results showed that the reanalysis-N400 and the P600 in double nominatives have the same frequency characteristics. That is, both components result from increased evoked power in the delta band (around 1-3 Hz), and from increased phase locking. The common frequency characteristics suggested that both components originate from the same underlying oscillation that only shifts in phase. Hence, the reanalysis-N400 and the P600 may reflect similar underlying mechanisms when elicited in syntax processing paradigms.

The interpretation of N400 and P600 reflecting the same underlying process might also clarify the data at hand. If this explanation is correct, the whole proc-

ess of reanalysis in Experiment IV may partially be reflected in the N400 and partially in the P600. As discussed above, all participants showed an N400-P600 pattern. However, in some participants reanalysis might be reflected in a larger N400, followed by a smaller P600. In other participants the relation might be reversed. If there is such a 'complementary' distribution of the two effects, one would predict a negative correlation between the amplitudes of N400 and P600. Alternatively, the two effects may be independent of each other, and both equally reflect the processing of the object-initial sentences. If so, one would predict a positive correlation between the amplitudes of N400 and P600.

To test these hypotheses, a post hoc statistical analysis of Experiment IV was carried out. Correlations of the N400 and P600 amplitude were computed, taking the maximal amplitudes in the time windows of 500-1000 ms for the N400 effect and 1000-1600 ms for the P600 effect into account. The result showed that the two amplitudes were positively correlated ($r = .46$, $p < .05$; Pearson Product Moment Correlation). This suggests that N400 and P600 are not two complementarily distributed reflections of the same underlying process. Rather, the positive correlation indicates that both components reflect the reanalysis of accusative-initial sentences in equal strength.

The third explanation for the emergence of the N400 effect concerns the prosodic properties of the stimulus material. In Experiment IV, the speaker succeeded in pronouncing all sentences as similarly as possible (cf. Appendix E). Acoustic analyses of the single phrases showed that there were no durational differences between subject- and object-initial sentences. In the course of fundamental frequency (f0) only minor word order differences emerged, amounting to approx. 5 to 6 Hz difference on the first NP. However, in natural speech a 5 or 6 Hz deviation from a frequency of about 230 Hz cannot be perceived by the listener. According to t'Hart et al. (1990) deviations from 230 Hz can only be perceived if they amount to at least 20 Hz.

Thus, in Experiment IV there were no salient prosodic cues indicating an object-initial word order. Nevertheless, the parser might expect prosodic cues of word order. For instance, in Experiments I-III word order had an effect on phrase length. The missing prosodic cues in Experiment IV may have reinforced the subject-first preference, such that the disambiguation towards the unexpected object-initial word order was more costly than in the visual modality. This might have elicited the additional N400 effect.

Fourth, ambiguous object-initial sentences may be less acceptable when participants hear them compared to when they read them. This lower degree of acceptability may have caused additional processing costs and elicited the additional N400 effect. Alternatively, ambiguous object-initial sentences may be less frequent in spoken speech than in written text and thus require additional processing capacities. Possibly, in written text word order is less restricted (e.g. Haider & Rosengren, 2003; Lenerz, 1977). Object-initial word order may be used in order to express and highlight specific meanings, for instance in novels, newspapers, or official texts. It might thus be the case that the context in written texts licenses non-canonical word orders more often than oral language does. Presumably, the most frequent auditory language input is that of colloquial everyday language. One could imagine that colloquial speech is more restrictive with regard to word order and does not allow as many non-canonical constructions as for example a novel does. Nevertheless, the reason why such a lower degree of acceptability or frequency should be reflected in the N400 effect, instead of an increased P600 effect, is unclear. It could be related to the fact that in single word processing low frequent words elicit a greater N400 than high frequent words (e.g. Rugg, 1990). However, it remains speculative whether effects of word frequency allow a generalization to effects of structural frequency.

A fifth point concerns results of experiments employing a completely different experimental method, namely that of functional magnetic resonance imaging (fMRI). Two recent fMRI studies attest to influences of modality in the processing of German word order variations. Identical sentence structures were once presented visually (Fiebach, Schlesewsky, Bornkessel, & Friederici, 2004), and once auditorily (Röder, Stock, Neville, Bien, & Rösler, 2002).

(9.2) Jetzt wird der Astronaut dem Forscher den Mond beschreiben.
now will [the astronaut]$_{NOM}$ [to the scientist]$_{DAT}$ [the moon]$_{ACC}$ describe

(9.3) Jetzt wird dem Forscher den Mond der Astronaut beschreiben.
now will [to the scientist]$_{DAT}$ [the moon]$_{ACC}$ [the astronaut]$_{NOM}$ describe

The sentences were either of basic word order (cf. (9.2)), or of a scrambled, object-initial word order (cf. (9.3)). Thus, the same word order variation was employed as in the present experiments. Sentences like (9.3) are grammatical in

German, but syntactically more complex and less acceptable than sentences like (9.2).

In visual presentation, syntactic complexity was correlated with brain activity in the pars opercularis of the left inferior frontal gyrus (IFG), a part of Broca's area (Fiebach et al., 2004). Thus, the more complex a syntactic structure, the more activation emerged in the left IFG. In addition, in auditory presentation not only the left IFG but also temporal brain areas (superior and medial temporal gyrus) showed increasing activity with increasing syntactic complexity (Röder et al., 2002).

Interestingly, the modality differences observed in fMRI might give a hint as to the interpretation of the modality differences observed in ERPs. Despite the differences in the stimulus material, one might cautiously associate the activations elicited by scrambled structures in the fMRI experiments with the ERP effects in the present ERP experiment. The additional temporal activation in auditory sentence processing reported by Röder et al. (2002) may be related to the additional N400 effect seen in Experiment IV. Hence, the N400 might result from a complexity dependent activation in the temporal region, which is bound to the processing of auditorily presented sentences. The P600 in contrast may then reflect modality independent reanalysis processes, which might be attributable to a network of inferior frontal areas and basal ganglia (cf. Frisch, Kotz, Von Cramon, & Friederici, 2003; Ullman, 2004).

Taken together, modality dependent differences in the processing of scrambled sentences appeared both in fMRI studies (Fiebach et al., 2004 vs. Röder et al., 2002) and in ERP studies (e.g. Bornkessel et al., 2004 vs. Experiment IV). Thus, certain aspects of auditory sentence processing possibly involve other underlying neural mechanisms than visual sentence processing. Nonetheless, all of the above explanations remain speculative at present.

Children

On the basis of the adult control group's results the data of the 8-year-old children are difficult to interpret. Superficially, children exhibited the same N400-P600 pattern for the reanalysis of accusative-initial sentences as the adult control group did. Nevertheless, at 8 years of age, all dative-initial sentences also elicit an N400-P600 pattern (Experiment III). In the face of these results, it cannot be decided whether the reanalysis of accusative structures is already adult-like, or

whether the N400-P600 is a sign of general mismatch or repair that is independent of the specific verb type.

Nonetheless, in order to describe the reanalysis mechanisms of ambiguous object-initial sentences, one single model for dative and accusative verbs would suffice. The ERP patterns observed in Experiments III and IV may easily be explained with the assumption of one general processing pathway that encompasses the establishment of thematic and syntactic properties. There was no evidence that 8-year-old children applied different reanalysis mechanisms depending on verb type. Nevertheless, the complexity of the described pattern of results is far from being completely understood, as becomes evident in the unexpected ERP pattern in the adult control group, but also in the unpredicted early word order related effect in the children.

Conclusion

To sum up, Experiment IV yielded surprising results on adults' processing of accusative sentences in the auditory modality. The disambiguation of an ambiguous structure towards an accusative-initial word order elicited an N400, followed by a P600 effect. Whereas the P600 was predicted from preceding visual studies, the N400 effect was unforeseen.

Several explanations might account for the modality dependent difference of reanalysis effects. For instance, processing costs might be increased due to the absence of prosodic differences on word order, or due to a lower acceptability of auditorily presented accusative-initial sentences. Finally, recent fMRI studies showed that compared to visual presentation, additional brain areas are involved in the processing of auditorily presented object-initial German sentences. This finding might be related to the additional ERP effect found in the present experiment.

Eight-year-old children also exhibited an N400-P600 pattern. As such, the ERP pattern did not differ between the reanalysis of dative (Experiment III) and accusative-initial structures (Experiment IV). Thus, independently of verb type, reanalysis mechanisms can be explained with the assumption of one single processing pathway.

Chapter 10
General Discussion

The major objective of the present thesis was to contribute to the understanding of how argument-processing mechanisms develop during childhood. The specific question was whether school-aged children already have two representational hierarchies for syntactic and thematic information, as adults have, and how the interplay of these hierarchies develops with increasing age.

Several ERP experiments revealed new insights into the development of the neural processes underlying the comprehension of auditorily presented sentences. They demonstrated that language acquisition is not yet fully accomplished when children enter school. Rather, the development towards the fine-grained structure of the adult sentence processing mechanisms still takes place throughout primary school years and beyond.

According to the Argument Dependency Model (ADM) (Schlesewsky & Bornkessel, 2004) adult speakers of German have two processing pathways at their disposal. Both serve the establishment of a hierarchical ranking of the arguments of a sentence, but each pathway uses a different type of information. The Morphological Pathway ranks the arguments thematically on the basis of morphological case markings. The Positional Pathway ranks the arguments syntactically on the basis of word order, if no unambiguous case markings are available.

Crucially, the precondition for the independent usage of these two pathways is the ability to represent syntactic and thematic properties separately. Only then, inverse hierarchical relations can be represented. This becomes necessary in the case of dative object-experiencer verbs. They require a cross-over representation of thematic and syntactic hierarchies, in which the thematically higher ranked argument is the syntactically lower ranked dative object. Finally, a true separation of the two pathways is only achieved if children have learned that only unambiguous morphological case information reliably indicates thematic relations, but that word order information does not.

Concerning the course of language acquisition there is increasing evidence that the development of the neural basis of language processing still takes place

throughout later childhood, and lasts well into the teenage years. Recent neuroanatomical studies revealed that language related areas undergo important developmental changes at least until the age of 11 (Amunts et al., 2003; Sowell et al., 2004). This fits well with previous ERP experiments on children's sentence processing which showed that ERP components related to syntactic structure building only attain adult-like characteristics around the age of 13 (Hahne et al., 2004). However, the exact nature of the abstract representation of children's argument hierarchies has never been specified, neither have respective neural processes.

The discussion will first focus on the developmental pattern that became evident in the ERP experiments of this thesis. Subsequently, the implications for adult sentence processing models will be discussed that emerged from the children's data and from modality dependent differences.

10.1 Developmental Steps

Experiments I to IV revealed clear developmental effects. An overview of the results from all experiments of this thesis is given in Table 10.1. The data showed that sentence processing mechanisms undergo important changes between 8 and 11 years of age. Even at 11 years of age they have not yet reached full-grown routines. The development towards the final adult system presumably extends further into the later teenage years.

Table 10.1 Summary of the results from Experiments I-IV. Overview of the ERP effects on the critical verb. 'Verb type effect' is the ERP effect for dative object-experiencer verbs in comparison to dative active verbs (Experiments I-III); 'word order effect' is the ERP effect for ambiguous object-initial structures in comparison to ambiguous subject-initial structures (Experiments I-IV); * in 11-year-old children object-experiencer verbs always elicited a P600 effect in comparison to subject-initial active conditions, but no word order related effect emerged.

condition	adults		11 yrs.		8 yrs.	
verb type effect: object-experiencer vs. active verbs						
case unambiguous	EPOS		EPOS		*- no experiment -*	
case ambiguous					early N400	
word order effect: object-initial vs. subject-initial sentences						
accusative	N400	P600	*- no experiment -*		N400	P600
dative active	N400	P600	N400	P600	N400	P600
dative obj.-exper.	N400		(always P600*)		N400	P600

The most prominent age related differences were observable in the processing of sentences with ambiguous arguments. Although the disambiguation towards an object-initial structure led to increased processing costs in all participants, the respective ERP patterns differed substantially between age groups.

Unlike the older age groups, 8-year-old children exhibited a uniform N400-P600 ERP pattern in the reanalysis of ambiguous object-initial sentences, independently of verb type. This suggests that 8-year-old children did not differentiate between verb types, such as accusative, dative active, and dative object-experiencer verbs.

By contrast, 11-year-old children clearly differentiated between verb types. In particular, with active verbs, the reanalysis of object-initial sentences elicited an N400-P600 pattern. On the other hand, there was no word order related N400 effect in dative object-experiencer verbs. Instead, object-experiencer verbs always elicited a P600 effect in comparison to active verbs in subject-initial sentences, which was not modulated by word order either. Finally, in adults, dative object-experiencer verbs also differed from the other verb types. Whereas accusative and dative active verbs showed an N400-P600 pattern for object-initial sentences, dative object-experiencer verbs elicited only an N400 effect. The whole pattern indicates that a clear developmental step occurs between 8 and 11 years of age, and that a further developmental step is necessary to reach the adult stage.

Supposably, the N400 seen in children and adults reflects different underlying processes. If the N400 always reflected the same process in each age group, it is difficult to explain why it should 'disappear' in 11-year-old children. A number of previous experiments had shown that, in adults, the N400 in dative structures has a special status, as the reanalysis towards a dative-nominative structure always elicits this effect. By contrast, in children, the observed N400 component seems to reflect processes that are not strictly bound to the processing of dative structures.

The processing of sentences with case marked arguments was very similar in 11-year-old children and adults. Both showed an Early Positivity ('EPOS') for dative object-experiencer verbs. No EPOS was elicited in ambiguous sentences. The EPOS effect is usually associated with a thematic reanalysis. A thematic reanalysis becomes necessary in object-experiencer verbs, which are associated with an

inverse hierarchical representation. The unique appearance of the EPOS in case marked sentences indicates that arguments are thematically ranked on the basis of unambiguous morphological case markings. In sentences with ambiguous arguments no EPOS emerges. Thus, here, no thematic ranking is established, for instance on the basis of word order. In 8-year-old children, dative object-experiencer verbs elicited an early N400 effect. The early N400 is probably related to the late acquisition of this verb type and indicates that the semantic integration of object-experiencer verbs is more difficult than with active verbs for children of 8 years of age. Alternatively, the early N400 may be related to the degradation of the Actor argument with object-experiencer verbs.

If full-grown adult mechanisms were already established during the early school years, no developmental differences would have been expected between 8-year-old children, 11-year-old children, and adults. That is, all age groups should have demonstrated the same, adult ERP pattern. Alternatively, one could have imagined a slow convergence from the 8-year-olds' to the adults' mechanisms. In this case, one would have expected a successive reduction of the P600 effect in object-experiencer verbs, together with a steady N400 effect. However, the data suggest something else. Especially the lack of the N400 effect at 11 years of age shows that such a slow transformation does not occur. Rather, the data suggest a step-wise developmental pattern, which is presumably due to a reorganization of abstract linguistic representations.

At the age of 8

Like the older participants, 8-year-old children relied on a subject-first preference. If the sentence was disambiguated towards an object-initial structure, reanalysis became necessary. Eight-year-old children always showed the same, uniform N400-P600 pattern for the reanalysis of ambiguous object-initial sentences, independently of verb type (Experiments III and IV). That is, unlike older children and adults, 8-year-old children did not differentiate dative object-experiencer verbs from dative active and accusative verbs. There are two ways to interpret the 8-year-olds' ERP pattern.

The first interpretation is that the abstract representation of dative object-experiencer verbs is not yet fully established. One point in favor of this interpretation is that an additional early N400 effect emerged on object-experiencer verbs. The early N400 may reflect increased difficulties of lexical integration (cf.

Hagoort et al., 1999). In addition, the behavioral pretests indicated that many children at the age of 8 and 9 are not familiar with dative object-experiencer verbs. Thus, it may well be the case that the missing cross-over representation was simply due to the late acquisition and low familiarity of these verbs.

