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Characteristics of processing morphological structural and inherent case in language comprehension

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To my parents,

Ilse and Uwe-Jens Jacobsen

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Contents

Chapter 1

Introduction

In psychology, the science of mental processes and behavior, the mental function of language processing stands out. Language is specific to the human species. Only the human mind, and the human brain that enables it, are capable of producing fully-fledged language skills. The human language processing faculty constitutes a highly developed and very complex skill that has fascinated researchers of numerous scientific disciplines since the beginnings of science. Today, investigators from linguistics, psychology, biology, neuroscience, computer science, philosophy and other fields demonstrate their interest in human language processing. It is only if these disciplines pool their efforts and join into an interdisciplinary endeavor that we will be able to create a unified theory of language and its functional implementation in the mind/brain. Since the cognitive revolution in the late 1940s (Gardner, 1985) and the invention of cognitive neuroscience in the late 1970s (Gazzaniga, Ivry & Mangun, 1998) the scientific joint venture to reveal how the brain enables the linguistic mind has come a long way (Friederici, 1998a).

This thesis is concerned with the intersection of three research areas: linguistics, cognitive psychology and electrophysiology. The study presented follows the approach of studying human language processing experimentally in a cognitive psychology and cognitive neuroscience framework. Building on the wealth of existing knowledge in the field, it attempts to pull together results from the linguistic, psychological, psycholinguistic, psychophysiological and brain imaging literature in order to investigate one facet of the mosaic of magnificent language skills - the processing of one specific syntactic feature in language comprehension. In particular, this study aimed at unraveling characteristics of processing overt morphological structural and inherent case information in German, a language with rich case morphology. To this end, theoretical linguistic concepts were operationalized in experimental materials and presented in a number of experimental settings.

For documenting the study this dissertation is structured as follows. First, the theoretical linguistic background of this study is introduced in Chapter 2. Followed by a brief introduction to psycholinguistics that focuses on aspects that are relevant for the present study, in particular syntactic processing (Chapter 3). The subsequent chapter (4) provides an introduction to the electrophysiology of the brain and the event-related brain potential technique. Also, an overview of the electrophysiological study of human language processing is provided. Again, this chapter is focused on relevant aspects of syntactic processing. Subsequently, the research questions and goals are described including a preview of the experiments (Chapter 5).

The experimental section follows. Here, a lexical frequencies analysis and seven experiments are described. The frequencies analysis investigated lexical frequencies of German accusative and dative verbs according to their complement structure (Chapter 6). It also served as a source for the subsequent construction of experimental material. In Experiment 1 grammatical acceptability judgments over syntactically correct and incorrect wh-question sentences featuring overt morphological accusative and dative case marking on the question pronouns and accusative and dative verbs were gathered (Chapter 7). Experiments 2 and 3 used sentence-initial fragments of the same type in a sentence completion verb generation task. This was done using a visual presentation variant in Experiment 2 (Chapter 8) and auditory presentation for a modified replication in Experiment 3 (Chapter 9). Subsequently, Experiment 4 investigated effects of case information in online sentence processing using the syntactic priming approach in a response time task (Chapter 10). Experiment 5 constitutes an extended replication of Experiment 4 (Chapter 11). Having establishing an effect of case information in online sentence comprehension using behavioral measures, Experiments 6 and 7 employed the event-related brain potential technique to investigate its processing characteristics and time-course more closely. Effects of overt case information on verb-last (Experiment 6, Chapter 12) [1] and verb-first clauses (Experiment 7, Chapter 13) [2] were studied. Finally, the thesis concludes with a general discussion.

Each chapter is followed by a brief summary of its content. Reading these summaries exclusively should provide the reader with a concise synopsis of this dissertation.

[1] Aspects of Experiment 6 were reported in Jacobsen and Friederici (1998).

[2] Aspects of Experiment 7 were reported in Jacobsen and Friederici (1999).

Part I

Theoretical Section

Chapter 2

Linguistics

Linguistics is the science of language (Bloomfield, 1935). As all scientists, linguists work on describing and explaining their subject. Traditionally, the following areas of study are distinguished: Semantics, syntax, morphology, phonology and phonetics - which also can be thought of as systematically structured layers, in this order from the conceptual system to acoustic output in the process of producing spoken language.

This thesis focuses on syntactic aspects of language processing, accordingly this introduction confines itself to relevant aspects of syntax. Haegeman (1991, 1994) provides an extensive introduction to syntax. Refer to Lyons (1977) for a comprehensive introduction to semantics, and to Matthews (1974, 1991) for extensive coverage of morphology. Selkirk (1984) and Nespor and Vogel (1986) give introductions to phonology with emphasis on relations to syntax and prosody respectively. See also Laver (1994) and Ladefoged (1993, 1996) for a comprehensive introduction to phonetics.

While semantics is concerned with aspects of content and meaning, syntax deals with formal aspects of building linguistic structure, thereby often stating general principles. Morphology studies the internal structure of words, the building blocks a word is made of. A morpheme is the smallest meaning-relevant particle or constituent of a word. The set of different morphemes of a language like English or German is in the range of 20.000. More than 95 percent of these are unbound morphemes or words (e.g. cat, dog, chase) and less than 5 percent are bound morphemes (e.g. -ed and -s). Furthermore, phonology is concerned with the sound units of a language. These sound units are called phonemes. The set of phonemes varies between 11 and 141 by language. Finally, phonetics studies the actual acoustic signal.

2.1 Syntax

Syntacticians build grammars. A grammar of a language is a coherent system of rules which determines the formation of the sentences of that language. Sentences that are well-formed according to the grammar of a language are grammatical. Those that are not are ungrammatical (in the literature examples of these sentences are usually marked by an asterisk "*"). Using a grammar's finite set of rules, of which some can be recursive (i. e., they can call themselves) and the finite set of lexical elements of a language an infinite number of sentences can be generated.

One very influential grammar has been proposed by Chomsky (1957, 1965, 1986a, 1992). It is called Government and Binding theory or GB (Chomsky, 1980, 1981a, 1982; Haegeman, 1991), which is the theoretical approach to syntax that is adopted in this thesis. In GB syntactic rules are called principles (Chomsky, 1981b).

In order to determine whether a sentence is formed according to a given grammar or not, grammaticality judgments are performed by the professional linguist. Whereas the native speaker's intuitive judgment about the grammaticality of a sentence is called grammatical acceptability judgment. Thus, all intuitive grammaticality judgments by native speakers are considered acceptability judgments rather than grammaticality judgments. For the reason that the term "grammaticality judgment" is reserved for judgments that employed scientific linguistic knowledge.

While the work presented here is based on the Chomskian tradition of Government and Binding Theory (Chomsky, 1981a; Haegeman, 1994), its scope in the domain of psycholinguistics is not restricted to this particular view on syntax. It is only necessary that the reader shares the critical basic assumptions (see Section 2.6 on page 9). Nevertheless, the following introductory sections are mainly based on GB.

2.2 Sentence constituents

Words are the ultimate constituents of a sentence. There are different categories of words: nouns, verbs, adjectives, prepositions etc.. The word itself along with its word category and other lexical information is represented in the lexicon of a language. To build a sentence, words are hierarchically organized into higher order constituents, which are called phrases and clauses that eventually build up a sentence. The syntactic analysis of a sentence determines its phrasal constituent structure. A tree diagram or labeled brackets (e.g. (2.3)) are common ways to represent the constituent structure of a sentence.

(2.1) Der Mann sieht die Frau.

(2.2) The man sees the woman.

(2.3) [S[NP[Det N]][VP[V][NP[Det N]]]]

(2.3) shows the syntactic analysis of (2.1) and also of (2.2) which is the English translation of (2.1). The bracket labeled "S" encloses the entire sentence. Sentences are the largest units of syntactic analysis. Grammars do not have anything to say about paragraphs or the discourse. Two brackets are nested within the outmost bracket. One labeled "NP", noun phrase, and one labeled ”VP”, verb phrase. The noun ”Mann” (”man”) is the head of the NP, and thus gives it its name. The NP consists of the determiner ”DET” ”der” (”the”) and the noun. While the VP consists of the verb ”V” ”sieht” (”sees”) itself and an NP. This verb phrase internal NP is the direct object of the verb. It is composed of the DET ”die” (”the”) and the N ”Frau” (”woman”).

2.3 Subcategorization and complement structure

The word category of verbs is divided into subcategories. At least three classes of verbs are distinguished in traditional linguistics: transitive, ditransitive and intransitive verbs. A transitive verb takes a complement, usually an NP (e.g., the verb ”see”). This complement, the direct object, is required to build a well-formed VP. Ditransitive verbs take two complements (e.g., ”give”). While intransitive verbs do not allow a complement at all (e.g., ”snore”).

These complements can be of different types: NP, prepositional, adverbial, etc. (see Appendix A.1 for types of complements that the CELEX lexical database (Centre for Lexical Information, 1995) cites for German verbs).

Notations that identify the subcategory of a verb and list its complements and their types (NP, PP etc.) are called subcategorization frames.

Complements are also specified for case where applicable (see below). In German, verbs can assign accusative, dative or genitive case to their complements. The complement structure of a verb contains a verb's complements, their type (NP, PP etc.) and their case where applicable. German verbs can feature obligatory or optional complements. See also Helbig and Schenkel (1973), which can be considered the standard in German linguistic research on complement structures (the German linguistic technical term being ”Valenzen”). A large number of German verbs feature more than a single complement structure. These can be labeled polyvalent verbs (Vogel, 1998). The respective term is ”polyvalente Verben” in German linguistic terminology. That is, a given verb can be used in a transitive as well as an intransitive reading in a sentence. [1]

According to CELEX (1995, 1990) verb lemmas, the layer of lexical representation of a verbs featuring syntactic specifications but no information about (phonological) form, carry verb complement structure information but not thematic roles (see Theta theory below). [2]

In the present study, the notion of complement structures as described above and used by CELEX is adopted. The study is concerned with investigating the processing of verbs that

[1] Note that there is an ongoing debate about the status of verb complement structures and case in contemporary linguistics (cf., Vogel, 1998). A single conceptualization that is shared by everyone in the field does not exist. Some critical aspects are the degree of cross-linguistic analysis, the degree of formalization and the basic theoretical background.

[2] Parallel distributed processing (PDP) accounts (McClelland & Rumelhart, 1986; Rumelhart, Hinton & McClelland, 1986; McClelland, John & Taraban, 1989) dissolve the notion of layered structured local representations of lexical elements. Thus, a completely different conceptualization of mentally implemented syntax must result.

either take an obligatory accusative or dative complement. Polyvalent verbs that subcategorize for both cases were not employed.

2.4 Argument structure

Linguists have adopted the notion of predicates and their arguments from formal logic (pp. 42 Haegeman, 1994). Here verbs are regarded as predicates, that define some kind of relation to an entity or a number of entities that refer to the outside world (e.g., Quine, 1966, 1982). These entities are called arguments. See Grimshaw (1991) for an introduction to verb-argument structures.

The linguistic term ”transitive” corresponds approximately to two-place predicates of logic. One, the VP internal complement is one argument. Two, the VP external subject of the sentence is the second argument. Ditransitive verbs have three arguments and thus form three-place predicates. While intransitive verbs only allow one VP external argument. This constellation of arguments is noted in the argument structure of a verb.

Hence, the argument structure of a verb contains all elements that a verb requires and allows formation of a predicate, or sentence in linguistic terms. This is contrasted by the complement structure introduced above, which only deals with the VP internal elements that the verb subcategorizes for.

All verbs used in the present study had an identical verb-argument structure. This syntactic feature was held constant.

2.5 Theta theory

Theta theory is concerned with ”Who does what to whom?” in a sentence. In linguistics these relations between verbs and their arguments are referred to as thematic roles or theta roles. Predicates in general have a thematic structure. A verb assigns a thematic role to each argument. It theta-marks its arguments. The grammar that GB builds has a modular structure. Theta theory is the module of GB that regulates the assignment of thematic roles. Haegeman (1994) notes ”Although many linguists agree on the importance of thematic structures for certain syntactic processes, the theory of thematic roles is still very sketchy”. According to Haegeman, the following thematic roles are commonly distinguished: Agent, Patient, Theme, Experiencer, Benefactive, Goal, Source and Location. In GB the thematic roles that a verb assigns are represented in its thematic grid or theta grid.

Clearly, theta theory has a partially semantic content. It can be considered an interface or gate between syntax and semantics. On the other hand, it is considered a syntactic device. See also below for a discussion of the interplay of Theta theory and Case theory.