A second, and much more conclusive interpretation is that 8-year-old children are not capable of representing crossed hierarchical structures. Crucially, all children participating in the ERP experiments knew the verbs, as they were able to circumscribe their meaning without any problems. Thus, all children had the correct abstract semantic representation of the dative object-experiencer verbs. However, this does not necessarily mean that they already had the inverse hierarchical representation, with crossed syntactic and thematic hierarchies. It might be possible to comprehend dative object-experiencer verbs even without crossed hierarchical structures. For instance, the verbs could be represented like accusative object-experiencer verbs (cf. Chapter 1). Accusative object-experiencer verbs like 'ängstigen' (to frighten) still allow a causative reading ('Angst machen'). Thus, the canonical hierarchical representation could be maintained, with the nominative marked subject being ranked higher in the thematic hierarchy. In addition, the ability to represent crossed hierarchies should have led to general processing difficulties, as indicated by the P600 in 11-year-old children (see below). This was not the case for the 8-year-old children.

The results support the interpretation that 8-year-old children apply a single (re)analysis mechanism to ambiguous object-initial structures of any verb type. In terms of the ADM, it suffices to assume only a single primal pathway for 8-year-old children. In ambiguous sentences, the first argument is ranked higher than the second argument (argument 1 > argument 2), both in a syntactic and in a thematic sense. This type of representation does not allow a separate reanalysis of thematic properties, which assumedly led to the observed processing difficulties in object-experiencer verbs (early N400). In sum, a separation into a Morphological and a Positional Pathway is not yet achieved at 8 years of age.

At the age of 11

Most likely, 11-year-old children already have two processing pathways at their disposal. Experiment II indicated that only unambiguous case markings lead to a thematic ranking of the arguments. Specifically, nominative marked arguments are ranked higher than dative marked arguments (nominative $>_{them}$ dative). In

object-experiencer verbs, this ranking turns out to be incorrect, and the thematic hierarchy has to be reversed (nominative $<_{them}$ dative). The reversal of the thematic hierarchy was reflected in an EPOS effect. As in adults, the EPOS effect only emerged in case marked sentences. In terms of the ADM, 11-year-old children process case marked arguments via the Morphological Pathway. However, in contrast to adults, the EPOS was delayed by 300 ms, which suggested a slower and therefore less well established routine of thematic information processing.

By contrast, no EPOS effect was elicited in sentences with case ambiguous arguments. Thus, in ambiguous sentences no thematic reranking had to be performed with object-experiencer verbs. Hence, ambiguous arguments are not thematically hierarchized, for example on the basis of word order information. Rather, word order is used to establish syntactic dependencies between the arguments of a sentence. In terms of the ADM, ambiguous arguments are processed via the Positional Pathway. Like adults, 11-year-old children embark on a subject-first strategy. Specifically, the first argument is ranked higher than the second argument (subject $>_{syn}$ object). If the sentence is disambiguated towards an object-initial word order, reanalysis must take place (object $<_{syn}$ subject). As in adults, the reanalysis towards an object-initial word order differed between dative active and object-experiencer verbs.

With dative active verbs, reanalysis was reflected in an N400, followed by a P600 effect. On the surface, this N400-P600 pattern emerged in all age groups. However, its functional interpretation clearly differs between the youngest 8-year-old children and adults (see below). The interpretation of the 11-year-olds' N400-P600 pattern is less clear. On the one hand, it might correspond to the 8-year-olds' pattern and reflect an unspecific 'mismatch detection' of the dispreferred sentence structure. Alternatively, the N400-P600 pattern might correspond to the adult data. Thus, the N400 might be bound to the reanalysis of dative structures, followed by a P600 reflecting the reanalysis towards the non-canonical object-initial word order (see below). Nevertheless, in this case, it would be difficult to explain why dative object-experiencer verbs did not elicit an N400 response.

The most striking results were visible in object-experiencer verbs. With object-experiencer verbs, the analysis of ambiguous sentences was hampered in 11-year-old children. Both in subject- and object-initial sentences, difficulties emerged that were reflected in a P600 effect. Thus, independently of word order,

ambiguous sentences with dative object-experiencer verbs were always more difficult to process than subject-initial sentences with regular active verbs.

The P600 for dative object-experiencer verbs could best be accounted for under the assumption that this verb type is not yet represented as intransitive in terms of macroroles. In consequence, object-experiencer verbs always require crossed hierarchies of two macroroles and the morpho-syntactic structure (cf. Figure 7.7). The cross-over assignment is either due to the violation of the subject-first preference in object-initial sentences, or it is due to the dispreferred Undergoer-Actor sequence in subject-initial sentences. Presumably, these crossed hierarchical structures always increase processing costs.

Nonetheless, the pattern in object-experiencer verbs clearly demonstrated that 11-year-old children represent thematic and syntactic properties separately. Only this separate representation allows a cross-over of the hierarchies, which led to the observed processing difficulties with object-experiencer verbs.

Summary and Outlook

Taken together, the abstract representations of argument hierarchies undergo important changes between 8 and 11 years of age. Whereas children are reliant on one single representational hierarchy at 8 years of age, three years later their processing system has split up into an adult-like Morphological and a separate Positional Pathway. However, even at 11 years of age, the sophisticated adult processing mechanisms are not yet fully developed. That is, both lexical representations as well as the automaticity of processing routines is not yet completely established by the age of 11.

As this was the first ERP study on the processing of argument hierarchies with children, there are, naturally, a number of open issues that await further systematic investigation. First of all, the transition from one type to another type of abstract representation should be investigated in greater detail. The present work showed that a whole developmental step lies between 8- and 11-year-old children. However, the process of the transition from a general hierarchy towards independent syntactic and thematic hierarchies is still unclear. Specifically, at an intermediate age, the word order related N400-P600 pattern must give way to the verb type related P600 pattern in dative object-experiencer verbs. Moreover, experiments with children older than 11 years of age are necessary in order to answer the question at what age the adult processing mechanisms is finally es-

tablished. That is, one should determine when the reanalysis-N400 for object-experiencer verbs emerges.

In the theoretical considerations it was stressed that the establishment of two separate processing pathways is dependent on the acquisition of dative verbs (cf. Section 4.3.4). One would thus suspect, that parallel to the developmental steps seen in the ERP experiments, developmental steps occur in the acquisition of dative verbs. More specifically, further data on the acquisition of dative object-experiencer verbs would shed more light on the representations of younger children.

Experiment III suggested that 8-year-old children have only one representational hierarchy at their disposal. Consequently, they must represent dative object-experiencer verbs in the same manner as accusative object-experiencer verbs, as was discussed above. This prediction could directly be tested. Crucially, the differences between dative and accusative object-experiencer verbs also encompass syntactic properties. For instance, accusative object-experiencer verbs can be passivized ('Ich wurde geängstigt', I was frightened), but dative object-experiencer verbs cannot (*'Mir wurde gefallen', *I was appealed to). If children really represent dative object-experiencer verbs like accusative object-experiencer verbs, they should allow them to passivize.

Though highly useful, object-experiencer verbs also have their disadvantages. The most prominent disadvantage is that these verbs are acquired relatively late, and they are unknown to many 8-year-old children. In order to investigate thematic reanalysis effects in even younger children, a design would be valuable that goes without this specific verb class. One possibility might be intransitive verbs that either assign an Actor role or an Undergoer role, as for example 'laufen' vs. 'leiden' (run vs. suffer). If the argument preceding the verb is assigned the thematic role Actor, a thematic reanalysis would become necessary on a verb that assigns the role Undergoer, for instance in sentences like 'der Mann läuft' vs. 'der Mann leidet' ([the man]$_{NOM}$ runs vs. suffers). By contrast, no such effect would be predicted for ambiguous arguments, like in 'Peter läuft/leidet'. Hence, this type of construction might allow an investigation of thematic reanalysis effects without being dependent on a restricted verb class like dative object-experiencer verbs (cf. also Bornkessel, Schlesewsky, & Van Valin, in preparation).

10.2 Consequences for Models of Language Processing in Adults

The present series of ERP experiments on auditory sentence processing yielded new insights into the development of children's sentence processing mechanisms. Moreover, the data also had consequences for models on language processing in adults. Specifically, the children's ERP data as well as differences between auditory and visual sentence processing led to new conclusions about the characteristics of adults' sentence comprehension.

The children's ERP data had a most important influence on the interpretation of the ERP components in adults. This primarily concerned the N400 component. Originally, the N400 effect in ambiguous dative-initial sentences was interpreted as a reflection of the relabeling of base generated syntactic positions (Bornkessel et al., 2004). It was assumed that the existence of canonical dative-initial structures in object-experiencer verbs was somehow overgeneralized in order to reanalyze object-initial sentences with dative active verbs, too.

Crucially, the data of the 11-year-old children (Experiment II) were not easily reconciled with the assumption of overgeneralization. At 11 years of age, only active verbs elicited an N400 effect, but object-experiencer verbs did not. Instead, object-experiencer verbs showed a P600 effect, compared to subject-initial active conditions. This indicated that the N400 seen in adults cannot originate from object-experiencer verbs.

Alternatively, the N400 could be explained within the macrorole account of Van Valin and La Polla (1997). They assume that all dative verbs are intransitive and assign only one macrorole (Actor or Undergoer). Consequently, the N400 effect may reflect the reassignment of this single macrorole to the dispreferred second argument. The subsequent P600 would then reflect the reanalysis towards the non-canonical word order in active verbs. For object-experiencer verbs, no further reanalysis is necessary, as they are associated with a canonical object-initial word order. Here, the macrorole reassignment suffices, which is reflected in the N400 effect.

A second point that had an important impact on the understanding of adults' language comprehension concerned data on modality dependent differences in sentence processing. All experiments in this thesis were conducted in the auditory

modality in order to avoid a confound of differing reading proficiencies between children and adults. Crucially, all previous ERP studies on the role of word order and case marking in German sentence processing were conducted in the visual modality. Thus, the adult control data turned out to be a test case for the generalizability of previous visual data.

Table 10.2 Overview of adults' ERP effects on the critical verb, separately for different verb types; results of the visual domain stem from Bornkessel et al. (2002; 2003; 2004); results of the auditory domain stem from Experiments I and IV, respectively; 'verb type effect' is the ERP effect for dative object-experiencer verbs in comparison to dative active verbs; 'word order effect' is the ERP effect for ambiguous object-initial structures in comparison to ambiguous subject-initial structures.

condition	visual modality		auditory modality	
verb type effect: object-experiencer vs. active verbs				
case unambiguous	EPOS		EPOS	
case ambiguous				
word order effect: object-initial vs. subject-initial sentences				
accusative		P600	N400	P600
dative active	N400		N400	P600
dative obj.-exper.	N400		N400	

The results from experiments on adults' sentence processing in the visual (Bornkessel et al., 2002; 2003; 2004) and in the auditory modality (Experiments I and IV) are summarized in Table 10.2. As in the visual modality, adults used morphological case markings in order to rank the arguments of a sentence thematically in the auditory experiment (Experiment I). As in prior visual experiments, the reversal of the thematic hierarchy in dative object-experiencer verbs was reflected in an EPOS effect, independently of word order. In auditory presentation, the EPOS effect emerged 100 ms later than in visual presentation. Such differences in latency could easily be explained by the fact that auditory stimuli unfold over time. Thus, it took longer to unambiguously recognize an auditorily presented word than a visually presented word. In terms of the ADM, adults use the Morphological Pathway to establish thematic dependencies if the arguments are unambiguously case marked.

If the arguments are ambiguous with regard to case, adults use word order to establish a syntactic hierarchy of the arguments. In terms of the ADM, the

processing of ambiguous arguments takes place on the Positional Pathway. The disambiguation towards an object-initial word order required reanalysis.

Crucially, the ERP patterns elicited by reanalysis differed between modalities. This was the case for dative and for accusative structures. Whereas the reanalysis of dative structures elicited only an N400 effect in the visual modality, dative active verbs additionally elicited a P600 effect in the auditory modality (Experiment I). With accusative verbs, all visual studies reported a P600 effect for the reanalysis of ambiguous object-initial sentences of the type examined here (e.g. Bornkessel et al., 2004; Friederici et al., 2001). By contrast, in auditory presentation surprisingly a clear N400 effect emerged that was followed by a P600 (Experiment IV).

The ERP differences in dative structures were most likely due to the time point at which specific types of information become available. Whereas in visual presentation the whole verb was displayed at once on the screen, in auditory presentation the verb unfold by and by, making verb type information available before agreement information (e.g. 'zuwink-t' vs. 'zuwink-en'; wave to, singular vs. plural). Hence, verb type specific information had time 'to sink in', before the sentence structure was disambiguated. In consequence, verb specific information could be activated before reanalysis took place. In the case of object-experiencer verbs, verb specific information supported reanalysis, as the dative-initial word order is the canonical one. By contrast, no such support was given in dative active verbs as they require a canonical subject-initial structure. Hence, reanalysis towards an object-initial word order was not supported with active verbs and thus elicited the additional P600 effect. The same ERP pattern also emerged in a visual experiment, in which the information types were pulled apart by presenting the verb before the disambiguating arguments (cf. Bornkessel, 2002).

However, such 'physical' explanations cannot account for the modality differences in accusative verbs. In contrast to the P600 reported in visual experiments, ambiguous accusative-initial structures elicited an N400-P600 pattern when presented auditorily. An N400 effect in connection with syntactic reanalysis had only been reported for the reanalysis of dative structures. The reanalysis-N400 in dative verbs may, for instance, reflect the reassignment of a single macrorole, as dative verbs are intransitive. Nevertheless, this type of reanalysis is not possible with accusative verbs, because they are associated with two macroroles (Van Valin & La Polla, 1997). Crucially, the reassignment of two macroroles is a

fundamentally different process, which in visual presentation was thought to be reflected in the P600 effect.

The observed differences in the processing of accusative structures are difficult to account for under a 'modular' interpretation of the ERP components N400 and P600. Typically, each ERP component is associated with a specific type of cognitive process (cf. also Chapter 2). Within such a modular account, the appearance of a new component would indicate a new underlying process. In the present case, the emergence of the additional N400 effect in the auditory modality would be interpreted as reflecting an additional cognitive process that was not present in all preceding visual experiments. Interestingly, recent fMRI studies also indicated that the neural network engaged in the processing of sentences with word order permutations differs depending on the input modality (cf. Fiebach et al., 2004; Röder et al., 2002).

However, the question remains why participants should apply different sentence processing mechanisms when reading compared to when listening to a sentence. It seems as if a modular account does not help in understanding the differences and commonalities of the ERP patterns in auditory and visual sentence processing.

The ERP pattern shall be summarized once more. It is always the case that reanalysis with dative verbs elicits an N400 effect, and reanalysis with accusative verbs elicits a P600 effect. In addition, the ERP effects may overlap, which results in an N400-P600 pattern. This was the case with dative active and with accusative verbs in the auditory modality. Perhaps one would need another level of abstraction in order to describe the specific function of each component and to explain why they may overlap under certain circumstances. Moreover, the conditions under which such overlaps occur need to be investigated in further detail. For instance, overlapping ERP patterns might not only occur in auditory presentation, but rather depend on a yet unknown third factor.

The investigation of auditory language comprehension is essential to developmental research. Children enter the language system by listening to their native language from the first day they are born. They start to talk long before they learn how to write. Thus, in order to track language development from the very beginning to the highly sophisticated adult processing mechanisms, research is naturally bound to the auditory modality. However, work on adult sentence proc-

essing predominantly focused on the processing of written sentences. Visual studies form the basis for many sentence processing models, often neglecting the auditory modality. As such, they provide an incomplete basis for research on language acquisition. The results of this work indicate that visual data do not simply reflect amodal sentence processing principles that can directly be transferred to the auditory modality. Rather, auditory sentence processing needs to move to the focus of language processing research in order to enhance investigations in language development.

In future studies, a systematic comparison of modality differences in sentence processing will be necessary. As discussed above, data on auditory sentence processing are underrepresented, a fact that renders research on language acquisition quite difficult. Thus, it would be fruitful to illuminate differences between auditory and visual modality. For instance, the role of prosodic information in auditory sentence processing should be investigated in greater detail. Acoustic analyses of the stimulus material indicated that word order differences are partly reflected in the duration of a sentence's phrases. On the other hand, verb type influenced the course of the fundamental frequency. It might be the case that such prosodic cues affect the parser's decisions right from the outset of a sentence (cf. also Eckstein & Friederici, submitted). Balanced experimental designs could disentangle the influence of the input's physical properties and profound differences in processing routines between auditory and visual modality.

10.3 Conclusion

Sentence comprehension is a complex process that takes a long time to fully develop. The results of the present experiments indicate that even at 11 years of age, children have not yet fully established adult processing routines. In order to determine 'who is doing what to whom' school-aged children still use linguistic cues in a different way to adults. In particular, the ERP experiments suggest that 8-year-old children do not distinguish between abstract thematic and syntactic representations. Only three years later, at 11 years of age, children are able to distinguish between these two representational hierarchies. However, even they have not yet reached the adult stage. Lexical verb representations still have to be refined, a developmental process that presumably takes place during the later teenage years.

Moreover, the experiments also pointed out that the processes of adult sentence comprehension are far from being completely understood. Interestingly, the children's data helped on the interpretation of syntax related ERP components. However, differences between auditory and previous visual data indicated that a lot more experiments will be necessary in order to resolve the mystery of on-line sentence comprehension.

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Appendix A: Pretesting the Stimulus Material

Introduction

For the construction of the stimulus material of Experiments I-III it had to be determined which dative verbs are familiar to school-aged children. To this end, a behavioral material-pretest was conducted. On the basis of word definitions it was determined which verbs are familiar to the children. Correct word definitions proved to be directly related to the understanding of these words (Dockrell, Messer, George, & Ralli, 2003) as they can only be given by accessing the corresponding semantic representation.

Method

Participants. Forty-one children (13 female) with a mean age of 8;3 (range 6;10-10;10) volunteered in the material-pretest. All of them were native speakers of German. The pretest was conducted in two primary schools. It lasted about 15-25 minutes and was conducted with each child individually in a quiet room. All participants received sweets as reward.

Material. Both dative object-experiencer and dative active verbs were presented. Being very restricted with the object-experiencer verbs, all eight items used by Bornkessel et al. (2004) were tested. For active verbs the material-pretest started with 22 items. As described in detail below, the number of items was reduced according to the results of the first cohort of participants. All verbs were embedded in subordinate clauses in order to keep the syntactic complexity comparable to the experimental stimuli. All sentences were identical apart from the verb (cf. (A.1)).

(A.1) In der Zeitung steht, dass der Mann den Kindern dankt.
'The newspaper says that the man thanked the children.'

Procedure. All sentences were presented auditorily. The children's task was to explain the meaning of the verbs to a glove puppet. On the basis of the explanations, the investigator classified the verb knowledge as 'familiar', 'unstable', or 'unfamiliar'.

Results

The first cohort consisted of 16 children (4 female, mean age 8;0). All 8 object-experiencer verbs and 22 active verbs were presented to them. The cohort was split at the median into two age groups (7;3 and 8;8). According to the results of both groups the most familiar verbs were determined (cf. Table A.1). For the second cohort (25 participants) the material was restricted to 3 object-experiencer verbs and 12 active verbs. That way, the material-pretest could be conducted faster, and the frustration with unfamiliar verbs could be reduced.

Table A.1 Material-pretest: first cohort. Dative object-experiencer verbs, listed according to degree of familiarity. Values in % of children.

verbs	7;3 (n=8)			8;8 (n=8)		
	familiar	unstable	unfamiliar	**familiar**	unstable	unfamiliar
gefallen *(to appeal to so.)*	**100.0**	0.0	0.0	**100.0**	0.0	0.0
auffallen *(to notice so.)*	**50.0**	25.0	25.0	**75.0**	12.5	12.5
einfallen *(to occur to so.)*	**50.0**	25.0	25.0	**50.0**	12.5	37.5
passen *(to accept so.)*	**37.5**	37.5	25.0	**12.5**	0.0	87.5
entgehen *(to elude so.)*	**12.5**	0.0	87.5	**12.5**	25.0	62.5
behagen *(to suit so.)*	**0.0**	25.0	75.0	**0.0**	0.0	100.0
entfallen *(to escape so.)*	**0.0**	0.0	100.0	**0.0**	0.0	100.0
missfallen *(to displease so.)*	**0.0**	0.0	100.0	**0.0**	0.0	100.0

For the final analysis, both cohorts were put together. All children were divided along the median into two age groups. The first group contained 21 children (8 female) with a mean age of 7;2 (range 6;10-7;8). The second group contained 20 children (5 female) with a mean age of 9;4 (range 8;03-10;10). The preliminary results of the first cohort were confirmed with all children (cf. Table A.2). The chosen object-experiencer verbs were 'auffallen', 'einfallen', and 'gefallen' (to notice so., to occur to so., to please so.). Out of the active verbs 3 items were selected that matched the object-experiencer verbs in frequency and number of syllables, and that were highly familiar to all children. The following active verbs were chosen: 'danken', 'zuhören', and 'zuwinken' (to thank so., to listen to so., to wave to so.; see Table A.2). A t-test revealed no significant differences between the two verb types. That was true for frequency and number of syllables (singular and plural forms).

Table A.2 Material-pretest (all participants): final verb choice. The verbs are listed according to degree of familiarity. Values in % of children. Frequency: combined oral and written lemma frequency according to the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993), logarithmic values. For 'zuwinken' (to wave to) the values of 'winken' (to wave) were used, as they appeared to be more plausible.

verbs	**7;2 (n=21)**			**9;4 (n=20)**			**frequency**
	familiar	unstable	unfamiliar	**familiar**	unstable	unfamiliar	(log)
object-experiencer							
gefallen *(to appeal to so.)*	90.5	0.0	9.5	100.0	0.0	0.0	1.7782
auffallen *(to notice so.)*	47.6	14.3	38.1	75.0	10.0	15.0	1.3424
einfallen *(to occur to so.)*	47.6	14.3	38.1	55.0	10.0	35.0	1.2304
mean value:	**61.9**	9.5	28.6	**76.7**	6.7	16.7	**1.4503**
active							
zuwinken *(to wave to so.)*	95.2	0.0	4.8	100.0	0.0	0.0	1.4314
danken *(to thank so.)*	95.2	0.0	4.8	95.0	5.0	0.0	1.9395
zuhören *(to listen to so.)*	85.7	9.5	4.8	100.0	0.0	0.0	1.0414
mean value:	**92.0**	3.2	4.8	**98.3**	1.7	0.0	**1.4708**

Appendix B: Pretest

In advance of the EEG experiment a behavioral pretest was conducted with all children in a separate session. Children with insufficient proficiency in one of the pretests were excluded from the EEG experiment. First, knowledge of the experimental verbs was tested by verbal definitions (cf. Dockrell et al., 2003). Definitions were rated as 'correct/familiar', 'unstable', or 'unfamiliar'. Second, general sentence processing abilities were tested by means of two subtests of the Heidelberger Sprachentwicklungstest (HSET) (Grimm & Schöler, 1990). They consisted in acting out an auditorily presented sentence, and in sentence imitation, respectively. Finally, a grammaticality judgment task on subject verb agreement was conducted. The test comprised 24 sentences like (B.1) that were presented auditorily.

(B.1) Sie sagt, dass Thomas Äpfel pflückt/*pflücken.
'She says that Thomas pick(s) apples'

The results are presented in Table B.1. Only the data of the children entering the final EEG analysis are reported.

Table B.1 Results of the behavioral pretest: data of all children, who participated in the EEG experiments, and who entered the final analyses; [1]percentage correct; [2]percentile score according to the HSET (age range 8-9 years of age).

	Experiment II: 11;6 yrs. (n=21)	Experiment III: 8;11 yrs. (n=24)	Experiment IV: 8;11 yrs. (n=25)
verb definition[1]	100	100	99.5 (94.0-100)
sentence comprehension[2]	56.5 (9.7-91.9)	44.7 (9.7-91.9)	58.5 (18.4-91.9)
sentence imitation[2]	72.2 (42.1-78.8)	57.2 (13.6-78.8)	60.8 (21.2-78.8)
subject verb agreement[1]	94.2 (88.0-100)	87.4 (71.0-100)	90.0 (75.0-100)

Appendix C: Stimulus Material

C.1 Experiments I-III

List a)

	noun, singular, masculine	noun, plural, masculine	proper name	noun, plural, feminine	object-exper. verb	active verb
01	Zauberer	Zwerge	Carsten	Eisverkäuferinnen	auffallen	danken
02	Briefträger	Gärtner	Daniel	Polizisten	auffallen	danken
03	Mann	Verkäufer	Petra	Sängerinnen	auffallen	danken
04	Hausmeister	Maler	Lisa	Verkäuferinnen	auffallen	danken
05	Cowboy	Goldgräber	Marco	Gärtnerinnen	auffallen	danken
06	Detektiv	Autofahrer	Eva	Künstlerinnen	auffallen	zuhören
07	Räuber	Taxifahrer	Klara	Hortnerinnen	auffallen	zuhören
08	Lokführer	Diebe	Monika	Nachbarn	auffallen	zuhören
09	Einbrecher	Diener	Nico	Besucherinnen	auffallen	zuhören
10	Cousin	Müllmänner	Peggy	Lehrerinnen	auffallen	zuhören
11	Ritter	Geister	Florian	Piraten	auffallen	zuwinken
12	Bademeister	Taucher	Marcel	Piloten	auffallen	zuwinken
13	Clown	Seiltänzer	Anna	Prinzessinnen	auffallen	zuwinken
14	Fußgänger	Bettler	Peter	Clowns	auffallen	zuwinken
15	Radfahrer	Wanderer	Sarah	Zuschauerinnen	auffallen	zuwinken
16	Reiter	Zuschauer	Jan	Astronauten	auffallen	zuwinken
17	Frisör	Musiker	Ingo	Tierpflegerinnen	einfallen	danken
18	Schatzsucher	Indianer	Laura	Zahnärztinnen	einfallen	danken
19	Onkel	Handwerker	Julia	Freundinnen	einfallen	danken
20	Kapitän	Fischer	Hanna	Turnerinnen	einfallen	danken
21	Bauarbeiter	Baggerfahrer	Katja	Musikerinnen	einfallen	danken
22	Vater	Lehrer	Jenny	Putzfrauen	einfallen	zuhören
23	König	Mörder	Torsten	Ärztinnen	einfallen	zuhören
24	Bruder	Schüler	Sandra	Frauen	einfallen	zuhören
25	Bauer	Tierärzte	Paul	Krankenschwestern	einfallen	zuhören
26	Kommissar	Zahnärzte	Stefanie	Dienerinnen	einfallen	zuhören
27	Apotheker	Urlauber	Sascha	Klavierspielerinnen	einfallen	zuhören
28	Lügner	Obsthändler	Kevin	Autofahrerinnen	einfallen	zuwinken
29	Schornsteinfeger	Dachdecker	Alexander	Postboten	einfallen	zuwinken

30	Millionär	Ärzte	Kai	Tennisspielerinnen	einfallen	zuwinken
31	Busfahrer	Schauspieler	Stefan	Briefträgerinnen	einfallen	zuwinken
32	Feigling	Feuerwehrmänner	Sonja	Königinnen	einfallen	zuwinken
33	Torwart	Schiedsrichter	Christian	Schülerinnen	gefallen	danken
34	Trainer	Sportler	Claudia	Fotografen	gefallen	danken
35	Direktor	Fensterputzer	Philipp	Omas	gefallen	danken
36	Bäcker	Köche	Tim	Kindergärtnerinnen	gefallen	danken
37	Fußballspieler	Freunde	Ralf	Bäckerinnen	gefallen	danken
38	Opa	Enkel	David	Sportlerinnen	gefallen	danken
39	Angler	Söhne	Christoph	Opas	gefallen	zuhören
40	Klavierspieler	Sänger	Benjamin	Tanten	gefallen	zuhören
41	Eisverkäufer	Tierpfleger	Katrin	Indianerinnen	gefallen	zuhören
42	Boxer	Tennisspieler	Jana	Köchinnen	gefallen	zuhören
43	Angeber	Gäste	Melanie	Jungen	gefallen	zuhören
44	Künstler	Tänzer	Britta	Tänzerinnen	gefallen	zuwinken
45	Doktor	Turner	Anja	Schauspielerinnen	gefallen	zuwinken
46	Erfinder	Rennfahrer	Martin	Fußgängerinnen	gefallen	zuwinken
47	Erzähler	Besucher	Ina	Reiterinnen	gefallen	zuwinken
48	Gewichtheber	Sieger	Lena	Prinzen	gefallen	zuwinken

List b) (different combination of nouns and verbs)

	noun, singular, masculine	noun, plural, masculine	proper name	noun, plural, feminine	object-exper. verb	active verb
49	Künstler	Gäste	Jenny	Krankenschwestern	auffallen	danken
50	Erfinder	Schüler	Sandra	Opas	auffallen	danken
51	Bruder	Tänzer	Alexander	Tanten	auffallen	danken
52	Gewichtheber	Turner	Anja	Fußgängerinnen	auffallen	danken
53	Busfahrer	Lehrer	Katrin	Reiterinnen	auffallen	danken
54	Lügner	Besucher	Kevin	Frauen	auffallen	zuhören
55	Feigling	Ärzte	Ingo	Postboten	auffallen	zuhören
56	Fußballspieler	Schiedsrichter	Martin	Briefträgerinnen	auffallen	zuhören
57	Schornsteinfeger	Fensterputzer	Claudia	Prinzen	auffallen	zuhören
58	Direktor	Handwerker	Tim	Bäckerinnen	auffallen	zuhören
59	Bäcker	Sänger	Laura	Tierpflegerinnen	auffallen	zuwinken
60	Kommissar	Mörder	Torsten	Putzfrauen	auffallen	zuwinken
61	Torwart	Sportler	Stefanie	Ärztinnen	auffallen	zuwinken
62	Frisör	Tennisspieler	Christian	Dienerinnen	auffallen	zuwinken
63	Angler	Baggerfahrer	Philipp	Indianerinnen	auffallen	zuwinken
64	Onkel	Zahnärzte	Jana	Fotografen	auffallen	zuwinken

65	Erzähler	Söhne	Florian	Hortnerinnen	einfallen	danken
66	Doktor	Taucher	Nico	Lehrerinnen	einfallen	danken
67	Cousin	Tierpfleger	Ina	Besucherinnen	einfallen	danken
68	Detektiv	Zuschauer	Melanie	Köchinnen	einfallen	danken
69	Eisverkäufer	Wanderer	Christoph	Tänzerinnen	einfallen	danken
70	Ritter	Zwerge	Sarah	Polizisten	einfallen	zuhören
71	Opa	Köche	Marco	Sängerinnen	einfallen	zuhören
72	Bademeister	Enkel	Anna	Zuschauerinnen	einfallen	zuhören
73	Radfahrer	Freunde	Lena	Astronauten	einfallen	zuhören
74	Trainer	Sieger	Ralf	Gärtnerinnen	einfallen	zuhören
75	Zauberer	Geister	Britta	Schauspielerinnen	einfallen	zuhören
76	Einbrecher	Maler	Klara	Kindergärtnerinnen	einfallen	zuwinken
77	Klavierspieler	Diener	Daniel	Jungen	einfallen	zuwinken
78	Räuber	Verkäufer	Eva	Schülerinnen	einfallen	zuwinken
79	Boxer	Diebe	David	Omas	einfallen	zuwinken
80	Angeber	Rennfahrer	Benjamin	Sportlerinnen	einfallen	zuwinken
81	Bauer	Obsthändler	Marcel	Nachbarn	gefallen	danken
82	Reiter	Seiltänzer	Peggy	Prinzessinnen	gefallen	danken
83	Lokführer	Urlauber	Monika	Autofahrerinnen	gefallen	danken
84	Apotheker	Tierärzte	Sascha	Freundinnen	gefallen	danken
85	Fußgänger	Autofahrer	Sonja	Tennisspielerinnen	gefallen	danken
86	König	Schauspieler	Kai	Klavierspielerinnen	gefallen	danken
87	Clown	Bettler	Carsten	Piraten	gefallen	zuhören
88	Millionär	Goldgräber	Peter	Piloten	gefallen	zuhören
89	Cowboy	Indianer	Petra	Königinnen	gefallen	zuhören
90	Bauarbeiter	Dachdecker	Jan	Zahnärztinnen	gefallen	zuhören
91	Kapitän	Musiker	Stefan	Clowns	gefallen	zuhören
92	Schatzsucher	Fischer	Lisa	Eisverkäuferinnen	gefallen	zuwinken
93	Vater	Gärtner	Paul	Künstlerinnen	gefallen	zuwinken
94	Briefträger	Müllmänner	Hanna	Musikerinnen	gefallen	zuwinken
95	Mann	Taxifahrer	Katja	Turnerinnen	gefallen	zuwinken
96	Hausmeister	Feuerwehr-männer	Julia	Verkäuferinnen	gefallen	zuwinken