A very important general rule of GB is the projection principle, which is also of relevance for case theory. It reflects the idea that lexical information, of the kinds introduced above, determines the syntactic structure of a sentence to a large extent. Projection principle:

(2.4) Lexical information is syntactically represented.

2.6 Case theory

Syntax matters. Sentences (2.1) and (2.5) cannot be fully comprehended without an operative knowledge of syntax. While it might still be possible to decode the meaning of (2.1) in a rudimentary fashion by resorting to the word order of the sentence, this strategy is bound fail with (2.5).

(2.5) Den Mann sieht die Frau.

(2.6) The man is seen by the woman.

(2.7) [S[VP[NP[Det N]][V]][NP[Det N]]]

The critical feature here is case. German has a rich system of overt morphological case marking. For instance, case is overtly morphologically marked on the definite articles. There is a difference of only one letter between the two sentences - ”den” versus ”der” (”the”), which changes the phrase structure (2.7) and the meaning of the sentence (2.5) entirely. The word order change of subject predicate object (SPO) in (2.1) to OPS in (2.5) is possible because of the overt case marking. In English the sentence has to be passivized in order to be able to keep the word order (2.6). Note that there are a number case syncretisms in the German system, however, which sometimes render the case marking of the determiner ambiguous (e.g. ”die” in (2.1) and (2.5)).

Case theory is the grammar module that introduces the traditional notion of case into GB (pp.155 Haegeman, 1994).

Overt morphological versus abstract case marking Chomsky (e.g. 1986b) proposed a universal grammar (UG). Being universal to all natural human languages, UG is based on a set of common principles and is adjusted to the specifics of a given language by setting parameters to their appropriate values. This is done by the learning child during language acquisition. [3] This theory is also called principles and parameters theory.

By far not all languages have a rich case marking system as German does. Furthermore, languages are not fixed. They change over time. In order to cover these phenomena and incorporate case into the principles and parameters theory, overt morphological and abstract case are

[3]This view on innateness of the human language faculty has not remained uncontested (e.g. Elman, Bates, Johnson, Karmiloff-Smith, Parisi & Plunkett, 1996).

distinguished. Abstract case is a fully-fledged case system that is not visible in the morphology of language but works in the syntactic analysis.

By comparing (2.1) and (2.5) we have seen that changing the overt morphological case marking on the first determiner in the sentence alters the sentence entirely. Since English lacks overt morphological case marking on the determiner, an additional change, namely passivization, was required in (2.6).

English has the remnants of a morphological case system (pp. 157, Haegeman, 1994). Case is marked overtly in the pronominal system and Genitive case is marked overtly on NPs in English (see Table 2.1). Note that there are also a number of case syncretisms.

Table 2.1: English case forms

	Nominative	Accusative	Genitive
a Lexical NPs:			
	the man	the man	the man's
b Pronominal NPs:			
1 sg.	I	me	my
2 sg.	you	you	your
3 sg. masc.	he	him	his
3 sg. fem.	she	her	her
3 sg. neut.	it	it	its
1 pl.	we	us	our
2 pl.	you	you	your
3 pl.	they	them	their

Note. Adapted from Haegeman 1994, page 15.

Therefore, English is not considered to lack case, but to feature a fully-fledged system of abstract case. Case is part of Universal Grammar. See also van Kemenade (1987) and Roberts (1983) for a treatment of the eroding system of overt morphological case in English.

Since the language of this study is German we are exclusively concerned with instances where abstract and overt morphological case marking fall together.

Structural versus inherent case marking At this point it is necessary to draw a second orthogonal dichotomy in order to classify case; structural and inherent case are distinguished as two instances of abstract case.

Verbs and prepositions assign case to their complements according to the specifications in their complement structure (see above), they case-mark their complements. The conditions of case assignment are partly structural. They are dependent on certain structural relations. For instance, a verb cannot assign accusative case to a NP outside the VP it heads. Case assignment is a function of verb type. Intransitive verbs cannot assign case to a complement NP (because they do not have one). Nevertheless, those VP external NPs are case marked, due to structural requirements.

Nominative is the structural default case for sentence subjects and Accusative is the structural default case for verb objects.

GB postulates a case filter:

(2.8) Every overt NP must be assigned abstract case.

As a consequence, every sentence construction containing an overt NP that is not assigned case is filtered out as ungrammatical. Constituent NPs must be visible. In other words, they must be licensed. In GB ”NPs are licensed by virtue of their case properties” (p. 189, Haegeman, 1994) GB specifies a number of additional criteria for structural case assignment (pp. 193, Haegeman, 1994) that are not necessary for the understanding of this study and are thus beyond the scope of this thesis.

In sum, structural case is assigned by means of structural grammatical reasons. Accusative is the structural case for verb objects. It is the default case that is assigned to the verb object by the verb. The object is thus case-marked.

Inherent case, on the other hand, is assigned under different conditions than structural case. The inherent case that a verb assigns has to be coded in the lexical entry of this verb. Assigning Dative case to a verb object thus constitutes a deviation from the default rule. Whether or not a verb assigns Dative or Genitive case to a VP internal NP has to be learned for each individual lexical item. Whereas this is not absolutely necessary for structural case, since it can be accounted for by the default rule.

The fact that structural and inherent case behave differently can be illustrated by the examples below also from Haegeman (1994). Note that this difference holds independently of the specific theory of syntax (e.g., GB) that one assumes. It follows from this fact that this is also true for the experimental manipulations carried out in this study.

The following examples demonstrate that Accusative as structural case is absorbed under passivization (2.9) while Dative as inherent case survives (2.14).

(2.9) Sie sieht ihn$_{acc}$. She sees him.

(2.10) Er$_{nom}$ wird gesehen. He is seen.

(2.11) *Ihn$_{acc}$ wird gesehen. Him is seen.

(2.12) Sie hilft ihm$_{dat}$. She helps him.

(2.13) *Er$_{nom}$ wird geholfen. He is helped.

(2.14) Ihm$_{dat}$ wird geholfen. him is helped

In the following paragraph a few thoughts are conveyed on the systematicity or arbitrariness of assignment of Accusative or Dative case by German verbs to their direct objects. Consider the examples in Table 2.2.

Table 2.2: Verb examples

Accusative	anhören	treffen	anlächeln
Dative	zuhören	begegnen	zulächeln
	listen to	meet	smile at

All these verbs are transitive. The pairs of words in the columns have highly synonymous meanings, identical verb argument structures, and theta grids. Only their complement structures differ. The upper row (”anhören” etc.) subcategorizes for an obligatory Accusative NP. While the lower row (”zuhören” etc.) subcategorizes for an obligatory Dative NP. Since the case that a given verb assigns does not necessarily co-vary systematically with its Theta grid or semantics, this fact constitutes another reason to investigate case independently. This notion, however, might have to be relativized, because it does not hold for the majority of ditransitive verbs.

On the interplay of Theta theory and Case theory in GB As introduced above, the grammar that GB builds has a modular structure. Case theory has its own functionality independent of Theta theory. Despite this fact, the goal is to build an integrated grammar. Thus it is necessary to link the modules. In this regard, attempts have been made to link case theory and theta theory. The critical feature here is visibility. During sentence comprehension, a sentence constituent, a player, has to be visible in order to be theta marked. This is done through licensing by virtue of case marking. Both syntactic devices interlock and build on each other to a certain extent. Sentence constituents need to be assigned case, and be thus visible by virtue of their case marking in order to be assigned thematic roles. In order to provide a complete syntactic analysis for a given sentence, case marking has to be completed prior to thematic role assignment. Note that this claim holds for the linguistic analysis that GB supports and cannot necessarily be extended to processes of language comprehension.

Case syncretism Languages are not fixed. They change over time and so does the case system of a given language. As introduced above, English features only the remnants of an morphological case system (see Table 2.1). Overt morphological realization of case in full lexical NPs is restricted to Genitive case in English. Whereas Nominative, Accusative and Dative case are not realized overtly in full NPs. This status quo has been arrived at over time by a long process of case erosion (van Kemenade, 1987; Roberts, 1983).

There is a tendency towards an erosion of the case system in a number of languages (cf., the work on word order universals by Hawkins, 1983). Case erosion is also proceeding in German.

2.7 Summary

The present chapter provides a brief introduction to linguistics. Emphasis lies on the relevant aspects of syntactic analysis, Case theory in particular. Other traditional domains of linguistic study, i.e. semantics, morphology, phonology and phonetics, are merely mentioned and references are given. This dissertation is based on a linguistic background that Government and Binding theory (Chomsky, 1981a; Haegeman, 1994) provides.

Within Case theory overt morphological and abstract case are distinguished. While German features a fully-fledged system of case morphology, English merely has the remnants of a morphological case system (pronominal system and Genitive marking on lexical NPs). Nevertheless, English is considered to feature a complete system of abstract case. An indispensable linguistic device that is used to license sentence constituents in syntactic analysis. In other words, abstract case is used to make players in a sentence visible. Verbs case-mark their objects. If a sentence constituent cannot be assigned abstract case it is filtered out as ungrammatical by the so-called case filter.

In addition, two instances of abstract case are distinguished: Structural and inherent case. Structural case is assigned by means of structural grammatical reasons. Accusative is the structural case for verb objects. It is the default case that is assigned to the verb object by the verb. The object is thus case-marked. The verb is the case assignor. Inherent case, on the other hand, is assigned under different conditions than structural case. The inherent case that a verb assigns has to be coded in the lexical entry of this verb.

This study is concerned with investigating the processing of morphological structural and inherent case associated with verbs that obligatorily take either accusative or dative complements. Polyvalent verbs that subcategorize for both cases were not employed.

Chapter 3

Psycholinguistics

An adult speaker commands a variety of specialized sources of knowledge and processing mechanisms that enable the linguistic mind: a passive knowledge of about 30 to 50 thousand words, a mental syllabrary, an operative knowledge of grammar, to name a few. The normal speaker can effortlessly produce or comprehend an average of two to three words per second. Given this speed and the size of the mental database the human language processing system must be organized very efficiently.

The present chapter provides a brief introduction to psycholinguistics. As in the previous chapter the focus is set on aspects of particular relevance to this thesis. Psycholinguistics is the branch of psychology that is concerned with the study of language comprehension, language production and language acquisition. See Gernsbacher (1994) for a comprehensive overview of the field of psycholinguistics (see also Caplan, 1992). The reader is referred to Levelt (1989, 1999) for an introduction to language production and to Friederici (1998a) for comprehensive coverage of the area of language comprehension. For a detailed introduction to language acquisition see Berko-Gleason (1992) or Ritchie and Bhatia (1999). [1]

3.1 Language comprehension

Psycholinguists are widely in agreement that a number of distinct mental processes have to be performed very rapidly and at the same time in a highly coordinated manner in order to decode a verbal message from the physical input to a conceptual representation. Traditionally these are conceptualized as stages or levels of language comprehension. These stages are:

[1] Other core issues in psycholinguistics are questions related to the degree of innateness of the human language processing system and the related issue of universality of language. For these topics the reader is referred to two prominent books in the nature-nurture debate (Pinker, 1994; Elman, Bates, Johnson, Karmiloff-Smith, Parisi & Plunkett, 1996)

- acoustic or visual processing
- phonetic decoding or visual form recognition
- word recognition
- syntactic structure building or parsing
- semantic integration and
- referential processes.

The acoustic processing consists of selecting speech from the acoustic background, extracting features for voice identification and features for distinguishing phonetic contrasts. Visual processing consists of extracting features from the visual input. Phonetic decoding then provides a decomposition of the continuous prelexical representation into constituent parts like syllables and words (Frauenfelder & Floccia, 1998). In the visual domain, visual form recognition, or orthographic analysis provides an identification of letters (see e.g. pp. 296 in Gazzaniga et al., 1998). The processes of word recognition can be split into two subclasses: accessing word candidates (lexical access), selecting one of them (lexical selection). Identification of the input word is the product of word recognition (see below for a more detailed account of word recognition). Syntactic parsing is the process of syntactic structure building. The parser builds syntactic phrases based on information associated with the identified words, establishes syntactic relations between phrases, builds clauses and eventually the phrase structure of an entire sentence (see below for a more detailed account of syntactic parsing). During semantic integration semantic relations between sentence constituents are established based on lexical semantics and general world knowledge. Finally, referential processes provide relations of constituents to correct referents, for instance pronominal or indirect references. They also perform pragmatic and discourse processing (Ferstl & d'Arcais, 1998; Noordman & Vonk, 1998).

One core feature of the human language processing system is incrementality. The specialized processing components, the different levels, work in parallel on any characteristic input to them. For example, the parser builds the syntactic structure of the first two words of a sentence while the third is being accessed in the lexicon. Optimal time management is mandatory in language use in order to achieve the fast processing rate.