C.2 Experiment IV

	noun, singular, masculine	noun, plural, masculine	proper name	noun, plural, feminine	accusative verb
01	Zauberer	Zwerge	Carsten	Eisverkäuferinnen	ansehen
02	Briefträger	Gärtner	Daniel	Polizisten	einladen
03	Mann	Verkäufer	Petra	Sängerinnen	begrüßen
04	Hausmeister	Maler	Lisa	Verkäuferinnen	anrufen
05	Lügner	Obsthändler	Kevin	Autofahrerinnen	filmen
06	Detektiv	Autofahrer	Eva	Künstlerinnen	hören
07	Räuber	Taxifahrer	Klara	Hortnerinnen	verfolgen
08	Lokführer	Diebe	Monika	Nachbarn	belauschen
09	Einbrecher	Diener	Nico	Besucherinnen	kennen
10	Cousin	Müllmänner	Peggy	Lehrerinnen	fragen
11	Ritter	Geister	Florian	Piraten	rufen
12	Bademeister	Taucher	Marcel	Piloten	filmen
13	Clown	Seiltänzer	Anna	Prinzessinnen	mögen
14	Fußgänger	Bettler	Peter	Clowns	rufen
15	Angler	Söhne	Christoph	Opas	umarmen
16	Reiter	Zuschauer	Jan	Astronauten	begrüßen
17	Frisör	Musiker	Ingo	Tierpflegerinnen	treffen
18	Schatzsucher	Indianer	Laura	Zahnärztinnen	hören
19	Onkel	Handwerker	Julia	Freundinnen	besuchen
20	Kapitän	Fischer	Hanna	Turnerinnen	anrufen
21	Bauarbeiter	Baggerfahrer	Katja	Musikerinnen	einladen
22	Vater	Lehrer	Jenny	Putzfrauen	suchen
23	König	Mörder	Torsten	Ärztinnen	treffen
24	Bruder	Schüler	Sandra	Frauen	belauschen
25	Bauer	Tierärzte	Paul	Krankenschwestern	filmen
26	Kommissar	Zahnärzte	Stefanie	Dienerinnen	fragen
27	Apotheker	Urlauber	Sascha	Klavierspielerinnen	suchen
28	Cowboy	Goldgräber	Marco	Gärtnerinnen	verfolgen
29	Schornsteinfeger	Dachdecker	Alexander	Postboten	mögen
30	Millionär	Ärzte	Kai	Tennisspielerinnen	umarmen
31	Busfahrer	Schauspieler	Stefan	Briefträgerinnen	verfolgen
32	Feigling	Feuerwehrmänner	Sonja	Königinnen	rufen
33	Torwart	Schiedsrichter	Christian	Schülerinnen	ansehen
34	Trainer	Sportler	Claudia	Fotografen	besuchen
35	Direktor	Fensterputzer	Philipp	Omas	besuchen
36	Bäcker	Köche	Tim	Kindergärtnerinnen	anrufen

37	Fußballspieler	Freunde	Ralf	Bäckerinnen	suchen
38	Opa	Enkel	David	Sportlerinnen	ansehen
39	Radfahrer	Wanderer	Sarah	Zuschauerinnen	einladen
40	Klavierspieler	Sänger	Benjamin	Tanten	belauschen
41	Eisverkäufer	Tierpfleger	Katrin	Indianerinnen	kennen
42	Boxer	Tennisspieler	Jana	Köchinnen	fragen
43	Angeber	Gäste	Melanie	Jungen	begrüßen
44	Künstler	Tänzer	Britta	Tänzerinnen	kennen
45	Doktor	Turner	Anja	Schauspielerinnen	mögen
46	Erfinder	Rennfahrer	Martin	Fußgängerinnen	hören
47	Erzähler	Besucher	Ina	Reiterinnen	treffen
48	Gewichtheber	Sieger	Lena	Prinzen	umarmen

Appendix D: Acoustic Analyses of the Stimulus Material (Experiments I to III)

The stimulus material used in Experiments I-III was acoustically analyzed with respect to the prosodic parameters duration and fundamental frequency (f0). The sentences were analyzed phrase by phrase (cf. Table E.1).

Table E.1 Phrases for acoustic analyses.

phrase	"Dass"	NP1	pause	NP2	pause	verb
example	*Dass*	*der Ritter*		*den Zwergen*		*dankt*

Duration. The duration of the single phrases up to the critical verb was calculated (cf. Figures E.1, E.2). In order to statistically evaluate differences between experimental conditions, a global ANOVA was calculated. The statistical design was composed of three factors with repeated measures. All of the three factors Case (marked/ ambiguous), Verb (active/object-experiencer), and Order (SO/OS) had two levels. No main effects Case will be reported. The results showed that main effects Order were visible on the complementizer "dass" ($F(7,760) = 52.70$, $p < .01$), the first NP ($F(7,760) = 62.53$, $p < .01$), the pause between first and second NP ($F(7,760) = 40.42$, $p < .01$), and the pause before the verb ($F(7,760) = 18.70$, $p < .01$). In object-initial conditions duration was always longer than in subject-initial conditions.

F0. The following f0 values were calculated for each phrase: onset, minimum, maximum, and offset of the f0-contour (cf. Figures E.3, E.4) (Winpitch Easy Prosody, version 1.87m, 1996-8, Pitch Instruments Inc.). In order to statistically evaluate differences between experimental conditions, a global ANOVA was calculated. The statistical design was composed of three factors with repeated measures. All of the three factors Case (marked/ambiguous), Verb (active/object-experiencer), and Order (SO/OS) had two levels. No main effects Case will be reported. Only positions with clearly visible frequency differences will be focused on. Clear main effects Verb were visible at the end of the second NP

($F(7,759) = 48.92$, $p < .01$), the beginning of the verb ($F(7,758) = 573.25$, $p < .01$), and at the minimal f0 value of the verb ($F(7,758) = 726.51$, $p < .01$).

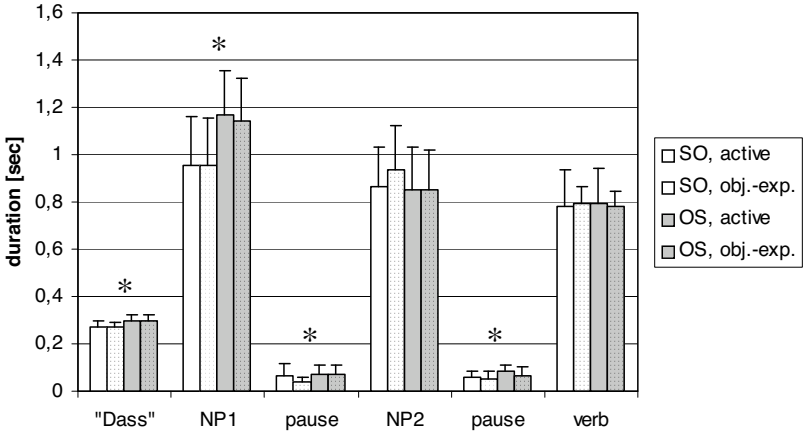

Figure E.1 Duration (+ standard error, s.e.) of the single phrases of all sentences with case marked arguments in Experiments I-III (dative structures), separately for subject- (SO) and object-initial sentences (OS) with active and object-experiencer verbs. Significant main effects of Verb are indicated by a star.

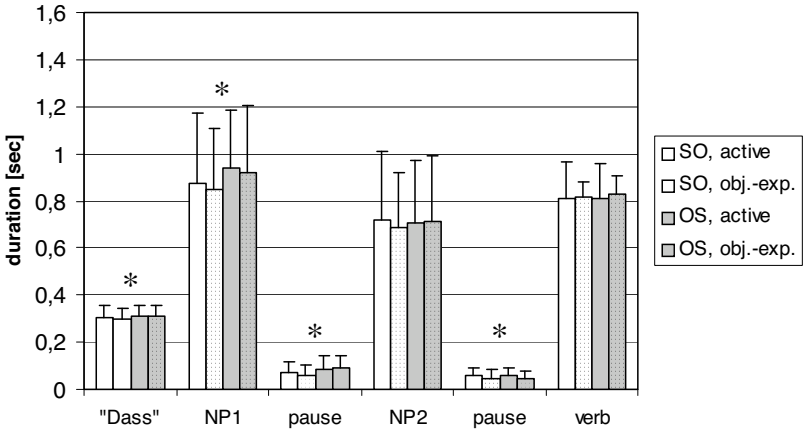

Figure E.2 Duration (+ s.e.) of the single phrases of all sentences with case ambiguous arguments in Experiments I-III (dative structures), separately for subject- (SO) and object-initial sentences (OS) with active and object-experiencer verbs. Significant main effects of Verb are indicated by a star.

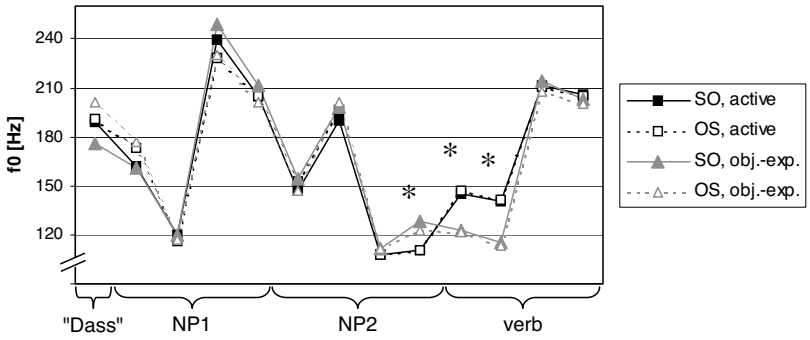

Figure E.3 Course of fundamental frequency (f0) in sentences with case marked arguments in Experiments I-III (dative structures), separately for subject- (SO) and object-initial sentences (OS) with active and object-experiencer verbs. Significant main effects of Verb are indicated by a star.

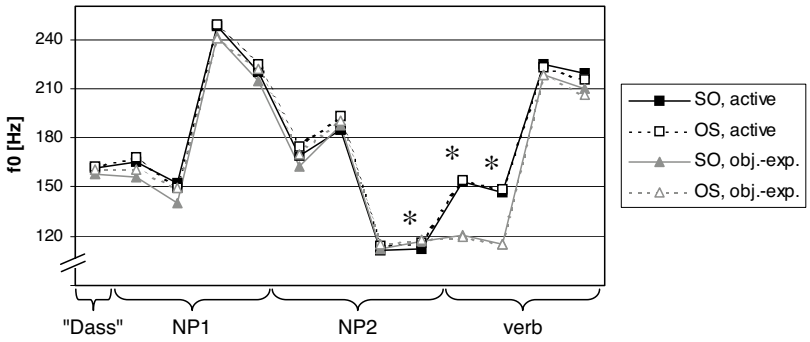

Figure E.4 Course of f0 in sentences with case ambiguous arguments in Experiments I-III (dative structures), separately for subject- (SO) and object-initial sentences (OS) with active and object-experiencer verbs. Significant main effects of Verb are indicated by a star.

Appendix E: Acoustic Analyses of the Stimulus Material (Experiment IV)

The stimulus material used in Experiment VI was acoustically analyzed with respect to the prosodic parameters duration and fundamental frequency (f0). The sentences were analyzed phrase by phrase (cf. Table E.1).

Duration. The duration of the single phrases up to the critical verb were calculated (cf. Figures F.1, F.2). In order to statistically evaluate differences between experimental conditions, a global ANOVA was calculated. The statistical design was composed of two factors with repeated measures. Both the factor Case (marked/ambiguous) and the factor Order (SO/OS) had two levels. No main effects Case will be reported. The results showed that no Order effects were present at any of the phrases.

F0. The following f0 values were calculated for each phrase: onset, minimum, maximum, and offset of the f0-contour (cf. Figures F.3, F.4). In order to statistically evaluate differences between experimental conditions, a global ANOVA was calculated. The statistical design was composed of two factors with repeated measures. Both the factor Case (marked/ambiguous) and the factor Order (SO/OS) had two levels. No main effects Case will be reported. The only main effect Order emerged on the maximal f0 value of the first NP ($F(3,380) = 4.55$, $p < .05$), although only amounting to 5.2 Hz in case marked sentences, and 5.7 Hz in ambiguous sentences.

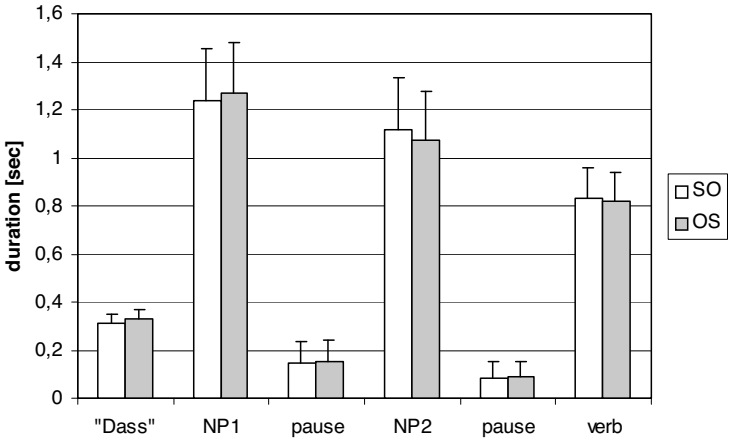

Figure F.1 Duration (+ s.e.) of the single phrases of all sentences with case marked arguments in Experiment IV (accusative structures), separately for subject- (SO) and object-initial sentences (OS).

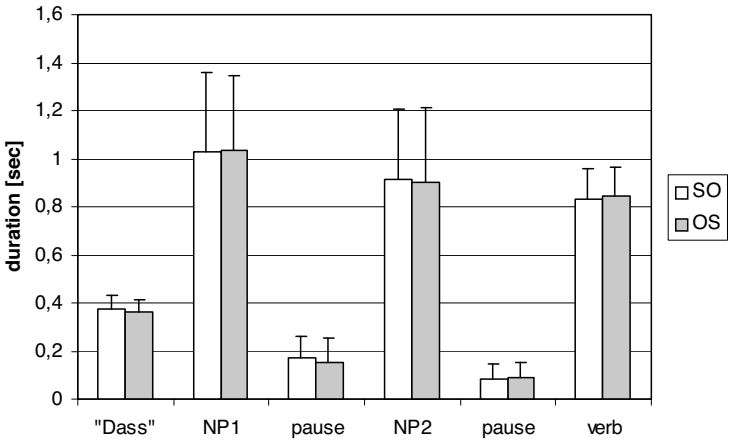

Figure F.2 Duration (+ s.e.) of the single phrases of all sentences with case ambiguous arguments in Experiment IV (accusative structures), separately for subject- (SO) and object-initial sentences (OS).

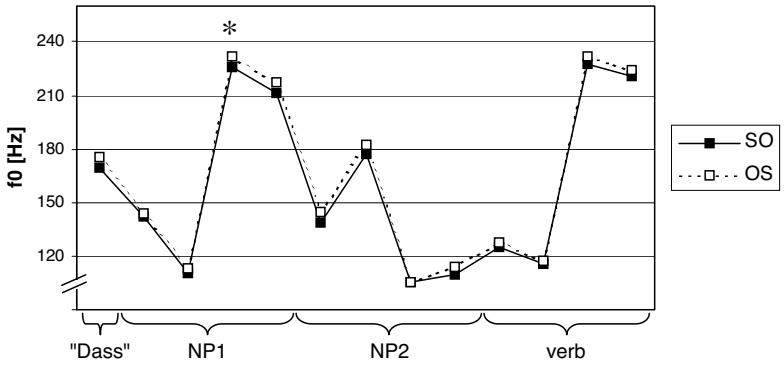

Figure F.1 Course of f0 in sentences with case marked arguments in Experiments IV (accusative structures), separately for subject- (SO) and object-initial sentences (OS). Significant main effects of Order are indicated by a star.

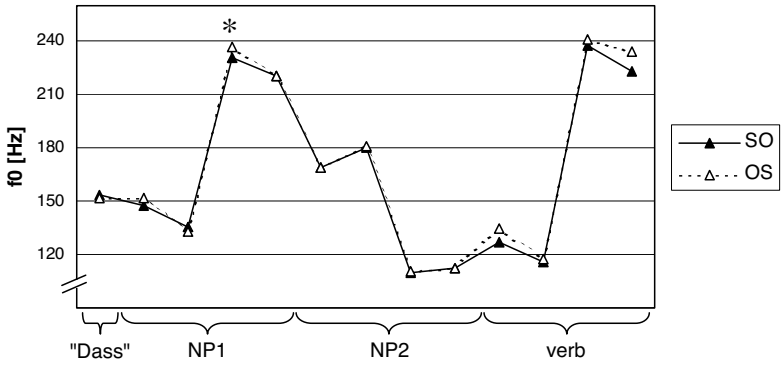

Figure F.2 Course of f0 in sentences with case ambiguous arguments in Experiment IV (accusative structures), separately for subject- (SO) and object-initial sentences (OS). Significant main effects of Order are indicated by a star.

Appendix F: Supplementary ERP Figures

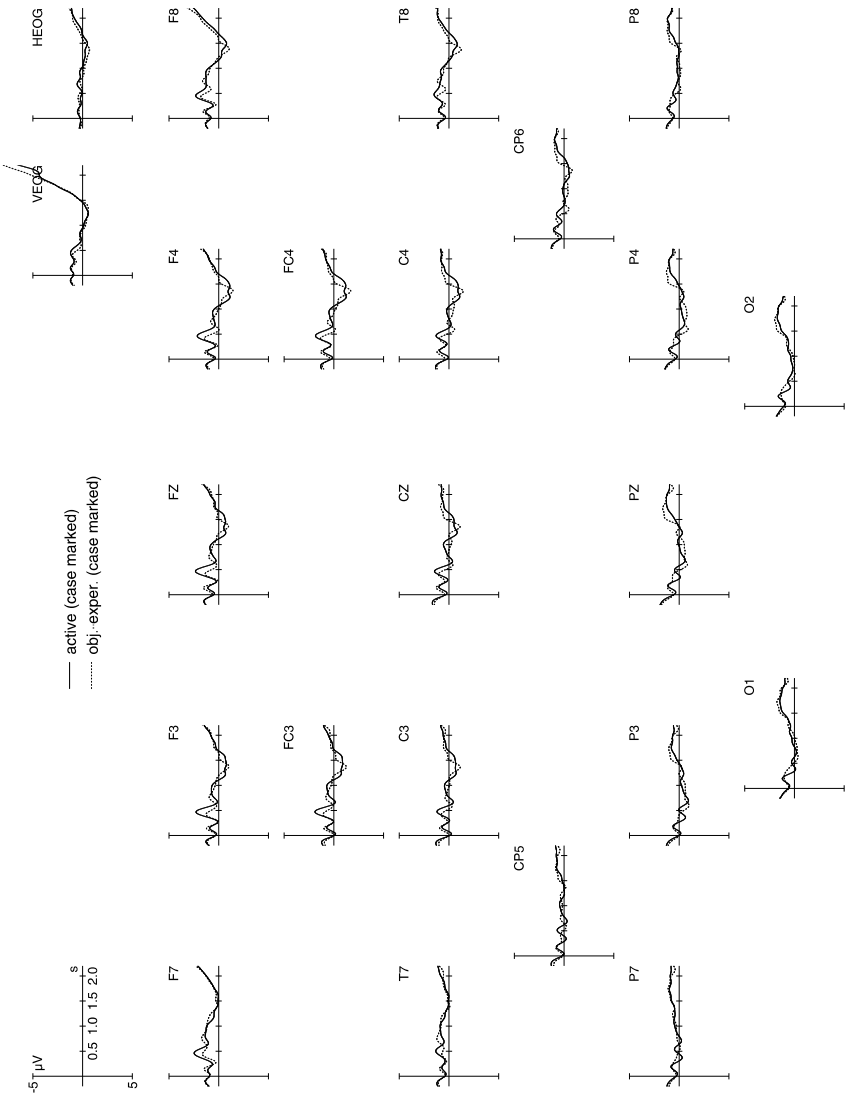

Figure F.1 Adults in Experiment I: Dative object-experiencer vs. dative active verbs in sentences with unambiguously case marked arguments.

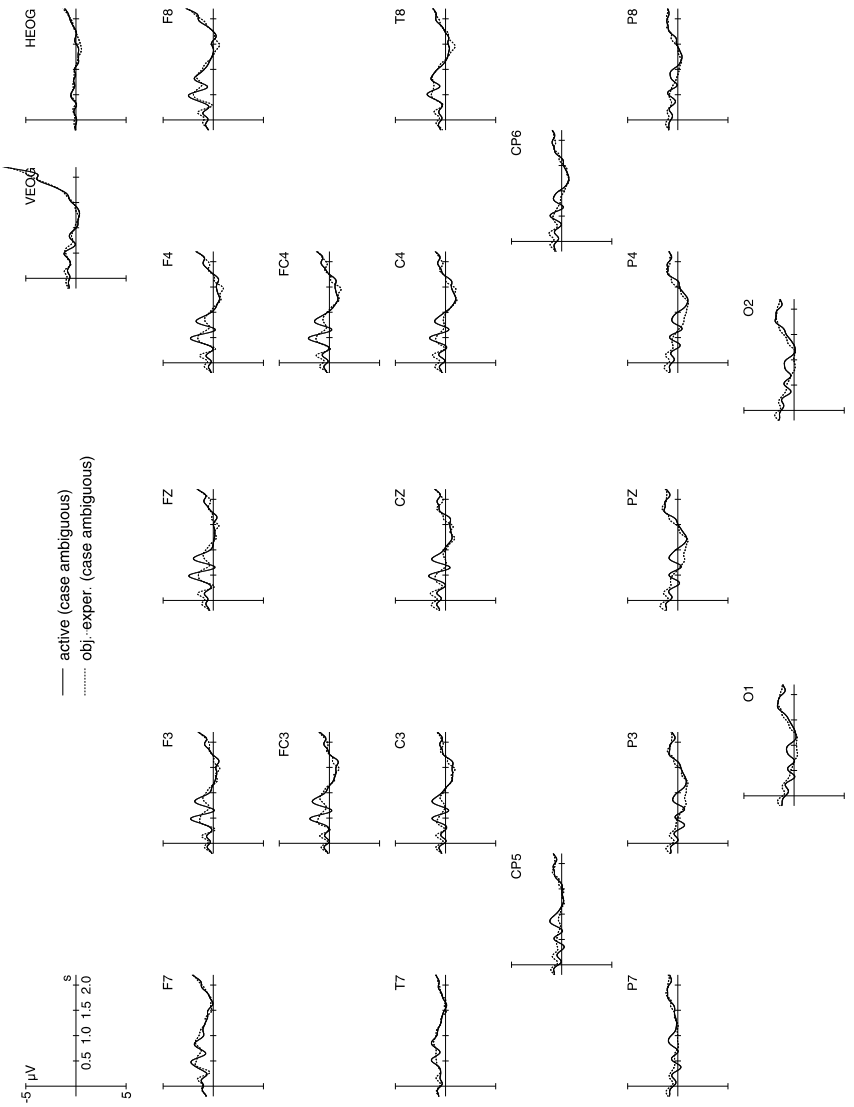

Figure F.2 Adults in Experiment I: Dative object-experiencer vs. dative active verbs in sentences with case ambiguous arguments.

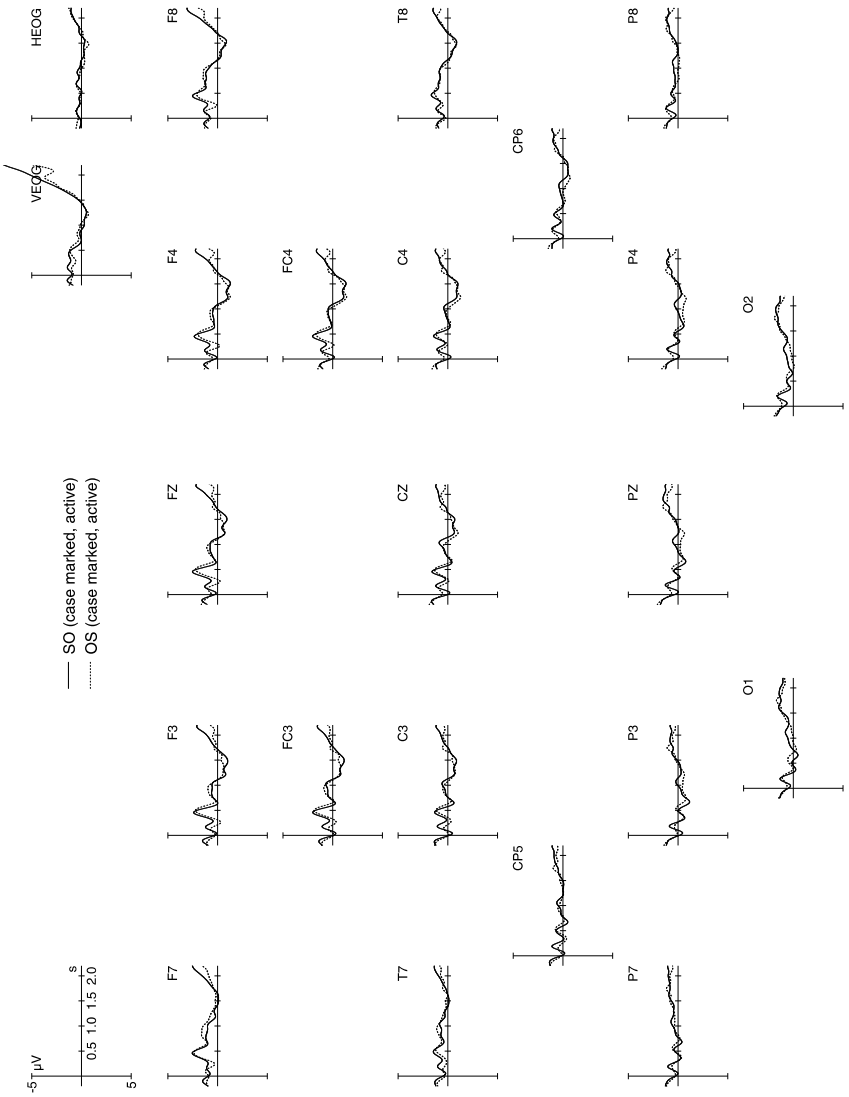

Figure F.3 Adults in Experiment I: Object-initial vs. subject-initial active structures in sentences with unambiguously case marked arguments.

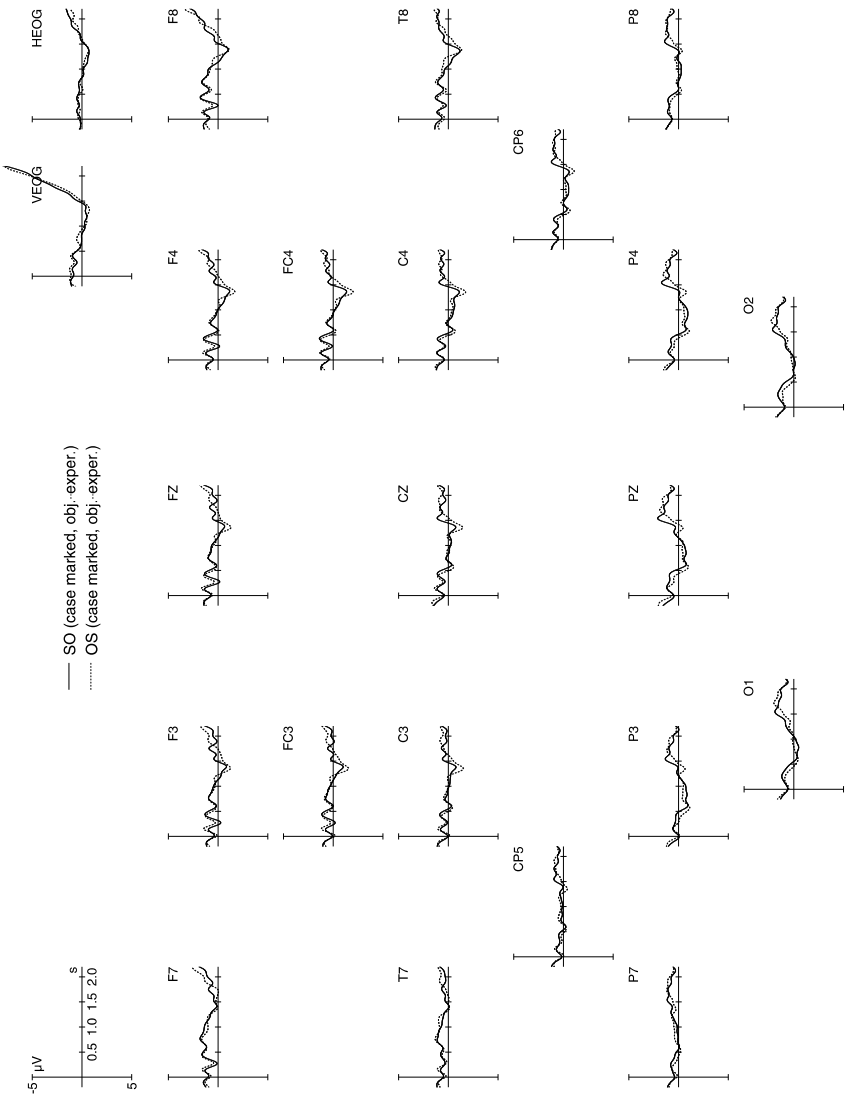

Figure F.4 Adults in Experiment I: Object-initial vs. subject-initial object-experiencer structures in sentences with unambiguously case marked arguments.