There is no general agreement, however, as to what extent these levels function independently of each other in a bottom-up fashion or use top-down feedback of information. Furthermore, some models of language processing dissolve the notion of levels or layers of analysis (MacWhinney & Bates, 1989; Bates, Devescovi, Hernandez & Pizzamiglio, 1996; Elman, 1995). Traditionally, two main frameworks of language processing models are distinguished, modular and interactive accounts. More recent overviews increasingly differentiate three types of theories in either comprehension or production:

- Modular or autonomist theories
- Interactive theories
- Hybrid theories

In modular or autonomous accounts normal comprehension is executed within separate and independent processing stages, the modules. According to the most prominent definition by Fodor (p. 37, 1983) a cognitive module is ”domain specific, innately specified, hardwired, autonomous and not assembled”. There is no top-down flow of higher-level information to a processing stage closer to the input. Information flow is strictly bottom-up. As a consequence, there is strict serial processing of the stages (on the properties of cognitive modules see also Friederici, 1990).

In contrast, fully interactive theories maintain that information from all levels of the analysis, higher and lower level information, can participate in the given specialized process. In radically connectionist implementations of the interactive framework the notion of levels of processing is dissolved. Here, the representation that is constructed during language comprehension is not strictly organized into the levels of analysis outlined above, rather it is conceptualized as an activation vector in a multidimensional state space (e.g., Elman, 1993).

Hybrid theories hold that one subprocess of a given processing level operates autonomously while another works in an interactive fashion. For example, the first phase of word recognition, lexical access, might be purely data driven, while higher-level context information is used in an interactive manner for lexical selection. Another core feature that largely co-varies with the theoretical framework is the format of the mental representation (Fodor, 1985). Modular theories usually postulate mental symbols, localist representations, manipulated according to a fixed set of well-defined rules independent of context. In contrast, many interactive theories are based on distributed, numerically coded mental representations (Rumelhart, Hinton & McClelland, 1986; Elman, 1995).

3.2 Word recognition

In the following section theories of word recognition are introduced (for a comprehensive introduction see also Balota, 1994). Word recognition, at times also labeled lexical processing, is traditionally split into lexical access and lexical selection. Furthermore, auditory and visual word recognition need to be distinguished. Specifics of both input modalities are described below. Finally, the relevance of the different models of word recognition for this thesis is discussed.

The Logogen model The logogen model (Morton, 1969) proposed word detectors, so called logogens, that operate on the basis of activation. Logogens sum up activation of letter detectors that is elicited by incoming words. The model proposes logogen-specific thresholds of activation. As soon as accumulating activation rises above the threshold of a given logogen, it fires, that is, it propagates activation to other elements of the language comprehension system. If a logogen fires, a word is recognized.

The logogen model proposes a highly interactive system. In the current discussion it has been almost entirely replaced by other interactive activation models. Thus, it is only mentioned here and not discussed in more detail.

Search models of lexical processing Search models of lexical processing are based on the computer metaphor of human information processing that is classic to cognitive science. This metaphor draws parallels between human mental processes and the processing characteristics of a computer with Von-Neumann-architecture (Gardner, 1985). Rule-based manipulations of localist representations, mental symbols, take place in a system that features processors and memories. [2]. The basic assumption of lexical search models thus is that information about words is mentally processed in a way a classic serial computer operates.

Every word that a person commands is associated with a lexical entry. This entry is organized like a computer file that contains all linguistic information associated with that word. Information like word category, subcatgorization, complement structure(s), gender etc. is specified. All lexical entries make up a person's mental lexicon. In a search model lexical access is accomplished by comparing the letter pattern of the incoming word with the orthographic specifications of the lexical entries until a match is found. Differences in recognition latencies between single words or groups of words are accounted for in terms of specifics of storage and search methods. Words are stored in lists that are searched in a serial fashion until a match is reached (theory of serial comparisons (Forster, 1990), page 112).

Rubenstein, Garfield and Millikan (1970) were the first to present a search model of lexical processing. The most prominent model, however, has been proposed by Forster (1976, 1979). His model features three access files to the mental lexicon: an orthographic, a phonological and a semantic. Each of these access files consists of a sorted set of pointers to the entries in the mental lexicon. The access code to the orthographic file could be a string of letters. These are matched against the access codes. The process progresses in serial order. In case of a match a word is recognized. Access files are organized in specific ways to accommodate common effects in word recognition. For instance, the frequency effect, i.e. a high frequency word is recognized faster in visual word recognition than other lower frequency words with comparable features (Forster & Chambers, 1973; Balota & Chumbley, 1984; Inhoff & Rayner, 1986). High frequency words are encountered more often by the reader and are thus processed more easily and faster. Other related factors have also been implied to influence word recognition: subjective familiarity (Gernsbacher, 1984; Connine, Mullennix, Shernoff & Yelens, 1990), concreteness (Bleasdale, 1987), or contextual availability (Schwanenfluegel, Harnishfeger & Stowe,

[2] For an introduction to concepts and formats of mental representation see Fodor (1985)

1988). In search models these effects can be accommodated by using frequency-ordered lists. Selection of an access file is modality specific. The semantic access file is used in language production. Search models of lexical processes are members of the class of serial, autonomist models.

The Cohort model The cohort model (Marslen-Wilson & Tyler, 1980; Marslen-Wilson, 1987) combines autonomous, serial and interactive features in auditory lexical processing. Three main functions are distinguished: lexical access, selection and integration.

The term access covers the bottom-up process of mapping incoming acoustic-phonetic information onto information stored in the mental lexicon. Matching entries are activated. In the cohort-model an initial set of candidate words, called a cohort, is activated on the basis of the first auditory input. This set of potential candidate words is refined on the basis of increasing disambiguating information as the auditory signal develops over time. This process is carried out autonomously in a bottom-up fashion.

The lexical selection function selects the candidate word from the cohort that fits the input best. If the word is heard in a sentence context, then the context information may be interactively used to select one of the candidate words in a cohort.

Finally, the lexical integration process combines syntactic and semantic features of the selected word to form a higher level representation.

The cohort model is specific to the auditory modality, tuned to the fact that the auditory signal develops over time. The lexical selection and lexical integration processes are partially overlapping in time. They constitute the interactive portion of the model, while the lexical access process operates autonomously.

Interactive activation models Interactive activation models (IAM) of word recognition stem from the connectionist tradition of psycholinguistics, or more generally cognitive science (McClelland & Rumelhart, 1981, 1986; McClelland & Elman, 1986; McClelland, John & Taraban, 1989; Rumelhart & McClelland, 1982; Rumelhart, Hinton & McClelland, 1986). They feature a number of important differences from serial models. The main distinctive feature is that they allow interactive processes between different levels of operation. Another important feature is that a large number of interactive models do not process localist representations but subsymbolic ones. In models of parallel distributed processing the capability to perform symbolic operations stems from activation patterns of numeric units (McClelland & Rumelhart, 1986; Rumelhart, Hinton & McClelland, 1986; Elman, 1995).

This class of models is discussed here on the basis of one exemplar that works with localist representations. The interactive activation model by McClelland and Rumelhart (1981, Rumelhart & McClelland, 1982). The model, originally designed to account for the word superiority effect (see below), is organized into separate layers, a feature layer, a letter layer, a word layer (a sentence layer has been added in other related models). Processing takes place in parallel, temporally as well as spatially. That is, in this model processing takes place on all layers and everywhere on a given layer at the same time. Bottom-up, e.g. stimulus driven, and top-down, e.g. concept-driven processes interact which each other. Another feature that distinguishes this model from serial models is the fact that information cascades through the system. In a classic serial model a processing stage finishes its task and then propagates its product on to the next stage. In this model incomplete information is fed forward.

The most prominent notion of the organization and conceptualization of the mental lexicon is derived from the semantic network model by Collins and Loftus (1975). A network consists of nodes and connections between nodes. A node constitutes a local representation of a word. The strength and length between entries is determined by semantic relations and associative relations between the words. In the interactive activation model units on a given layer are interconnected in the manner of a spreading activation network (Collins & Loftus, 1975). Connections can be excitatory or inhibitory. Activation of a unit can thus result in lateral inhibition of competing tokens for example.

In the interactive activation model word recognition works as follows. Every unit is assigned an activation level and resting state. When an input is given, activation spreads through the network. Units sum up excitatory and inhibitory inputs over time. They regress towards their resting state if no input arrives. The unit that remains most activated represents the recognized word. The Luce rule (Luce, 1959) is used to determine the probability of recognition of the given word.

The frequency effect is accomodated by setting corresponding resting levels in this model. The McClelland and Rumelhart (1981) model was originally designed to account for the word superiority effect (Cattell 1885, cited in Balota, 1994). Perceptual identification of a single letter is easier if it is presented within a word rather than in isolation or embedded in a non-word letter string (Reicher, 1969; Wheeler, 1970). [3]

Seidenberg and McClelland (1989) proposed a mental lexicon based on distributed representations in a connectionist network.

While connectionist models that work on local representations like the IAM use an architecture of the mental lexicon that is somewhat comparable to the classic account, PDP models instantiate the lexicon by a number of numeric vectors in multidimensional state space. Vectors are activation patterns of a neural network, each of which represent a word (Elman, 1993). These models work in a highly interactive fashion, taking semantic as well as syntactic features, top-down as well as bottom-up information, into account in a parallel fashion. The concept of cue validity, i.e., the predictive power of a feature, is of importance here (Bates & MacWhiney, 1989). The notion of levels of processing is dissolved (Bates, Devescovi, Hernandez & Pizzamiglio, 1996).

In sum, it is still a mater of debate how words are mentally represented. Besides this point

[3] It has been argued that an import feature of interactive models is their capability of correction of erroneous input (but see Gaskell & Marslen-Wilson, 1993).

there is general agreement that a functioning and efficiently organized mental store of words is crucial to normal language comprehension and production.

Differentiation of input modalities A number of the characteristics of the visual and the auditory sensory modality differ to a large extent. As a consequence, listening and speaking, on the one hand, and reading and writing, on the other hand, also differ substantially. These differences are of importance for this thesis as background. All target words were presented visually in this study. In a number of experiments context was provided auditorily.

First of all, there is a phylogenetic and an ontogenetic primacy of auditory language. Script is a cultural invention and written language skills are acquired later during ontogenesis than listening and speaking.

Auditory speech signals unfold over time, they necessarily have a duration. Information is temporally organized. Furthermore, processing auditory language stimuli as such is almost obligatory. Provided a good quality of the signal, hearing speech sounds of a familiar language as noise or anything but language is virtually impossible. Reading differs. It is dependent on the allocation of attentional resources. Written language has a spatial extension. Temporal extension is of secondary importance. Foveally presented words can be processed in one short time window. If we look at a word, then processing it as language is obligatory.

Reading usually is a self-paced task. Thus, the rate of comprehension is self-controlled. Backtracking is usually possible. Listening, on the other hand, depends on the speed of the speaker's utterance. The rate of comprehension is not self-controlled, backtracking is impossible, and comprehension might accordingly break down.

Visual linguistic input comes clearly segmented, given a familiar type of script. Whereas, words have to be parsed from the acoustic input. Segmentation has to be constructed from the auditory stream. Furthermore, prosodic cues, i.e., fundamental frequency, length of auditory segments, pauses etc., in the auditory signal convey additional information that might be used for the immediate resolution of ambiguities, or provides, focus or emotional content (Steinhauer, Alter & Friederici, 1999; Jescheniak, Hahne & Friederici, 1998).

In sum, there are a number of significant differences between auditory and visual language comprehension. In the area of word recognition a number of models have been formulated for one of the two input modalities in a specialized way (see above).

Bradley and Forster (1987) extended the validity domain of the search model to the auditory stimulus modality. A comparable explicit extension of the cohort model is not available. Simpson, Peterson, Casteel and Burgess (1989) discussed results by Sanocki, Goldman, Waltz, Cook, Epstein and Oden (1985) and Rueckle and Oden (1986) that support the notion that linguistic context does not influence a first activation of lexical candidates but does influence lexical selection in visual word recognition. This corresponds to the sequence of processing stages of the cohort model.

Relevance for the present study In the present study participants had to listen to, as well as read, words and sentences. All recognition processes of critical targets were visual. In a number of experiments a combination of auditory and visual material has been used. The degree of restriction of the flow of information is a central issue in experimental psycholinguistics (see below) and has to be discussed against the background of the above sketched models of word recognition.

3.3 Syntactic structure building

As we have seen in the previous chapter (2), syntax matters. The sentence example (2.5) was used to demonstrate that a number of sentences cannot be fully comprehended without a sufficient operative knowledge of syntax. Syntactic structure building, or short, syntactic processing or syntactic parsing, is necessary.

From a different perspective, we can easily read Chomsky's (1957) famous sentence (3.1) and also produce a positive grammatical acceptability judgment, although the sentence is senseless. This example might serve as a hint that syntax has an independent role in natural language processing.

(3.1) Colorless green ideas sleep furiously.

Syntactic processing is concerned with incrementally building syntactic structure of a sentence we are comprehending as it unfolds in time. Altman (1989) conceptualizes parsing as consisting of "the assignment of grammatical categories and structural relations to the constituents of a sentence". The mental mechanism that builds syntactic structure is called the parser. The parser is a hypothetical special purpose mental mechanism that builds syntactic sentence structure online. Syntactic relations between sentence constituents are established, phrases are built, syntactic relations between phrases are established, i.e. building the current partial phrase marker (CPPM). All parsing decisions have to conform with the grammar in order to produce well-formed sentences.

A large variety of different types of parsers have been proposed and discussed in the literature (Ferstl & d'Arcais, 1998; Kempen, 1999). In this field of research, two different dimensions of classification need to be distinguished. On the one hand, parsers differ with respect to the number of different candidate structures a parser processes at a given time. Serial, parallel and minimal commitment parsers have been proposed (for more detail also see Kempen, 1999). On the other hand, parsers differ with respect to the types and the amount of information they use for their parsing decisions at a given time. Here autonomous and interactive parsers need to be distinguished.

A serial parser commits itself to one of the possible syntactic structures at a given choice point. Parsing decisions are not delayed. When the selected structure proves to be inappropriate the parser backtracks and performs a reanalysis. Parallel parsers hold more than one structure active if necessary. This taxes working memory but usually renders reanalysis unnecessary. Minimal-commitment parsers compute a single structure but delay parsing decisions until multiple possible structures are disambiguated later in the sentence (for a detailed discussion see Mitchell, 1994; Kempen, 1999).

Autonomous parsers make use of purely syntactic information. The CPPM is used and bottom-up syntactic information, such as word category information for instance. There is no top-down information used in autonomous processing. Interactive parsers, on the other hand, use top-down semantic, pragmatic and even discourse information to help guide their parsing decisions.

Autonomous serial parsers The most prominent modular serial parser has been proposed by Frazier and colleagues (Frazier & Fodor, 1978; Frazier, 1979; Frazier & Rayner, 1982, 1987). It is also known as the garden-path model.

Parsing has to be very efficiently organized and fast. Accordingly, this parser operates by an economy principle in order to be able to meet the demands of the enormous time-pressure of language comprehension. The garden-path model proposes a two-stage parsing process. The first autonomous parsing stage makes use exclusively of word category information of an incoming word and clearly defined principles, so-called parsing strategies (Bever, 1970), to build an initial phrase structure. No other lexical information, syntactic or semantic and no context information is used for, or can influence, the first pass parse. As a modular model, the parser operates in a domain-specific and autonomous fashion.

Two examples of parsing principles are discussed here: minimal attachment and late closure. Minimal attachment causes the computation of the simplest structure consistent with a given grammar, i.e. the structure with the least number of syntactic nodes. Late closure states that a new constituent is integrated into the current phrase rather than postulating a new one. In the garden-path model the flow of information is highly restricted. This is fast and efficient, but it might be inaccurate at times. In such a case a revision is necessary. Ambiguities are used as a testing ground for the inner workings of the parser. The sentences (3.2) provide an example for a successful parse according to the postulated principles and (3.3) an example where the parser is led down the garden-path and a revision is necessary.

(3.2) John put the book on the table and went to sleep.

(3.3) John put the book on the table into his briefcase.

Information other than word category is used at the second parsing stage. In this second step more detailed syntactic information, such as subcategorization information, case, thematic roles etc., lexical semantics and also other kinds of higher level information are taken into account to build the CPPM.

The syntactic phrase structure provides the basis for thematic role assignment. For the example in (2.5) that means that case has to be processed before thematic role assignment can take place.

See Frazier (Frazier, 1995; Frazier & Clifton, 1996) for more detailed accounts and the latest developments.

Bresnan and colleagues (Bresnan, 1978; Bresnan & Kaplan, 1982; Ford, Bresnan & Kaplan, 1982) developed another influential serial parser. As in the garden-path model, this theory also assumes that only one structure is computed serially at a time, but the first pass parse is based on lexical information associated with the verb, rather than only word category information and structural principles.

Interactive parsers Altman and Steedman (1988) distinguished weakly and strongly interactive models of parsing. Interactive parsers allow information other than syntactax to influence the syntactic structure building even for initial structure building. Strongly interactive models take information from all levels of analysis into account. In the most prominent models to date, language comprehension is viewed as a constraint-satisfaction process that uses multiple sources of information in parallel. No restrictions, like those in the autonomous models, are postulated (MacDonald, Pearlmutter & Seidenberg, 1994; Bates & MacWhiney, 1989; McClelland, 1997; Marslen-Wilson, 1975; Trueswell, Tanenhaus & Garnsey, 1994; Waltz & Pollack, 1985).

In these models, semantic, pragmatic and discourse information can be used to guide the building of sentence structure. The class of interactive parsers comprises a large variety of different architectures. While the MacDonald model proposes a connectionist network that operates on localist representations and produces a separate level of representation for syntactic structure, other models assume distributed representations in multidimensional state space that do not produce a separate specific syntactic representation (Bates & MacWhiney, 1989). See also McClelland, St. John and Taraban (1989) for a fully interactive account of parsing on the basis of parallel distributed processing.

As a consequence of these differences in architectures, modular serial and interactive theories of parsing make qualitatively different predictions. In the context of this thesis it is of particular importance as to which predictions a parser makes concerning the use of different types of lexical information during the parsing process - case information in particular. While the Frazier model holds that only word category information and a set of well-defined principles is used during the first-pass parse, interactive models claim that other lexical syntactic information, such as subcategory information, can be used as soon as it becomes available with word recognition. One of the central issues of this study is to illuminate the time course of the use of structural and inherent case information during sentence comprehension.

The empirical method, the experimental setting that is selected for a study to investigate a time-course is crucial as it determines the quality of the temporal resolution of the study. This also determines the precision of the use of the word ”immediate” in this context.

A number of studies have been carried out to address this issue. Some that are of particular relevance to this study are discussed in detail below (3.8). See also the chapter on electrophysiology (4).

3.4 Semantic integration

Semantic integration in sentence processing entails processes of integrating a new element into the message structure of a sentence. Since this study is concerned with processing syntactic information, they do not lie at the heart of this study. Care was taken that the experiments reported in this thesis have not manipulated semantic processes (See below). For a comprehensive review of processes of semantic integration the reader is referred to the literature (e.g. Gernsbacher, 1994).

3.5 Psycholinguistic experimentation

The following sections provides a brief introduction to psycholinguistic experimentation. Its main purpose is to introduce the concepts, techniques and results that are central to the study presented in this dissertation.

Experiments that are used to demonstrate processing effects and are often used to investigate the constituting conditions of an experimental effect as well as their time courses in more detail. This information is then used to infer the architecture of the human language processing system.

Locus of an effect When working with psychological experiments to illuminate mental architecture, it is central to determine the locus of an effect within this architecture. The notion of levels of processing has been introduced above. From this notion of stages or levels of processing follows the idea of various possible loci of experimental effects within the architecture. For word recognition prelexical and postlexical processes have been distinguished (cf. Seidenberg, Waters, Sanders & Langer, 1984; Seidenberg, 1990). Prelexical, sometimes also labeled intralexical, processes refer to effects that take place before a word is identified, and thus usually refer to processes within the stage of lexical processing, within the mental lexicon. Postlexical effects, on the other hand, refer to processes that are carried out after a lexical element has been recognized. This distinction is of central importance in the debate between autonomist and interactive theories of language processing (see below).

Lexical decision and naming: two important tasks In the following paragraphs two experimental tasks that are frequently used in psycholinguistic research are introduced. The lexical decision and the naming task.

In psycholinguistic experiments participants are typically instructed to work accurately and as fast as possible. Differences in responses between conditions as well as their latencies are then taken to reflect differences in recognition time for instance or other processes.

In the lexical decision task (LDT, Rubenstein, Garfiled & Millikan, 1970) the participant is asked to decide whether or not a given letter string is a word of the language under investigation. In the naming task (NT, see e.g. Forster & Chambers, 1973) the participant is required to pronounce a word, visually or auditorily presented, accurately and fast as possible.

Traditionally, pre- and postlexical processing stages have been distinguished empirically by using these two tasks. The naming task has been considered more sensitive to pre-lexical processes and the lexical decision task more susceptible to post-lexical decision and integration processes (p. 180, Ferstl & d'Arcais, 1998).

This notion, however, cannot be upheld anymore. A number of experiments have demonstrated syntactic priming on naming ascribed to post-lexical processes (see below and West & Stanovich, 1986; Jacobsen, 1999) Furthermore, naming also contains a decision stage, i.e., the decision to initiate a response. Also, post-lexical checking mechanisms have been postulated that influence the naming response (see below for more detail).

3.6 Priming

In the following section the notion of priming is introduced. Priming can be characterized as a temporary modification of the internal processing characteristics of a given mental mechanism or process elicited by a prime, that leads to altered processing of a subsequently presented target. In experimental psycholinguistics semantic priming and syntactic priming are differentiated. Semantic priming is priming on the basis of semantic context information (see below and for a comprehensive review see Neely, 1991). Syntactic priming is priming on the basis of syntactic information. Nicol (1996) provides a definition. She distinguishes different conceptualization of the term "syntactic priming". Note that in the context of this thesis syntactic priming is viewed as temporarily altering processing conditions of a target, the syntactic analogue of semantic priming as defined by Nicol.

Two dimensions of classification need to be distinguished. One concerns the distinction between prelexical and postlexical effects as introduced above. The other is based on the types of primes used in experiments. Single-word-primes, phrasal, clausal and sentential primes are distinguished. The terms Word-level and phrase- or sentence-level primes have also been used but might be misleading because they can be confused with word-level and phrase- or sentence-level effects. The latter would correspond to pre- and post-lexical effects respectively.

The traditional understanding of the term priming in psycholinguistics entails preactivation of lexical candidates on the basis of prior information. Thus priming was considered to have its locus within the lexicon and have its effect prelexically. As a consequence, the term priming is somewhat of a misnomer if it is applied to post-lexical effects.

The baseline issue Another important issue in determining the nature of an experimental effect is the question of whether the effect is facilitatory of inhibitory relative to a baseline. Based on Donders' subtraction logic (original and English translation Donders, 1868, 1969), the idea of a neutral experimental baseline calls for the exclusion of the critical information, and only this information, from one experimental condition that is otherwise equivalent to the other experimental conditions. See Jonides and Mack (1984) for a review (see also de Groot, Thomassen & Hudson, 1982). Such a baseline, if achieved, allows an independent assessment of facilitatory and inhibitory effects on the dependent measure. The basic null baseline obviously departs from this requirement since it differs informationally on a number of stimulus dimensions. So do the non-verbal 'xxx' and pseudo-word baseline.

Effects of context and word recognition Given the discussion above, effects of linguistic context on word recognition need to dissociated from effects of such context during or after word recognition. Prelexical effects need to be distinguished from postlexical ones. If possible, the locus of an effect needs to be determined more precisely. It is still a matter of debate, however, which linguistic feature, which information, allows for prelexical priming effects and which does not (see below). Thus, case information, the linguistic dimension that has been varied in this study, could from a theoretical perspective lead to intralexical priming effects. The following section will introduce relevant empirical evidence and will argue against this view. It will be demonstrated on the basis of the results in the literature that effects of prior case information, if they exist, are of a post-lexical nature. Note that the present study is concerned with how case information that was made available during word recognition is used in sentence processing.

3.7 Priming experiments

In the following section, effects of linguistic context on word recognition are briefly introduced. They are of relevance for this study, because effects of context on word recognition need to be differentiated from context effects on sentence processing. The focus is on effects on visual word recognition, because all targets and critical words were presented visually in the present study.

3.7.1 Semantic context effects

The famous study by Meyer and Schwaneveldt (1971) sparked a wealth of studies in a new field, priming (for a comprehensive review of semantic priming see Neely, 1991).

As introduced above, in discussing priming effects single-word-primes are distinguished from sentential primes. Also pre- and postlexical loci of effects are discussed.