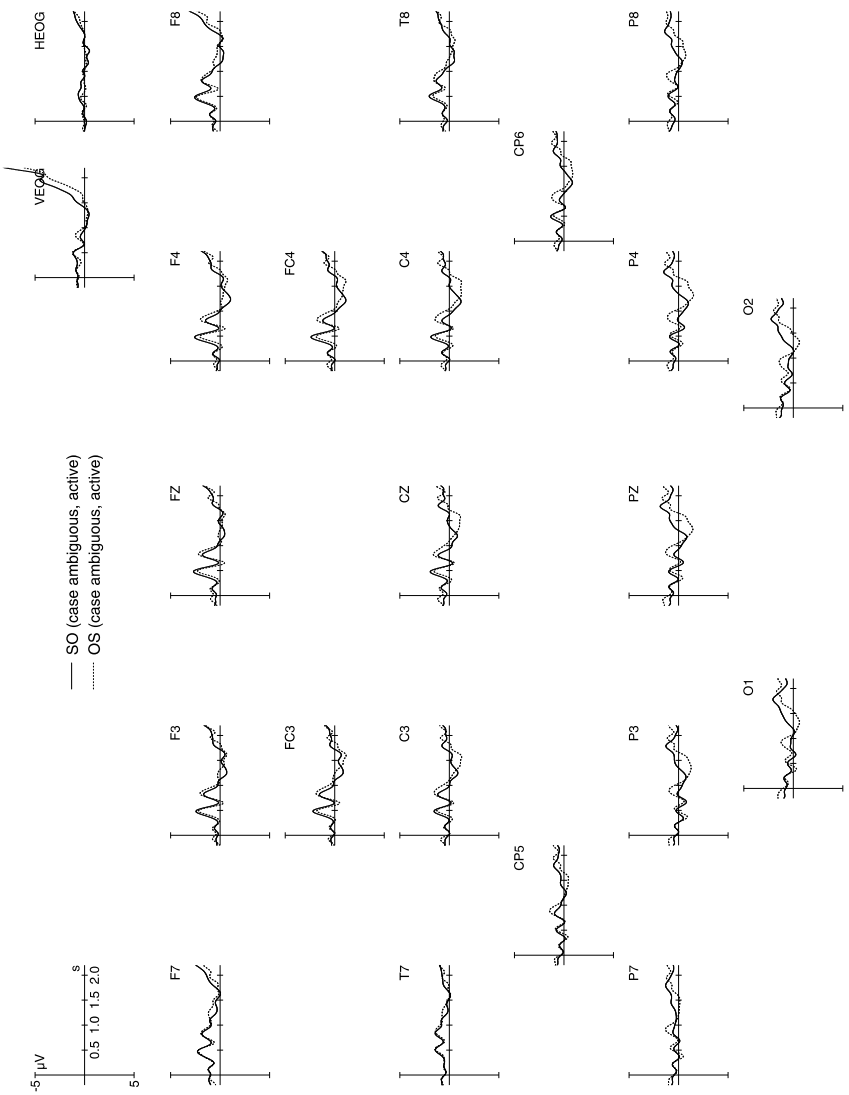

Figure F.5 Adults in Experiment I: Object-initial vs. subject-initial active structures in sentences with case ambiguous arguments.

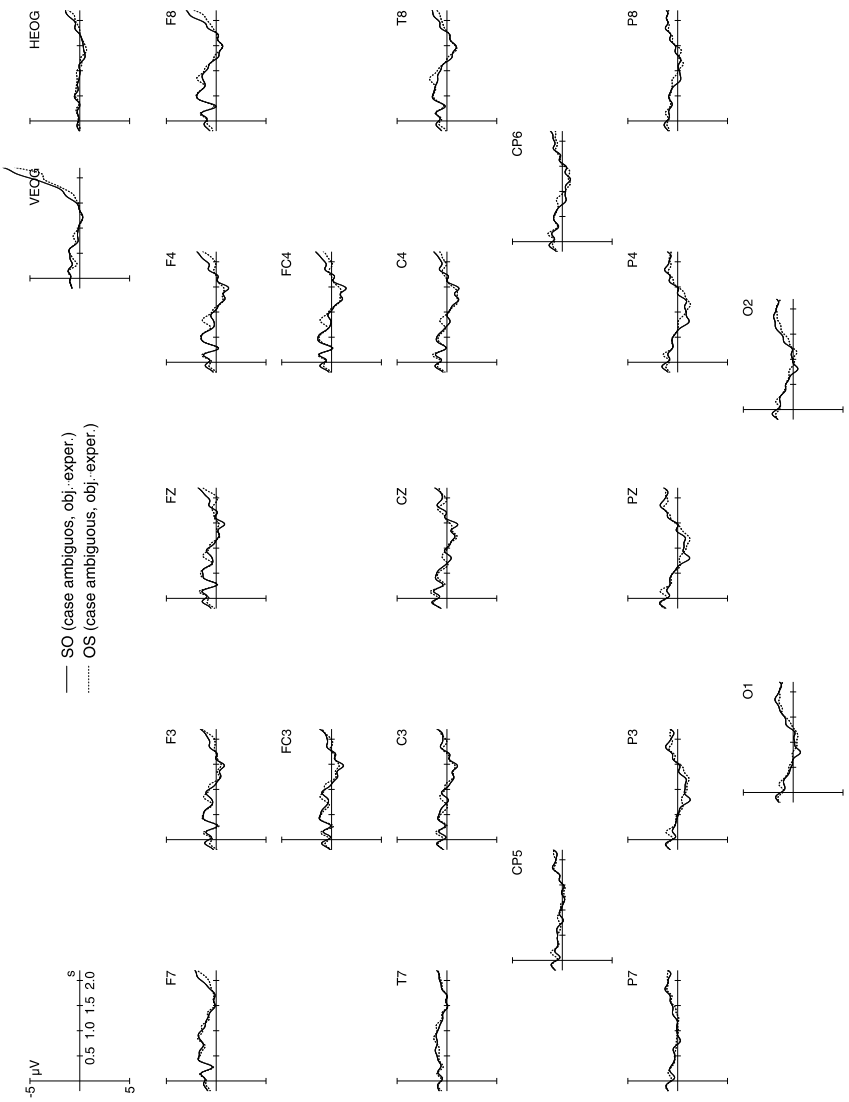

Figure F.6 Adults in Experiment I: Object-initial vs. subject-initial object-experiencer structures in sentences with case ambiguous arguments.

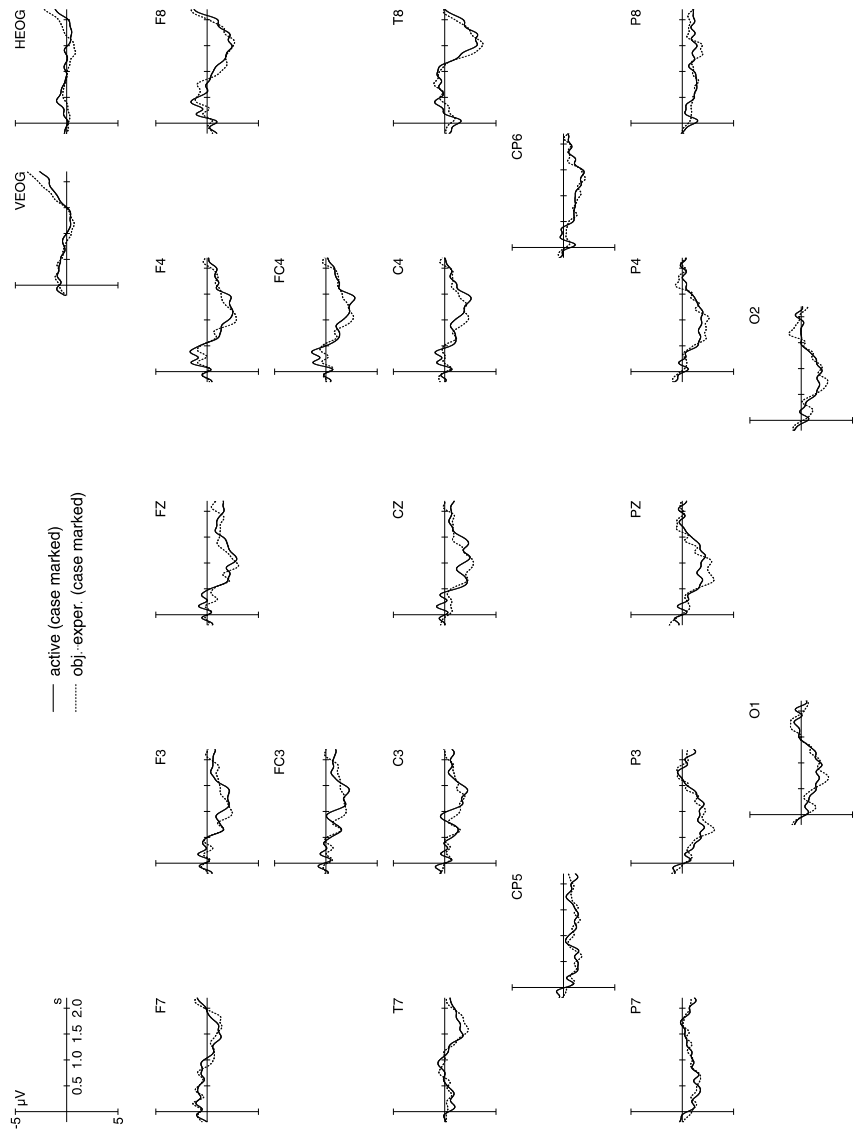

Figure F.7 Eleven-year-old children in Experiment II: dative object-experiencer vs. dative active verbs in sentences with unambiguously case marked arguments.

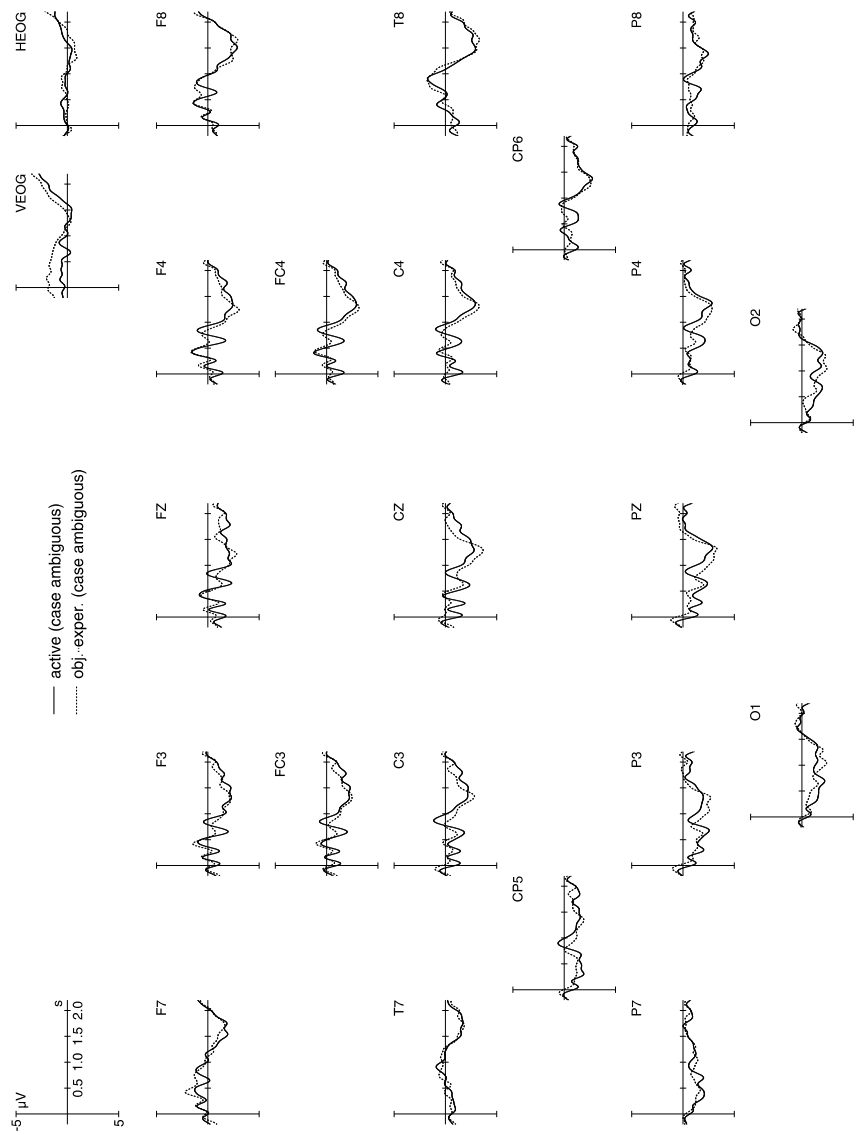

Figure F.8 Eleven-year-old children in Experiment II: dative object-experiencer vs. dative active verbs in sentences with case ambiguous arguments.

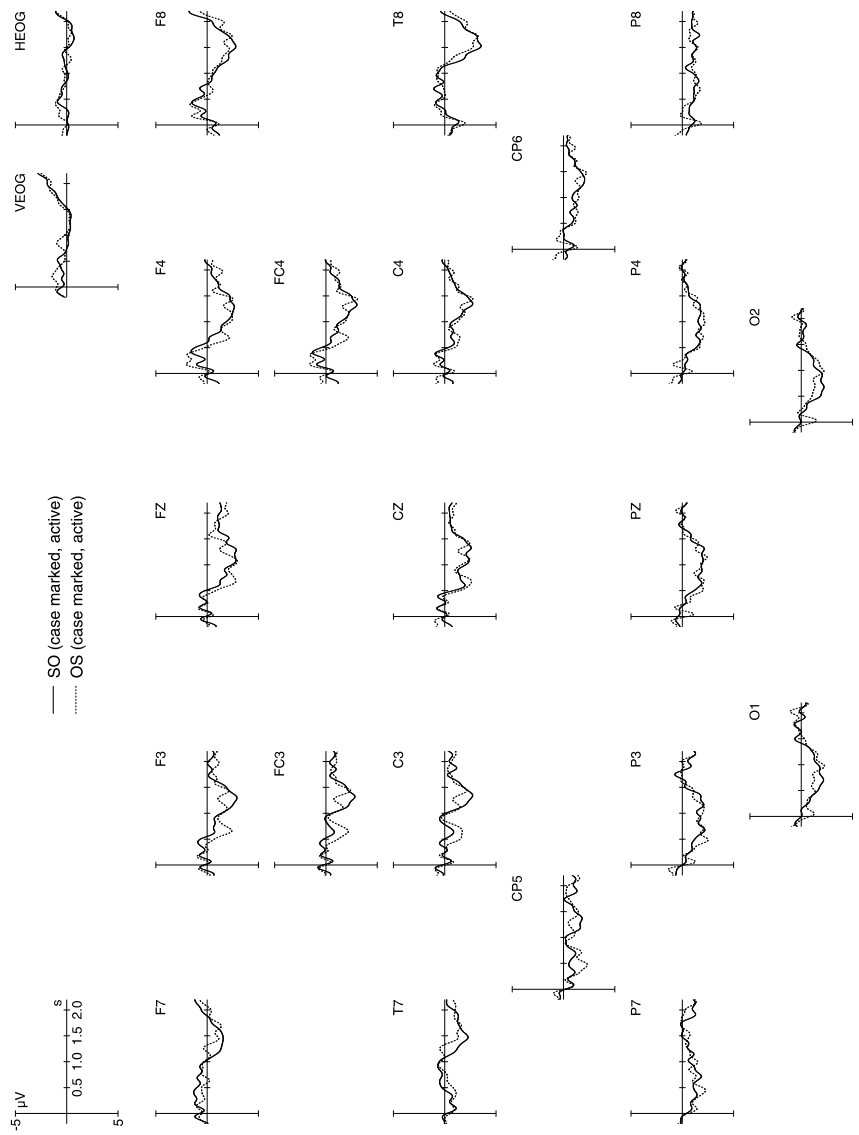

Figure F.9 Eleven-year-old children in Experiment II: object-initial vs. subject-initial dative active structures in sentences with unambiguously case marked arguments.