Semantic single-word-prime effects Meyer and Schwaneveldt (1971) demonstrated that the second word in a sequence of two words is recognized faster if it is preceded by a semantically related word (3.4) than when it is not (3.5).

(3.4) doctor - nurse bread - butter

(3.5) doctor - butter bread - nurse

Participants were instructed to read the first word and then make a lexical decision judgment to the second word. The effect of facilitation of the processing of a target preceded by a semantically related prime can be accounted for by a spreading activation mechanism in the network of the mental lexicon.

Semantic sentential context effects Studies of sentential semantic context are not of central relevance for this study, because it deals with aspects of processing syntax. However, there were experimental demonstrations that syntactic integrity of the sentential prime has to be present in order to produce priming effects.

O'Seaghdha (1989) used sentences with normal and scrambled word order to investigate the locus of semantic sentence-level effects. (see also Schriefers, Friederici & Rose, 1998). He observed priming effects in regular sentences but not in scrambled sentences. The author concluded that the ease of integration of a new word into the existing sentence fragment was responsible for the priming effect in grammatically correct sentences. He thus argued for a postlexical locus of the effect. Simpson, Peterson, Casteel and Burgess (1989) reported similar results using the naming task.

3.7.2 Syntactic context effects

In the following section syntactic context effects, also labeled syntactic priming (Nicol, 1996), are introduced. An increasing number of studies have been contributed in recent years (Bates, Devescovi, Hernandez & Pizzamiglio, 1996; Colé & Segui, 1994; Friederici & Kilborn, 1989; Friederici & Schriefers, 1994; Goodman, McClelland & Gibbs, 1981; Gorrell, 1989; Grosjean, Cornu, Guillelmon & Besson, 1994; Gurjanov, Lukatela, Lukatela, Savic & Turvey, 1985; Lukatela, Moraca, Stojnov, Savic, Katz & Turvey, 1982; Lukatela, Kostic, Feldman & Turvey, 1983; Seidenberg, Waters, Sanders & Langer, 1984; Sereno, 1991; Stanovich & West, 1981, 1983; van Berkum, 1996; West & Stanovich, 1982, 1986; Wright & Garrett, 1984).

A central issue providing the background for studies of syntactic priming is the question of whether, and if so, how and when prior syntactic information affects the processing of subsequent words. At least two contrasting views are possible: First, prior syntactic information provided by, for example a pronoun, an article or an adjective, could in principle reduce the search space in the lexicon to only those elements that match this particular syntactic feature.

Second, it is also possible that prior syntactic information does not preselect particular matching elements, but comes into play only at a postlexical stage during which agreement of the two (or more) elements is checked. Here an important question is how and when syntactic information made available during word recognition is used in sentence processing. Both of these positions have been formulated, each on the basis of different models of language comprehension. See e.g., Friederici and Jacobsen (in press) for a recent review of grammatical gender priming.

Syntactic single-word-prime effects Goodman, McClelland and Gibbs (1981) investigated the effect of syntactic information on word recognition using a word-word priming setting. They presented pairs of words that either featured a syntactic (your - power) a semantic (door window) or no relation. Lexical decision latencies to the second word were shorter under the semantic and syntactic conditions relative to the unrelated condition. The syntactic effect, however, could only be demonstrated with blocked presentation. Lukatela, Kostic, Feldman and Turvey (1983) reported an effect of syntactic context on the lexical decision latency for serbo-croatian nouns. Morphologically inflected nouns were preceded by prepositions such that syntactically congruent and incongruent pairs resulted. Response latencies were shorter for nouns presented in the congruent condition than in the incongruent condition (see also Lukatela, Moraca, Stojnov, Savic, Katz & Turvey, 1982; Gurjanov, Lukatela, Lukatela, Savic & Turvey, 1985).

Seidenberg, Water, Sanders and Langer (1984) as well as Sereno (1991) also used word-level priming settings. The naming task was used in addition to lexical decision. Syntactic priming effects could only be demonstrated for the LDT, but not for the naming task. These results were accounted for in terms of the greater sensitivity of the LDT to post-lexical processes (see Section 3.5 on page 25).

Syntactic sentential context effects Wright and Garrett (1984) used the LDT to investigate syntactic sentence-level effects on word recognition. To this end, they employed word category violations induced after sentence preambles like 3.6 in their first experiment.

(3.6) After you have added three eggs, you must enter / units

The verb ”enter” constitutes a syntactically correct continuation of the sentence fragment in (3.6), whereas the noun ”units” is not and thus constitutes a syntactic violation. Lexical decision latencies were longer to words presented in an incongruent condition than in a congruent one. This result was replicated be West and Stanovich (1986) using an additional neutral baseline condition and the naming task as an additional task. Syntactic congruency effects were obtained with the LDT as well as the NT. These effects, however, solely revealed inhibition of the dependent measure relative to the baseline condition. They did not reveal facilitation of word recognition. The authors argued that the effect was due to an implicit response by a post-checking mechanism that was obligatorily generated and affected the execution of the task at hand.

The results cited here seem to argue that it is easier to generate a syntactic congruency effect using sentential rather than single-word primes.

Syntactic priming as viewed by different comprehension models Top-down interactive approaches allowing the interaction between sentence level syntactic and lexical information hold that the language comprehension system is predicting lexical candidates on the basis of prior sentence-level information, be it semantic or syntactic, by reducing the search space for possible elements in the lexicon (Bates & MacWhiney, 1989; Bates, Devescovi, Hernandez & Pizzamiglio, 1996; MacDonald, Pearlmutter & Seidenberg, 1994) According to this view syntactic information will preactivate a subset of lexical elements and should, therefore, facilitate word recognition when the syntactic information is congruent and inhibit word recognition when this information is incongruent.

The autonomous view holds that syntactic effects are postlexical, rather than prelexical. Effects are taken to be caused by a postlexical checking mechanism. After recognition a new incoming word is obligatorily processed in coreference with the existing (structural) representation of the prime. The result of this process then influences response execution. This view is held by proponents of a modular theory of lexical access. Within modular theories lexical access - at least in its initial stage - is thought to be independent of prior information, be it syntactic (Tanenhaus & Lucas, 1987) or be it semantic (Swinney, 1979). The syntactic priming experiments introduced above in which a given target either matched the required word category or not, were interpreted to locate the effect at a postlexical stage. (Seidenberg, Waters, Sanders & Langer, 1984; West & Stanovich, 1982, 1986). The review of syntactic priming in grammatical gender processing by Friederici and Jacobsen (in press) presents more converging evidence for this view (but cf. Bates et al., 1996).

Thus, an autonomist view holds that gender information given prior to the noun is not used to guide lexical access, but is only relevant postlexically. This view is backed up by the idea that the computational costs involved in pre-activating all feature-matching word in a lexicon would - in the majority of instances - be too high to be valuable if the set of lexical items is very large (Tanenhaus & Lucas, 1987; O'Seaghdha, 1997). An assumed postlexical mechanism underlying gender priming could be described as follows: Syntactic information provided by the context is active until it can be checked against the syntactic information provided by the word that is currently processed. Thus, syntactic priming effects are described as a syntactic congruency check that takes less time for a gender-congruent element than for a gender-incongruent element. Such a congruency check is a binary decision and should, therefore, mainly lead to inhibition effects but not to facilitation since the check would be equally fast for a neutral condition (unmarked prime) and a congruent condition.

These two views make clearly different predictions with respect to facilitatory and inhibitory grammatical priming effects, while the former predicts both, the latter only predicts inhibitory effects.

The combined data from the studies reviewed so far suggest that inhibition is observed independent of task and language type. Facilitation is only found under particular conditions: (a) in lexical decision or naming tasks using auditory target presentation (Grosjean, Cornu, Guillelmon & Besson, 1994; Bates, Devescovi, Hernandez & Pizzamiglio, 1996) - in these cases possibly reflecting processes of lexical selection rather than lexical access or preactivation (e.g., Marslen-Wilson, 1987). The majority of the results do not confirm the predictions based on the interactive view or the intralexical view, rather they are more in line with a checking mechanism view.

As reviewed above, there are a number of behavioral experiments investigating the effect of syntactic structural context on word recognition. See also Tanenhaus and Lucas (Tanenhaus & Lucas, 1987) for a review. In their review they conclude that there is little evidence for syntactic context effects. Those effects that have been found were purely inhibitory (West & Stanovich, 1986) and thus postlexical. This was also supported by Tanenhaus, Leiman and Seidenberg (1979) and by Seidenberg, Tanenhaus, Leiman and Bienkowski (1982), who used a cross modal priming task and found that for syntactically ambiguous words (they all rose vs. they bought a rose) both readings were activated initially, but that the syntactic context had its (facilitatory) effect when a 200 ms delay was introduced. These data suggest that the initial stage of lexical access is independent of syntactic context and that syntactic context was used to select the syntactically adequate lexical element only at a later stage.

From the available data on syntactic priming it can be concluded that during normal language comprehension syntactic information does not preselect particular feature-matching lexical candidates, but that a postlexical checking mechanism evaluates the syntactic congruency of the incoming element.

The findings from the experiments investigating pure syntactic priming in combination with those crossing syntactic priming and semantic priming on the one hand and those crossing structural priming and semantic priming on the other suggest a general independence of syntactic and semantic aspects during the early stage of comprehension, but indicate that interaction takes place at a later stage during comprehension.

3.8 Syntactic features and sentence comprehension

The question of if and when subcategorization information that is associated with a verb is used during sentence comprehension, requires two aspects to be distinguished. One concerns the obligatory subcategorization, if a given verb has only one complement structure. And the other concerns the preferred complement structure of polyvalent verbs (see Section 2.3 on page 7).

Processing subcategorization information A number of studies investigated whether or not specific lexical subcategorization information is available and used immediately after word recognition to guide sentence parsing during the first-pass parse (for a review see Boland & Tanenhaus, 1991).

The results of these studies are inconsistent. This might primarily be due to the different experimental methods that were used (self-paced reading, tracking eye-movements, different presentation rates etc.). The temporal resolution of these methods differs considerably and might in some cases not be high enough to draw conclusions about first-pass parsing processes. Also, the exact time quantum that is associated with the word ”immediately”, as in ”immediate use of information” differs between studies due to the experimental methods chosen. These issues render the evidence from these studies open to interpretation (see also Boland & Tanenhaus, 1991).

Mitchell (Mitchell, 1987, 1989) and Ferreira and Henderson (Ferreira & Henderson, 1990) hold that subcategorization information, even if it is obligatory, is ignored during the first pass-parse.

In an eye movement and word-by-word self-paced reading study, Ferreira and Henderson (1990) investigated whether or not readers use specific lexical verb information to guide their initial first-pass parse during syntactic structure building of temporarily ambiguous sentences. Their material was designed such that the minimal attachment and lexical guidence hypothesis could be contrasted. Two classes of verbs were used. Verbs like ”wish” are biased towards taking a subordinate sentence complement ((3.7), (3.8)). Whereas, verbs like ”forget” have a bias towards taking a NP-object complement ((3.9), (3.10)). This experimental verb factor was crossed with the use versus the omission of a complementizer like ”that” ((3.7), (3.9)).

(3.7) He wished Pam needed a ride with him.

(3.8) He wished that Pam needed a ride with him.

(3.9) He forgot Pam needed a ride with him.

(3.10) He forgot that Pam needed a ride with him.

From the results of their Experiments 1 and 2 Ferreira and Henderson concluded that verb information does not influence the first-pass parse and that Frazier and Rayner’s (1982) garden-path model was supported.

In the present study the syntactic priming technique using the cross-modal naming task was employed to investigate processing characteristics of structural and inherent case information during sentence processing.

Case processing In the following section studies that investigated the processing of case information in particular are reviewed as they are of central relevance for this study.

In a cross-modal naming study Trueswell, Tanenhaus and Kello (Exp. 1, 1993) manipulated the case marking of a masculine singular pronoun target (see Table 2.1 on page 10). Structural case was varied, as they were using nominative (”he”) and accusative (”him”) case marking. Inherent case was not investigated. Two classes of verbs were used. Verbs like ”insist” are biased towards taking a subordinate sentence complement. Whereas, verbs like ”observe” have a bias towards taking a NP-object complement. This experimental verb factor was crossed with the use versus the omission of a complementizer like ”that”. The sentence fragment primes that they used are given in (3.11) - (3.14).

(3.11) The old man insisted Him / He$_{S-bias/nocomp}$

(3.12) The old man insisted that Him / He$_{S-bias/comp}$

(3.13) The young boy observed Him / He$_{NP-bias/nocomp}$

(3.14) The young boy observed that Him / He$_{NP-bias/comp}$

Auditory primes preceded target pronouns. The ISI was close to 0 ms. After the naming response, grammatical acceptability judgments were also gathered. The results revealed interaction effects of verb type (S- vs. NP-bias) and case of pronoun (nom. vs. acc.) as well as complementizer presence and case of pronoun on pronoun naming latencies. These were in the realm of 500 ms. Naming latencies were longer for incongruent targets. These results were taken to indicate rapid use of verb-specific subcategorization information during sentence comprehension, since this information was associated with the verb immediately preceding the target in (3.11) and (3.13) must have been available to affect the naming of the pronoun target. The authors assumed a postlexical checking mechanism as described above to account for the effect.

More recently, Traxler and Pickering (1996) set out to investigate the time-course of this effect more closely by employing eye-tracking data as the dependent variable. They used an experimental manipulation comparable to the previous study. They made use, however, of the fact that the English pronominal system features case syncretisms (see Section (2.6) and Table 2.1 on page 10). Participants read syntactically correct sentences of which some were locally ambiguous. Examples of their sentence material are given in (3.15) - (3.18).

(3.15) I recognized you and your family would be unhappy here.

(3.16) I recognized she and her family would be unhappy here.

(3.17) I recognized that you and your family would be unhappy here.

(3.18) I recognized that she and her family would be unhappy here.

Participants took longer to read the NP region (pronoun, ”and” and conjunct) of the sentences under the condition that featured no complementizer and a marked pronoun (3.16) than the other conditions. The effect indicated that the verb-specific information must become available while reading this region of the sentence.

The authors concluded that the verb-specific information is immediately used in sentence comprehension. Their study, however, fails to specify the time course of these processes more closely.

To call the effects of the two previous studies case priming in the tradition of syntactic priming or gender priming would be somewhat of a misnomer. These effects, as well as the RT effects reported for the present study, could more accurately be labeled sentential case congruency effects.

In a case study, Druks and Marshall (1995) reported two aphasic patients with complimentary performance patterns. One of them (B.M.) performed better on passive versions of sentences than on the regular actives. The authors argued that none of the theories of aphasic performance (Caplan & Futter, 1986; Grodzinsky, 1986, 1990; Hagiwara, 1993; Ouhalla, 1993; Schwartz, Saffran & Marin, 1980) that were available at the time of the study could account for the pattern of aphasic performance that they found. Rather, they employ Government and Binding theory (see Section 2.1 on page 5) to account for the processing difference. This was done in a tradition of attempts to establish the psychological relevance of grammar (see Fodor, Bever and Garrett, (1974), and Clark and Clark, (1977) who attempted to establish a psychological relevance for Chomsky’s (1957, 1965) then prevalent transformational grammar). Structural case is assigned configurationally on the basis of syntactic rules in GB. Whereas, inherent case is assigned on the basis of lexical information. Structural and inherent case are affected differentially during the process of passivization (see Section 2.6 on page 9). These characteristics of Case Theory fit nicely with the performance patterns of patients M.H. and B.M. that Druks and Marshall reported. ”The assumption, therefore, that structural and inherent case can be selectively impaired in (some) aphasic patients seems valid.” (p. 325, Druks & Marshall, 1995). They claim that the ”case module” is differentially affected in the two cases they report. By the term ”Case module” they refer to Case Theory, the module of GB, as introduced in Section 2.6. Druks and Marshall conceptualize the case module as a processing mechanism that is part of the human language faculty. This is done, however, in a rather naive way, because Case theory, in its original form, is part of syntax, a device of theoretical linguistic analysis and not a mental mechanism of psycholinguistic theory.

3.9 Summary

Psycholinguists are widely in agreement that a number of distinct mental processes have to be performed in order to decode a verbal message from the physical input to a conceptual representation. Traditionally these are conceptualized as the following stages or levels of language comprehension. These stages are acoustic or visual processing, phonetic decoding or visual form recognition, word recognition, syntactic parsing, semantic integration and referential processes.

The acoustic processing consists of selecting speech from the acoustic background, extracting features for voice identification and features for distinguishing phonetic contrasts. Visual processing consists of extracting features from the visual input. Phonetic decoding then provides a decomposition of the continuous prelexical representation into constituent parts like syllables and words. In the visual domain, visual form recognition, or orthographic analysis provides an identification of letters. The processes of word recognition can be split into two subclasses: accessing word candidates (lexical access), selecting one of them (lexical selection). Identification of the input word is the product of word recognition (see below for a more detailed account of word recognition). Syntactic parsing is the process of syntactic structure building. The parser builds syntactic phrases based on the identified words, establishes syntactic relations between phrases, builds clauses and eventually the phrase structure of an entire sentence (see below for a more detailed account of syntactic parsing). During semantic integration semantic relations between sentence constituents are established based on lexical semantics and general world knowledge. Finally, referential processes provide relations of constituents to correct referents, for instance pronominal or indirect references. They perform pragmatic and discourse processing.

Models of word recognition and syntactic structure building were introduced. Also, the notion of priming, semantic as well as syntactic, in psycholinguistic experimentation was described. The use of syntactic features during sentence comprehension was introduced, followed by an account of case processing in syntactic structure building.

In the present study the syntactic priming technique using the cross-modal naming task was employed to investigate processing characteristics of structural and inherent case information during sentence processing.

Chapter 4

Electrophysiology of Language

The present chapter introduces the electrophysiology of the brain in general and of language processing in particular. First, a brief introduction to aspects of language regarding its implementation in the brain is given. Then, the generation of electric brain potentials that can be recorded by means of the electroencephalogram (EEG) are introduced. Subsequently, the technique of scalp-recorded event-related brain potentials (ERP) is described followed by an introduction of the componentry of the ERP. Then research on ERPs elicited by processing linguistic stimuli is described in terms of the various ERP components found to reflect natural language processing. Here, the focus is on language comprehension. In the following two sections, perspective is shifted from distinct language-elicited brain responses to the characteristic brain responses reflecting specific language processes, i.e. syntactic and semantic processing. Here, studies that are of particular importance for this thesis are discussed in more detail. Finally, a neurobiologically informed theory of sentence comprehension is introduced as the working model of this thesis. A summary is given at the end of the chapter.

For a comprehensive overview of the neural sciences the reader is referred to Kandel, Schwartz and Jessel (1999) as a general reference. Stemmer and Whitacker (1998) and Gazzaniga (1999) give a detailed introduction to aspects of language and the brain. Niedermeyer and Lopes da Silva (1995) provide a detailed treatment of the electroencephalogram, its origins and applications (see also Nunez, 1981). An introduction to the event-related brain potential technique is provided by Nunez (1990) and Coles and Rugg (1995). For an introduction to the electrophysiology of mind see e.g. Rugg and Coles (1995). The following sources provide detailed coverage of the neurocognition of language: Friederici (1998b), Brown and Hagoort (1999a), and Brown, Hagoort and Kutas (1999).

4.1 Language and the Brain

The brain enables the linguistic mind. Yet, we are still unable to map the complex mental function of the human language system (that has been identified so far) onto the brain's incredibly complex functional architecture. But, rapid progress in being made. Converging evidence is provided by researchers in various fields using a variety of methods to achieve this function-to-brain mapping.

The first approach was to perform post-mortem analyses on the brains of aphasic patients. The term aphasia refers to collective deficits in the language faculty, comprehension and/or production, that were acquired due to neural damage (see (Dronkers & Pinker, in press) for a comprehensive treatment of the aphasias).

Broca (1861) reported a patient who was not able to produce much more speech than a repeated ”tan” while his language comprehension, general intelligence and articulation were intact. Autopsy revealed a lesion in the posterior portion of the left inferior frontal gyrus (lower part of Brodmann area (BA) 44 (Brodmann, 1909), lower part of the frontal operculum) that Broca took to be crucial for the patients aphasia. An area which later became known as Broca's area.

In 1874 Wernicke published a monograph in which he argued for different types of aphasia. He described six patients who after suffering strokes showed preserved fluent speech, but spoke nonsensical words and sentences. When Wernicke later performed an autopsy on one of the patients brains he discovered a lesion in the posterior regions of the superior temporal gyrus, Heschl's gyrus. This area later became known as Wernicke's area. The combined results of mainly these two researchers dominated the classical view for almost 100 years.

For a long time studies of language and the brain were restricited to this source of information. Without the techniques of modern brain imaging and the possibility to use animal models, the research had to wait for and use these unfortunate experiments of nature resulting in aphasia. Analyses that carried further were made possible by the advent of modern brain imaging methods. These methods differ largely with respect to their capabilities of spatial and temporal resolution. Techniques like the positron emission tomography (PET) or magnetic resonance imaging (MRI) that measure regional cerebral blood-flow (rCBF) feature spatial resolution in the millimeter range (MRI better than PET). Whereas, their best temporal resolution, to date, lies in the order of several hundred milliseconds. The temporal resolution of techniques that measure the electromagnetic activity of the brain, the EEG (see Section 4.2) and the magnetoencephalogram (MEG), feature temporal resolution in the millisecond range. This appears better suited for investigating the fast paced and highly organized processes of the language system. These techniques and their derived measures, the event-related brain potential (ERP) and event-related field (ERF), in turn, feature less accurate spatial resolution than the above-mentioned techniques, the ERP more so than the ERF. Source localization based on these measures however is improving. The latter methods and their use for investigating aspects of process analysis using high temporal resolution is the focus of the following chapter.

The interested reader is referred to more detailed sources for comprehensive coverage, since source localization in the human brain does not lie at the head of this study (see Gazzaniga et al. (1998), Howard (1997), Meyer (in preparation) and Stemmer and Whitacker (1998)). For a recent review of the literature on the aphasias see Dronkers and Pinker (in press),

4.2 The Electroencephalogram

The first report of the human electroencephalogram (EEG) was published by Hans Berger (1929).The EEG has since then become an indispensable tool in a number of disciplines.

Using electrodes attached to the scalp an electrical potential on the order of 10 to 100 microvolts can be recorded that fluctuates over time. This potential is the portion of the brains electrical activity that is being volume conducted to the scalp. Neuronal action potentials by themselves cannot be measured on the scalp. Whereas, a large number of synchronous excitatory post-synaptic potentials will create an extracellular flow of electric current between the excited dendrites and the neuron's soma. This can be modeled as an electrical dipole with the soma being the positive and the dendrites being the negative pole. It takes the summed activity of synchronously active cortical (and also subcortical) neuronal populations with a magnitude in the order of 10000 in order to create an electrical potential that can be recorded at the scalp. Furthermore, a specific spatial architecture of the electrical dipoles is required. A so-called open-field arrangement is necessary for the current to be volume-conducted out of the immediate area of the neural population. Pyramidal cells of the neocortex for instance meet this prerequisite. These cells are ordered in parallel with their somas located in lower layers and apical dendrites located in upper layers of six-layer cortex. Most thalamical cells also have an open-field architecture. On the other hand, when the neurons of a synchronously active population feature a closed field architecture, i. e., a radial configuration of dendrites and somas, their extracellular currents are likely to cancel out within the population, no large dipole results and no electrical current is volume conducted to the scalp. As a consequence, the electrical activity of these neurons, although sufficient in number, cannot be measured by means of the EEG.

4.3 The event-related potential (ERP)

Event-related brain potentials (ERPs) are voltage changes in the ongoing EEG that are time locked to an event. This event can be a sensory, a motor or a mental event in general terms. The ERP is a measure of the brain's electrical activity correlated in time with the critical event that is volume-conducted to the scalp. Overall, the magnitude of the ERP is smaller by a power of ten than fluctuations of the ongoing EEG reflecting unspecific brain activity. For this reason, in general, a number of equivalent EEG epochs from a single participant are averaged time-locked to the critical event in order to derive a usable ERP. Using this procedure uncorrelated spontaneous brain activity cancels out. The number of epochs that is necessary for this procedure is determined by the issue under investigation and the signal-to-noise ratio. It is usually larger than 25 or 30. In order to compensate for interindividual differences and to be able to compute inferential group statistics, a group average of ERPs from a given condition is generally derived. This so-called grand average is then usually presented in the documentation of a study, whereas single subject averages are seldom reported for normal populations.

ERPs have features that make them an attractive research tool. Using reaction time measures in cognitive psychology, only the completed product, the outcome of a mental process, can be observed and its latency recorded. The time course of the processes and their underlying mental architecture have to be inferred. Whereas the EEG and derived ERPs provide a continuous online measure of brain activity with a high temporal resolution in the millisecond range. ERPs can be considered a reflection of mental processing activity. Thus, the dependent measure can be recorded while the processes under investigation are being carried out. ERPs do not require prior or simultaneous overt behavior as the participant performs an additional e.g., reaction time task.