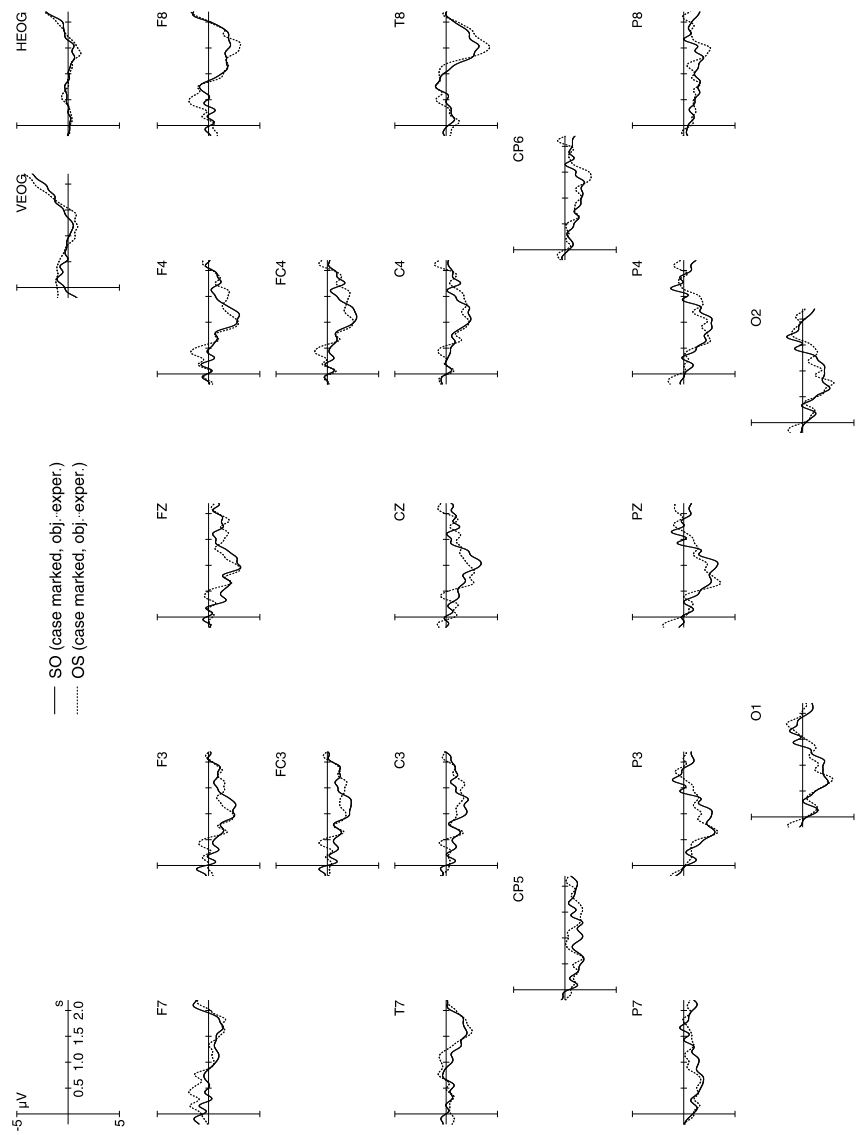

Figure F.10 Eleven-year-old children in Experiment II: object-initial vs. subject-initial dative object-experiencer structures in sentences with unambiguously case marked arguments.

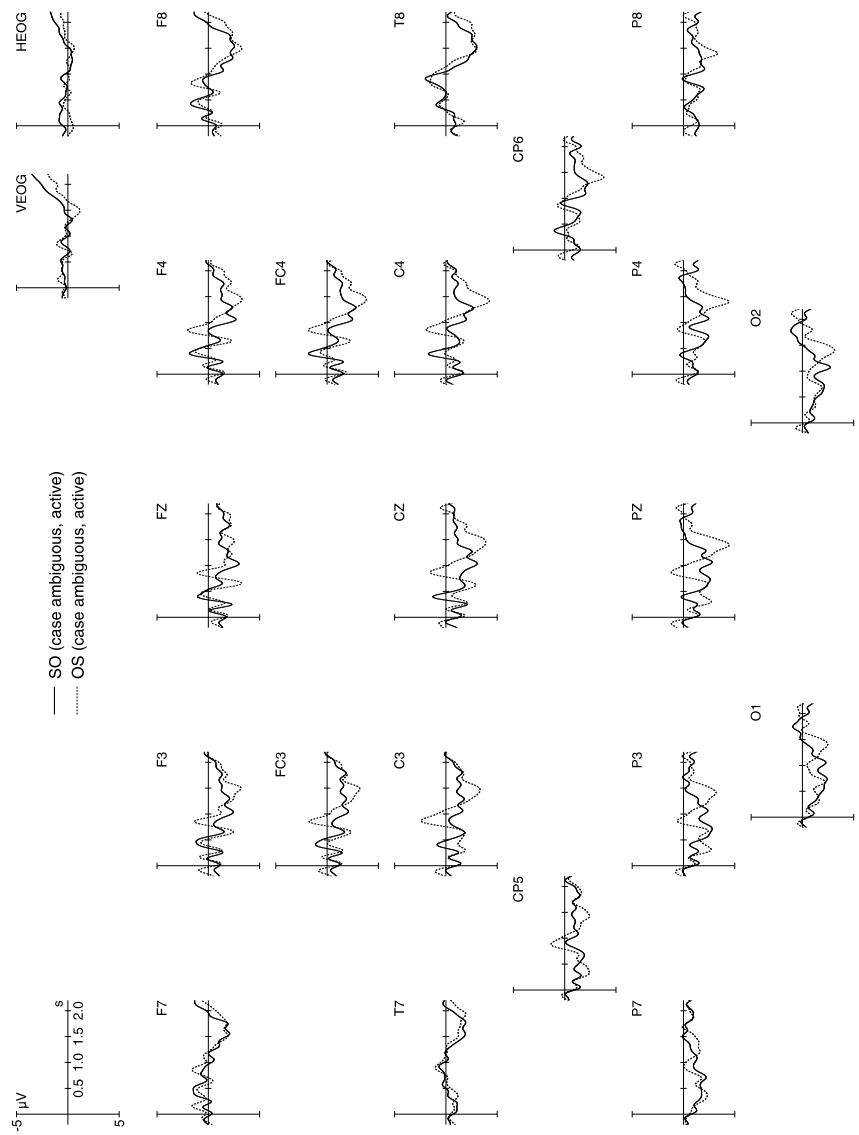

Figure F.11 Eleven-year-old children in Experiment II: object-initial vs. subject-initial dative active structures in sentences with case ambiguous arguments.

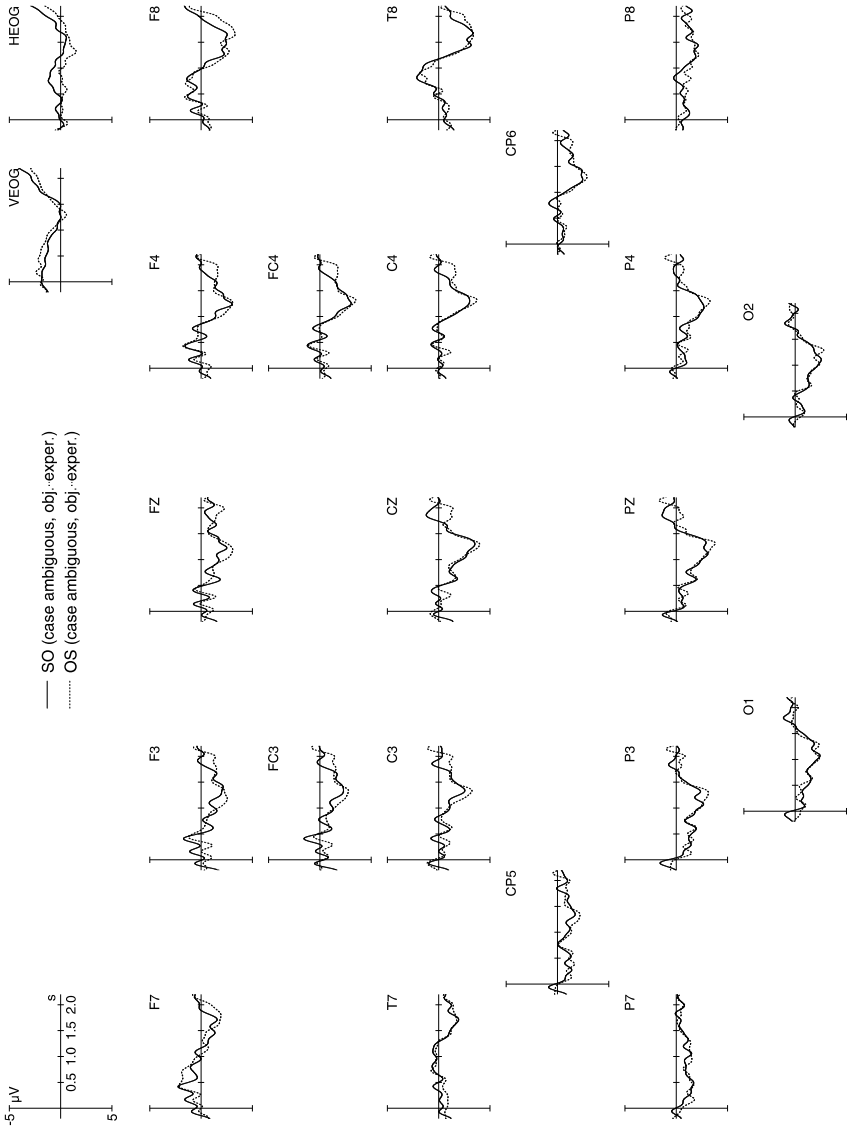

Figure F.12 Eleven-year-old children in Experiment II: object-initial vs. subject-initial dative object-experiencer structures in sentences with case ambiguous arguments.

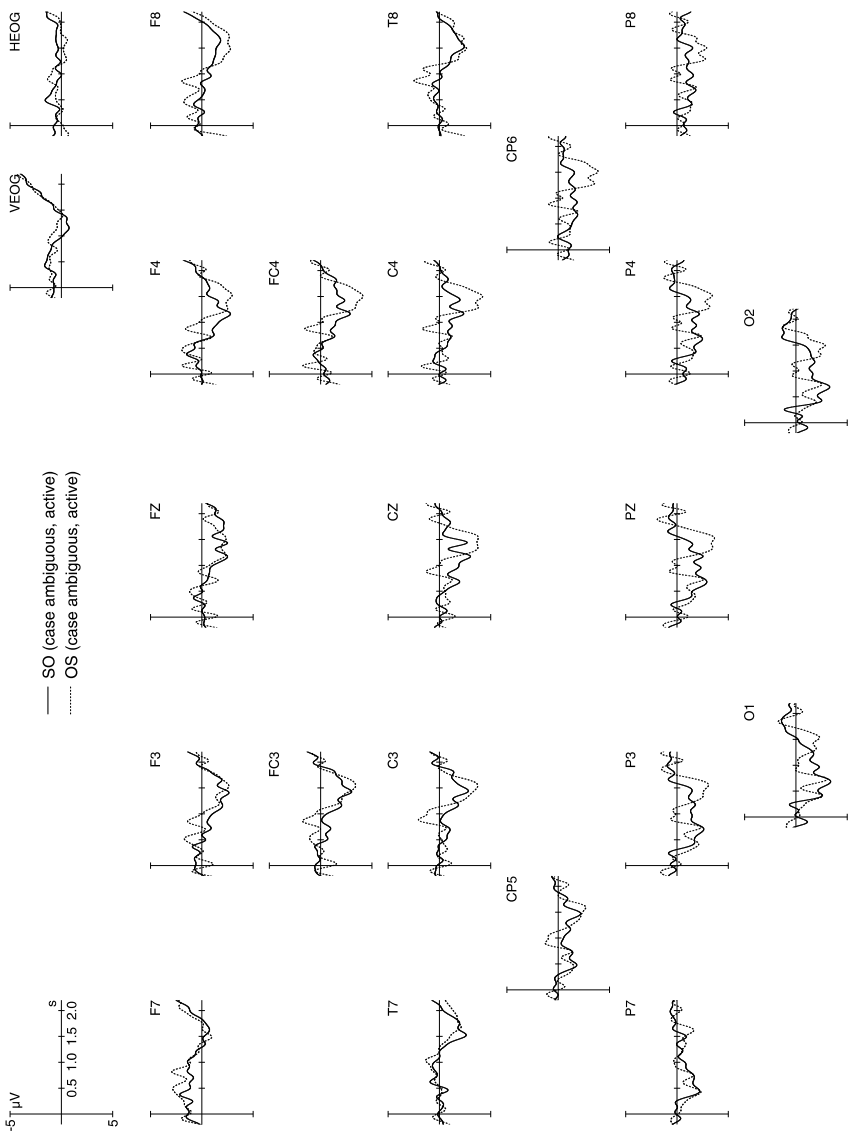

Figure F.13 Eight-year-old children in Experiment III: object-initial vs. subject-initial dative active structures in sentences with case ambiguous arguments.

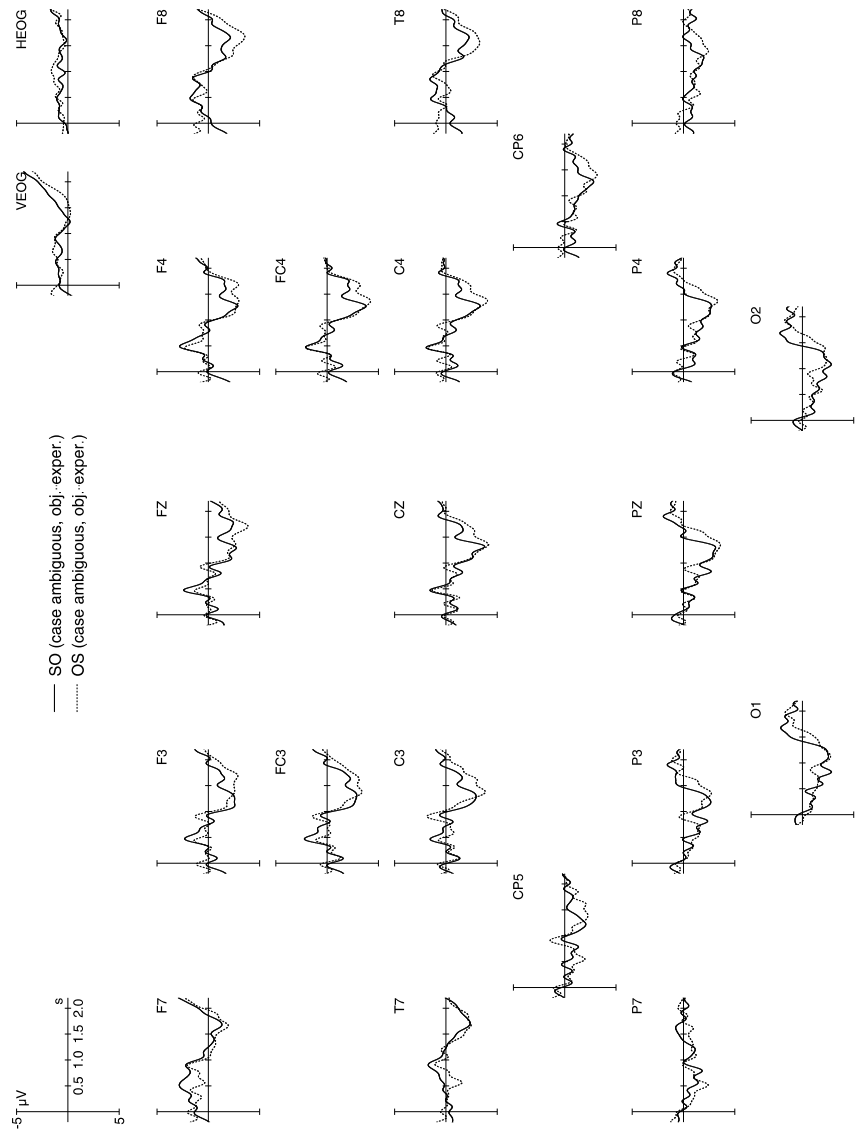

Figure F.14 Eight-year-old children in Experiment III: object-initial vs. subject-initial dative object-experiencer structures in sentences with case ambiguous arguments.