4.4 Components of the ERP

Within the series of voltage changes that make up an ERP, a number of positive and negative polarity peaks can be identified. These peaks occur at various latencies relative to the critical event. Furthermore, they can be characterized by their (maximal) amplitude and scalp topography. Following the classic approach to component definition (Donchin, Ritter & McCallum, 1978), if a particular peak or portion of the ERP can be characterized by these four descriptors as well as the stimulus or mental conditions under which it is systematically elicited, it can called a component of the ERP. Notice that polarity and distribution imply consistency regarding the neurophysiological source, while latency and sensitivity to experimental manipulation imply consistency regarding mental function. There is, however, an ongoing debate as to how an ERP component should be defined (Donchin, Ritter & McCallum, 1978; Donchin, 1981; Näätänen & Picton, 1987; Picton & Stuss, 1980; Rugg, 1995). Näätänen and Picton (1987) argued that a component should be defined relative to its neural generator on the basis of anatomical knowledge. Whereas characteristic ERP wave-forms of unknown origin should be labeled ”deflections”. Due to the fact that ERPs represent summed potentials volume conducted to the scalp, more than one generator with differing time courses of activation can contribute to a given ERP deflection.

In the psychophysiological literature components are broadly categorized into exogenous and endogenous ones. Exogenous components are sometimes referred to as early components, reflecting the fact that they occur with the beginning of the ERP waveform. They are exogenous because they reflect stimulus-driven information processing. They are modulated by physical stimulus parameters rather than mental events (cf., Coles & Rugg, 1995). On the other hand, endogenous components are elicited by information processing of mental events independent of specific stimulus parameters (they can also be elicited by the absence of a stimulus).

Components are usually labeled with respect to their polarity and peak amplitude. Thus a positive peak occurring 300 ms after stimulus onset would be referred to as a P300.

Furthermore, it is important to note that ERP scalp topography does not allow immediate inferences about intracranial neural generators (e. g., Scherg, 1986). As introduced above, a neural generator of the ERP can be regarded as an electrical dipole (or a configuration of dipoles). The location and orientation of this dipole in terms of head coordinates determines the scalp topography of the ERP. Two different dipoles in the same location but featuring different orientations will evoke different ERP scalp topographies.

If the topographical characteristics of two ERPs differ and given that they were elicited under experimental conditions differing only with respect to the critical manipulation, it can be inferred that a different constellation of neural generators was involved in their generation.

Limitations of the ERP method The method of scalp-recorded ERPs records synchronous neural activity of cell assemblies on the order some 10,000 plus neurons that furthermore have a specific neuronal architecture in an open-field arrangement. Thus, any cognitive processes that recruits insufficient neural machinery to produce an ERP will not be reflected by the ERP method.

Furthermore, the ERP represents the summed activity of all generators active in a given time window (Coles & Rugg, 1995). The volume conducting properties of the head cause potential problems of ERP interpretation due component overlap and latency jitter.

Also, as introduced above, determining the functional significance of a component or deflection in the ERP waveform is far from trivial. It depends on the degree of experimental control of the experiment and the theoretical background. An unequivocal interpretation of ERP results is possible only on the basis of the latter.

4.5 Language processing and ERPs

Scalp-recorded event-related brain potentials provide a highly sensitive, continuous on-line measure with a high temporal resolution. These characteristics render ERPs an attractive tool for the study of the fast, highly organized and hierarchically layered processes of the human language faculty. The breakthrough results in the ERP research of language processing were reported by Kutas & Hillyard (1980a,b,c). They presented a negative ERP component peaking at about 400ms after the onset of a semantically anomalous, sentence-final word - the N400 (see below). Since then this research has come a long way.

The present chapter provides a brief introduction to the electrophysiology of language processing. For recent reviews of ERPs elicited by the processing of linguistic stimuli during listening, i.e., language comprehension in the auditory modality, and reading, i.e., language comprehension in the visual modality, see Friederici (1998b), Brown and Hagoort (1999a) and Brown, Hagoort and Kutas (1999) (see also Kutas & van Petten, 1995; Osterhout & Holcomb, 1995; Garnsey, 1993).

ERP work on speech production has only emerged very recently. Motor-related brain potentials were used to investigate the relative time-courses of semantic, syntactic and phonological processes during language production. This line of research is not elaborated upon here, because this thesis is solely concerned with language comprehension. The interested reader is thus referred to the work of van Turennout and colleagues (van Turennout, Hagoort & Brown, 1997, 1998).

In the current scientific discourse mainly four ERP components are being discussed in the electrophysiology of language comprehension as markers of different processes. These component are, in the order of the temporal sequence of their occurrence during comprehension:

- ELAN or early left anterior negativity
- LAN or left anterior negativity
- N400
- P600 or syntactic positive shift (SPS)

In addition, ERP effects have been reported that do not fit this scheme nicely. For example, Kutas and Hillyard (1983) reported a negativity effect in the time range from 300 to 500 ms past onset of the critical stimulus elicited by syntactic violations that neither fits the LAN nor the N400 descriptors (see also ”SAN” p. 320 Gazzaniga, Ivry & Mangun, 1998). Furthermore, given the highly complex mental system, the number of brain structures, and the multitude of processes involved in and necessary for language comprehension, it appears unlikely that these can be accounted for by four unitary ERP components. Thus, it seems possible that based on more detailed experimentation in the future additional ERP deflections elicited by language comprehension processes will be identified.

4.5.1 The ELAN

The early left anterior negativity (ELAN) is an ERP effect that is elicited by phrase structure violations induced by word category errors during sentence comprehension (e.g. ”*... Max's of proof the theorem.”; Neville, Nicol, Barss, Forster & Garrett, 1991). This negativity at left anterior electrode sites in the time range between 150 and 250 ms has been reported for reading (Neville, Nicol, Barss, Forster & Garrett, 1991; Gunter, Friederici & Hahne, in press) as well as listening (Friederici, Pfeifer & Hahne, 1993; Friederici, Hahne & Mecklinger, 1996; Hahne & Friederici, 1999). Usually, It is followed by a late positivity (P600/SPS) (but see Hahne & Friederici, 1999).

Using auditory presentation, Hahne and Friederici (1999) demonstrated that the ELAN reflects early obligatory automatic rather than controlled processes of syntactic processing by employing a variation of proportions of experimental conditions (cf., Posner & Snyder, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

Furthermore, Gunter, Friederici and Hahne (in press) using a variation of contrast in visual presentation showed that the latency of the ELAN can be contingent on physical stimulus properties.

The ELAN is interpreted to reflect disruptions of first-pass parsing processes (e.g., Hahne & Friederici, 1999; Friederici, 1999).

Friederici (p. 291, Friederici, 1999) proposed the inferior part of Brodmann area 44 (BA 44; Brodmann, 1909; Garey, 1994) in the left hemisphere as the neural generator of the ELAN.

There are, however, researchers who do not make a qualitative distinction between the ELAN and the syntactic LAN (e.g., Brown, Hagoort & Kutas, 1999). Rather, they conceptualize the difference as a quantitative one due to factors influencing the component's time course.

4.5.2 The LAN

The LAN, first described by Kluender and Kutas (1993), is hypothesized to reflect syntactic processing or working memory operations. The syntactically driven left anterior negativity is an enhanced negativity ERP effect that is elicited by a variety of syntactic violations. These might best be summed up by the term morphosyntactic violations. This negativity over left anterior electrode sites has a time range between 300 and 500 ms after onset of the critical word. It is usually followed by a P600.

The LAN has been observed following phrase structure violation in the visual domain (Friederici, Hahne & Mecklinger, 1996; Gunter, Friederici & Hahne, in press), word category violations (Münte, Heinze & Mangun, 1993), violations of verb tense (Kutas & Hillyard, 1983), subject-verb agreement violations in English (Kutas & Hillyard, 1983; Osterhout & Mobley, 1995; Coulson, King & Kutas, 1998), in Dutch (Gunter, Stowe & Mulder, 1997), and in German (Penke, Weyerts, Gross, Zander, Münte & Clahsen, 1997), violations of verb-argument structure (Rösler, Pütz, Friederici & Hahne, 1993) and violations of inflectional morphology in the auditory domain in German (Friederici, Pfeifer & Hahne, 1993).

In addition, LANs have been observed and interpreted as a function of variation of working memory load during sentence comprehension. A LAN has been observed following processing of long-distance dependencies (Kluender & Kutas, 1993), the processing of ambiguities in subject-object relative sentences (King & Kutas, 1995), as a function of the degree of deviation from the canonical word order in German (Rösler, Pechmann, Streb, Röder & Hennighausen, 1998),

Recently, Kluender, Muente, Cowles, Szentkuti, Welenski and Wieringa (1998) demonstrated that both types of a LAN can be dissociated experimentally.

Friederici (p. 288, 1999) proposed Brodmann area 44 (BA 44; Brodmann, 1909; Garey, 1994) to subserve the syntactic LAN and BA 46/45 to hold the generator of the working memory dependent LAN. Both areas are located in the left inferior frontal gyrus.

Sometimes syntactic negativity effects in the LAN time range were called SAN, if they did not feature a clearly left anterior topography and also clearly were not N400s (cf. Gazzaniga, Ivry & Mangun, 1998; Münte, Heinze & Mangun, 1993).

Given the considerable variability in experimental settings, peak latency and topography of the LAN, and disparate views on the functional specificity of the component, it appears plausible that a number of different effects show up in the summed potential measured on the scalp (cf., also Brown & Hagoort, 1999b)

4.5.3 The N400

In 1980 Kutas and Hillyard (Kutas & Hillyard, 1980c,b,a) reported results that turned out to be the breakthrough data of electrophysiological research on language comprehension. They described a negativity effect elicited during sentence reading by a semantically anomalous sentence-final word. This ERP component, called the N400, has since then been investigated extensively.

The N400 is a pronounced monophasic negative ERP deflection in the time window between 250 and 600ms with a centro-parietal distribution peaking around 400ms after onset of the critical word. It is elicited when participants comprehend a semantically anomalous word in a sentence ("He spread the warm bread with socks."). Congruent words elicited a smaller N400 than incongruent words.

N400 effects have been demonstrated for a variety of semantic manipulations: semantic anomaly (Kutas & Hillyard, 1980c,b,a) cloze probability (Kutas & Hillyard, 1984), and semantic expectancy (Kutas & Hillyard, 1984; Kutas, 1993; van Petten & Kutas, 1991). Most studies on the N400 were carried out in the visual domain. The N400, however, is not modality dependent (McCallum, Farmer & Pocock, 1984; Connolly & Phillips, 1994). The amplitude of the N400 is sensitive to repetition (Rugg, 1990; Besson, Kutas & van Petten, 1992). It has also been investigated and obtained in single-word settings (Kutas, 1993; Rugg, 1990). Furthermore, the N400 has been shown to be modulated by levels of processing (cf., Craik & Lockhardt, 1972). Deeper, semantic processing elicits a N400 while shallow processing is less prone to do so (Kutas & Hillyard, 1989; Chwilla, Brown & Hagoort, 1995; Bentin, Kutas & Hillyard, 1993).

In sentence comprehension research the magnitude of an N400 effect is taken to reflect the ease of semantic integration processes. The easier the integration process, the smaller the amplitude of the N400 (Osterhout & Holcomb, 1992; Hagoort, Brown & Groothusen, 1993; Friederici, 1995; Holcomb, 1993; Chwilla, Brown & Hagoort, 1995).

While the N400 can be considered the most reliable and most extensively studied ERP correlate of language comprehension, there is also cumulating evidence that it is not language-specific. More recently, N400s have been described for processing semantically related versus unrelated pictures (Barrett & Rugg, 1990; Holcomb & McPherson, 1994), combinations of words and semantically (un)related pictures (Ganis, Kutas & Sereno, 1996; Nigam, Hoffman & Simons, 1992), and in the processing of (un)familiar faces (Bentin & McCarthy, 1994).

4.5.4 The P600/SPS

The P600 or syntactic positive shift (SPS) is a late positive component that was first reported by Osterhout and Holcomb (P600; 1992) and Hagoort, Brown and Groothusen (SPS; 1993). This deflection starts at about 500ms past onset of the critical word and usually extends for several hundred milliseconds, it has a broad distribution over the scalp with a centro-parietal maximum. P600s have been observed following locally ambiguous sentences structures (e.g., "The broker persuaded to sell the stock was sent to jail.", Osterhout & Holcomb, 1992), also (Osterhout & Holcomb, 1993; Osterhout, Holcomb & Swinney, 1994), phrase structure violations (Neville, Nicol, Barss, Forster & Garrett, 1991; Osterhout & Holcomb, 1992, 1993; Friederici, Hahne & Mecklinger, 1996), morphosyntactic congruency violations (Kutas & van Petten, 1995; Friederici, Pfeifer & Hahne, 1993; Osterhout & Mobley, 1995; Gunter, Stowe & Mulder, 1997; Coulson, King & Kutas, 1998), and subcategory violations (Osterhout, Holcomb & Swinney, 1994).