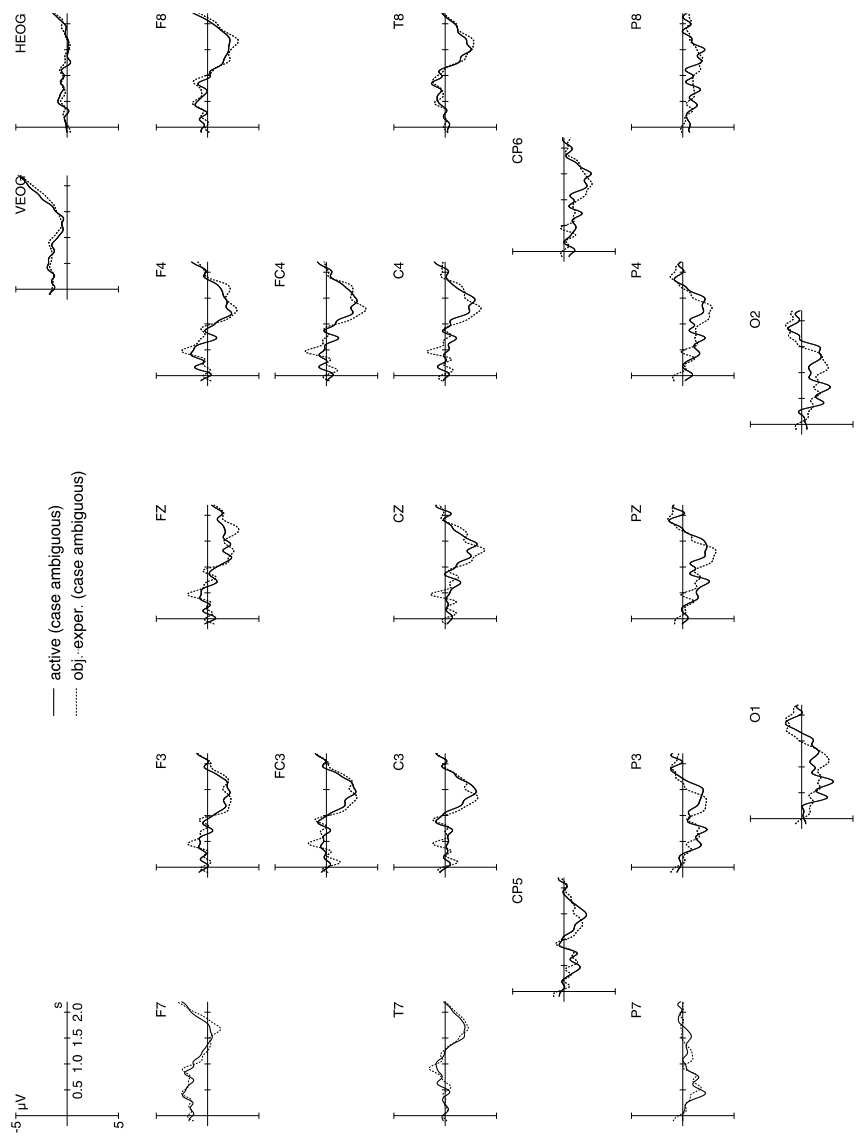

Figure F.15 Eight-year-old children in Experiment III: dative object-experiencer vs. dative active verbs in sentences with case ambiguous arguments.

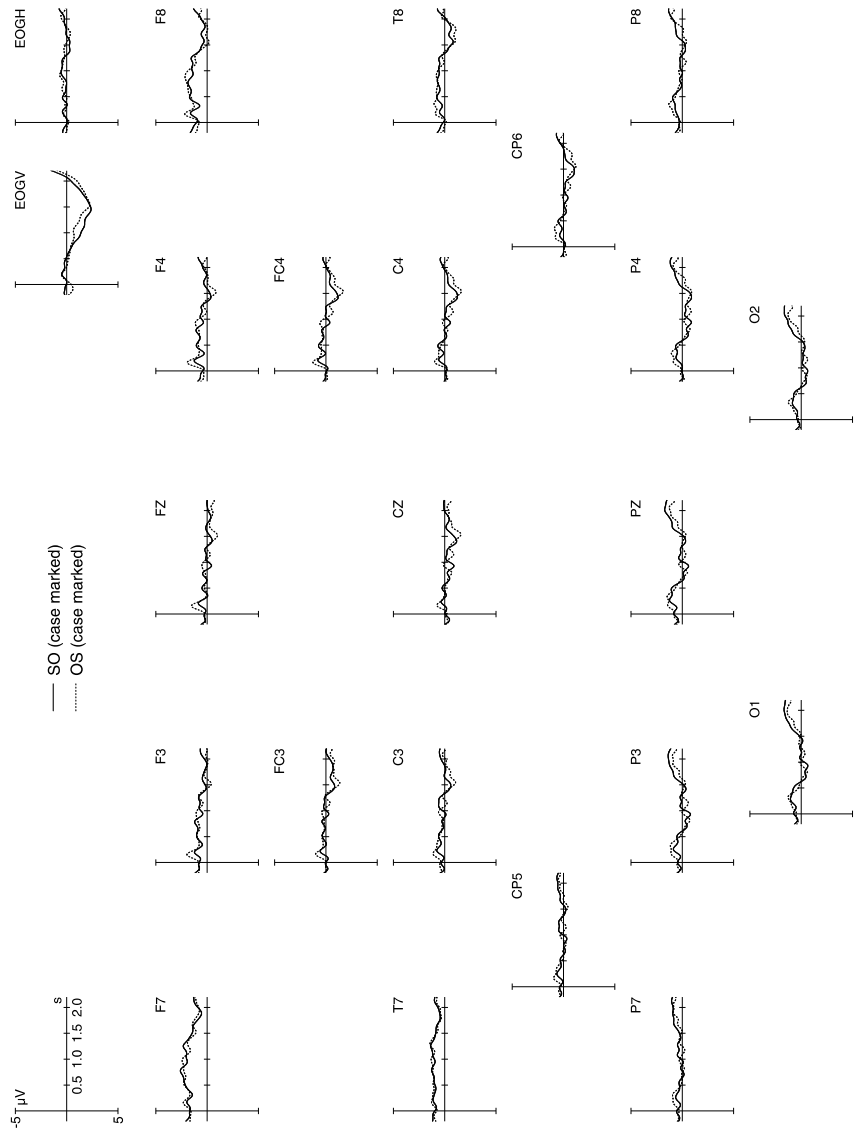

Figure F.16 Adults in Experiment IV: object-initial vs. subject-initial accusative structures in sentences with unambiguously case marked arguments.

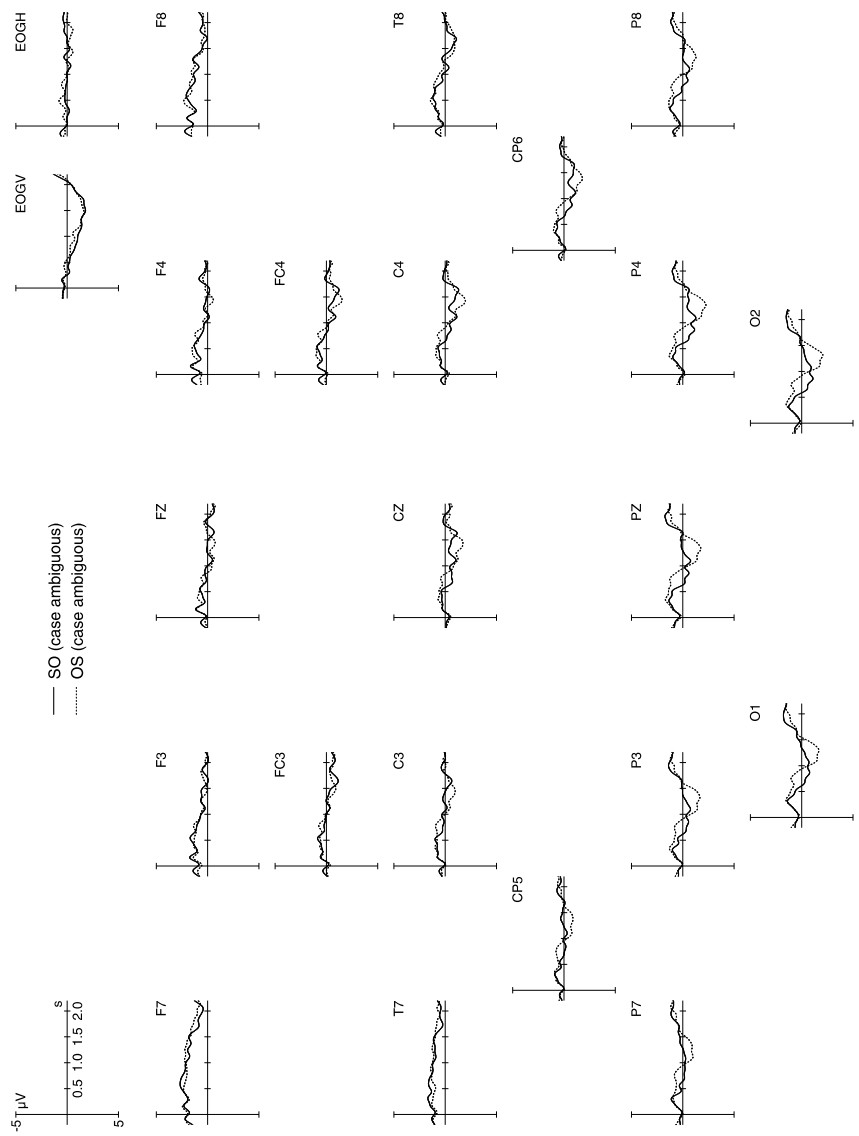

Figure F.17 Adults in Experiment IV: object-initial vs. subject-initial accusative structures in sentences with case ambiguous arguments.

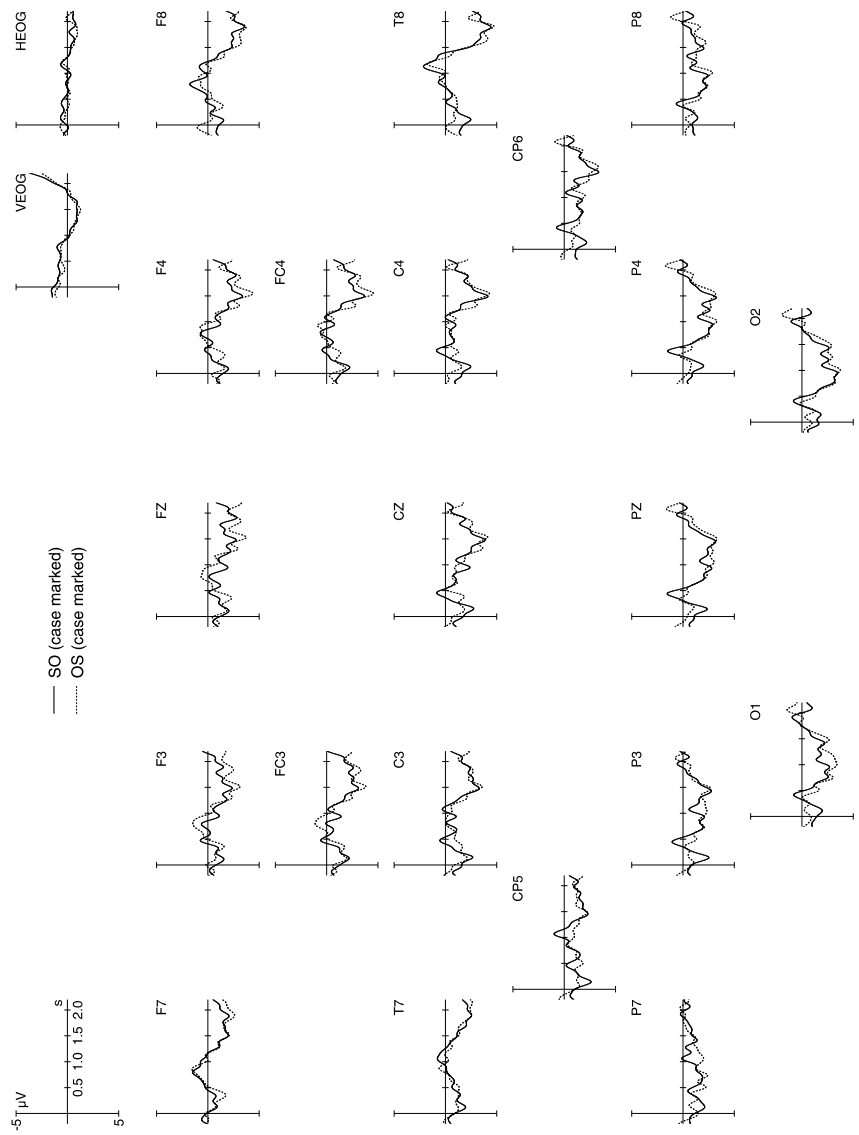

Figure F.18 Eight-year-old children in Experiment IV: object-initial vs. subject-initial accusative structures in sentences with unambiguously case marked arguments.

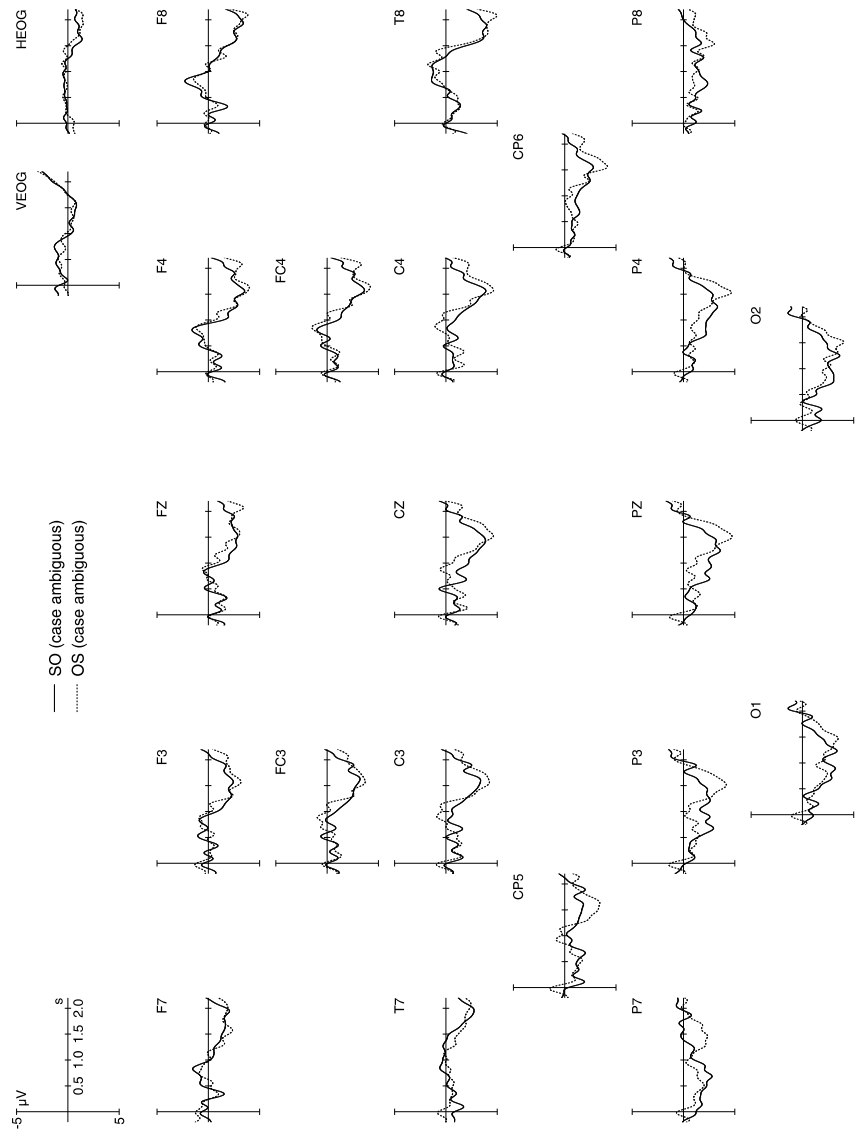

Figure F.19 Eight-year-old children in Experiment IV: object-initial vs. subject-initial accusative structures in sentences with case ambiguous arguments.

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