In the above mentioned study, Hahne and Friederici (1999) demonstrated that the P600 reflects controlled processes of syntactic processing by employing a variation of proportions of experimental conditions.

The P600 is interpreted as an index reflecting processes of syntactic reanalysis or phrase structure revision (e.g. Mecklinger, Schriefers, Steinhauer & Friederici, 1995; Gorrell, 1995; Fodor, 1994).

Currently, there is an ongoing debate about the nature of the P600/SPS. A number of researchers claim that it is part of the P300 family (P3b) (Coulson, King & Kutas, 1998; Münte, Heinze, Matzke, Wieringa & Johannes, 1998)). Osterhout and Hagoort (Osterhout & Hagoort, in press), on the other hand, maintain that it is a language-specific component.

Factors modulating language-related ERPs There are a number of factors that have been investigated systematically and shown to modulate language-related ERP effects (see above). In addition, a large variety of factors given in Appendix A.2 could be considered as potential influences. A systematic exploration of these items is beyond the scope of this thesis, but certainly appears to be worthwhile. Notice that the majority of studies in the electrophysiology of language comprehension differ on one or more of these factors. This issue awaits further systematic examination.

4.6 ERP correlates of semantic processing

The following section briefly introduces ERP correlates of semantic processes during sentence comprehension.

Kutas and Hillyard showed that a semantically incongruous, sentence-final word elicited a N400 (see 4.1, the critical word is underlined). In a subsequent study (1984) they demonstrated that the effect was modulated by association between sentence constituents and the critical word 4.2. A semantically incongruous and not associated word (”cry”) elicited a larger N400 than an incongruous but associated word (”drink”).

(4.1) He spread the hot bread with socks.

(4.2) The pizza was too hot to eat/drink/cry.

Many subsequent studies investigated the processing nature of the N400 more closely (see above). Currently, it is widely held that the N400 reflects the ease of integration of a new word into the existing sentence on semantic grounds. (Rösler, Pütz, Friederici & Hahne, 1993; Mecklinger, Schriefers, Steinhauer & Friederici, 1995; Gunter, Stowe & Mulder, 1997).

In the present study, syntactic processes of sentence comprehension, namely processing morphological structural and inherent case, were experimentally isolated. Thus, processes of semantic integration during sentence comprehension do not lie at heart of this thesis.

4.7 ERP correlates of syntactic processing

In the present section, ERP correlates of syntactic processing during sentence comprehension are introduced in more detail. First, phrase structure violations, morphosyntactic congruency violations, subjacency violations and attachment ambiguities are introduced. Then, studies on subcategory violations are presented. The latter are of particular importance for the present study.

4.7.1 Phrase structure violations

If the phrase structure rules of a language are violated, that is if a sentence cannot be continued in a grammatical fashion on the basis of phrase structure rules, a characteristic ERP component series is elicited: a left anterior negativity (ELAN or LAN) followed by a P600.

Neville, Nicol, Barss, Forster and Garrett (1991) used phrase structure violations (4.3) among other syntactic violations to investigate syntactic processing in a reading experiment.

(4.3) * Max's of proof the theorem

The critical element ("of") elicited an early left anterior negativity followed by a P600. The other syntactic violations they investigated did not elicit a similar early negativity. This suggests that processing phrase structure violations involves distinct processes from processing other syntactic violations.

Friederici, Pfeifer and Hahne (1993) also used a word category error (4.4) to induce a phrase structure violation. This experiment used continuous speech.

(4.4) * Der Freund wurde im besucht - The friend was in the visited

The critical word ("besucht") elicited an early left anterior negativity between 150 and 300ms after word onset.

Patterns of this kind were obtained in the visual (Neville, Nicol, Barss, Forster & Garrett, 1991; Osterhout & Holcomb, 1992; Münte, Heinze & Mangun, 1993; Friederici, Hahne & Mecklinger, 1996; Gunter, Friederici & Hahne, in press) as well as the auditory modality

(Friederici, Pfeifer & Hahne, 1993; Osterhout & Holcomb, 1993; Friederici, Hahne & Mecklinger, 1996; Hahne & Friederici, 1999). Phrase structure violations, however, do not always elicit early left anterior negativities (Osterhout & Holcomb, 1992, 1993; Friederici, Hahne & Mecklinger, 1996; Gunter, Friederici & Hahne, in press). The latency of the left anterior negativity varies between studies. While Neville et al. (1991), Friederici et al. (1993), Friederici et al. (auditory, 1996) and Hahne and Friederici (1999) report negativity effects that are consistent with the descriptors of the ELAN, negativities that are more in line with a LAN characterization were obtained in the other experiments (Osterhout & Holcomb, 1992; Münte, Heinze & Mangun, 1993; Friederici, Hahne & Mecklinger, 1996; Gunter, Friederici & Hahne, in press). This discrepancy might largely be due to experimental parameters of visual presentation (stimulus durations and ISI) that slowed the processing down (p. 286 Friederici, 1999) or strategies of data analysis. The ELAN (or also LAN for these studies) is taken to reflect a disruption of first-pass parsing processes, whereas the P600 is interpreted as reflecting processes of repair (Friederici, 1995, 1999).

4.7.2 Morphosyntactic violations

A number of violations of syntactic agreement between sentence constituents have been investigated. Frequently these violations are realized via inflectional morphology. Violations of number (Kutas & Hillyard, 1983; Osterhout & Mobley, 1995), verb tense (Kutas & Hillyard, 1983), verb inflectional morphology (Friederici, Pfeifer & Hahne, 1993; Hagoort, Brown & Groothusen, 1993; Gunter, Stowe & Mulder, 1997; Penke, Weyerts, Gross, Zander, Münte & Clahsen, 1997), third person singular ”s” (Osterhout & Mobley, 1995; Coulson, King & Kutas, 1998) were investigated.

Friederici, Pfeifer and Hahne (1993) investigated incorrect verb inflections in the auditory domain (see sentence example (4.5)).

(4.5) *Die Bahn wurde fahre - The train was drive

They reported a broadly distributed, left anteriorly pronounced negativity between 300 and 600 ms after onset of the critical word (”fahre”) followed by a parietal positivity between 750 and 1200 ms.

In sum, negativity effects, often with left anterior pronunciation (LAN) in the time window between 300 and 500 ms after onset of the critical word, are elicited by morphosyntactic violations during sentence comprehension. These negativities are regularly followed by a P600.

4.7.3 Attachment ambiguities

Syntactic attachment ambiguities, or garden-path sentences, that play a prominent role in syntactic parsing research (see Section 3.3), were also investigated using ERPs (Osterhout & Holcomb, 1992, 1993; Mecklinger, Schriefers, Steinhauer & Friederici, 1995).

An initial study was reported by Osterhout and Holcomb (1993). In sentences (4.6) and (4.7) the structural attachment of the verb ”persuaded” is locally ambiguous until the following word is recognized. In (4.6) persuaded is the main verb requiring a direct object. Whereas, in (4.7) it is part of a reduced relative sentence (”The broker who was persuaded to sell the stock ...”). In (4.8) there is no ambiguity, because the verb ”hope” is intransitive.

(4.6) The broker persuaded the man to sell the stock.

(4.7) The broker persuaded to sell the stock was sent to jail.

(4.8) The broker hoped to sell the stock.

For reduced relative sentences (4.7) a late positivity following ”to” by 500 to 800ms was observed. Osterhout and Holcomb labeled it ”P600” (for an auditory version see Osterhout & Holcomb, 1993).

Mecklinger, Schriefers, Steinhauer, and Friederici (1995) investigated locally ambiguous subject- (SR) and object relative clauses (OR) in German. Behavioral studies have shown that there is an attachment preference for SR structures (Frazier, 1987; King & Just, 1991; Schriefers, Friederici & Kühn, 1995). For fast comprehenders a positivity labeled P345 was obtained for the unpreferred OR structures. The authors hold that the latency difference of the positivity effects between their study and the study by Osterhout and Holcomb (1992) is due to less complex processes of structural reanalysis for the reduced relatives in their study. See also the study by Osterhout, Holcomb and Swinney (1994) below.

4.7.4 Subjacency violations

In Government and Binding Theory (see Section 2.1 on page 5) a number of principles have been formulated that control insertion and ordering of sentence constituents, also called movements. Subjacency is a group label for these principles.

McKinnon and Osterhout (1996) used violations of the subjacency principle in sentences featuring identical critical words in the correct and incorrect conditions. Sentence (4.10) violates the so-called empty-category principle (Haegeman, 1994).

(4.9) It seems that it is likely that the man will win.

(4.10) *The man seems that it is likely to win.

For the incorrect sentences, they found a broadly distributed positivity beginning 300ms after onset of the critical word (”that”) and extending up to 800ms. A comparable positivity effect was reported by Neville et al. (1991) for a subjacency violation. Kluender and Kutas (1993), however, reported a left anterior negativity between 300 and 500ms after onset of the critical word that they attributed to processes of working memory.

4.7.5 Subcategorization violations

All further distinctions between classes of words within a given word category can in principle be considered subcategory classifications. For verbs one subcategorization reflects the number of arguments a verb allows or requires (see subcategorization frames in Section 2.3 on page 7).

In a reading experiment, Rösler, Friederici, Pütz and Hahne (1993) used, among other experimental variations, transitive (4.11) and intransitive verbs (4.12) in passivized sentences. Due to their subcategorization properties, intransitive verbs cannot form grammatically correct passive sentences 4.12.

(4.11) Der Präsident wurde begrüßt. - The president is being greeted

(4.12) *Der Lehrer wurde gefallen. - The teacher is being fallen

The violation on the sentence-final participle elicited a left anteriorly pronounced negativity between 400 and 700 ms after verb onset and a marginally significant positivity between 700 and 1200 ms.

Hagoort, Brown and Groothusen (1993) also investigated a subcategorization violation in Dutch and reported no systematic result.

Osterhout, Holcomb and Swinney (1994) used reduced relative sentences (4.13 - 4.16) in a reading experiment (word-by-word, SD 300ms, ISI 350ms). Noun phrases (”the patient”) followed the verb of the matrix sentence. Verbs were either obligatorily intransitive (4.13), polyvalent with an intransitive bias (4.14), obligatorily transitive (4.15) or polyvalent with a transitive bias (4.16). While sentence (4.13) is a correct sentence, a word category error is induced on the auxiliary (”was”) by the subcategorization properties of the transitive verb (”forced”) in sentence (4.15). Acceptability judgments were used as a secondary task.

(4.13) The doctor hoped the patient was lying.

(4.14) The doctor believed the patient was lying.

(4.15) *The doctor forced the patient was lying.

(4.16) The doctor charged the patient was lying.

The violation induced a negativity, labeled N400 by the authors, followed by a P600 relative to the correct condition. While the verbs in the transitive bias condition induced solely a P600 and the verbs in the intransitive bias condition showed no difference relative to the correct condition. The latter findings show that a bias of subcategorization properties has a functional consequence. Syntactic structure building is guided at some point in a way that revision processes are contingent upon this bias, as indicated by the P600. The finding of the N400, however, is surprising. Since they used an purely syntactic violation the authors did not expect an N400 as a correlate of semantic processing. One possible explanation is that the anomalous sentence structure also rendered the sentence hard to interpret semantically. (see p. 799, Osterhout et al., 1994). Given that the verbs of the transitive bias condition (”charge”) feature a reasonably strong bias, then a semantically induced N400 should also have been obtained in this condition. This was not the case. Thus the incorrect and the transitive bias condition do not necessarily differ on semantic grounds, but they do differ with regard to their subcategorization properties. As a consequence, the effect might be a mainly syntactically induced negativity, that simply does not fit the standard scheme of LAN and N400 (cf. also Gazzaniga, Ivry & Mangun, 1998; Kutas & Hillyard, 1983).

In sum, these studies do not produce a unitary pattern of results. While one found a left anteriorly pronounced negativity effect and no reliable P600 the other found a negativity labeled N400 followed by a large P600.

In the present study, violations of complement structure information, case information in particular, were used. This manipulation is relatively close to the variation of subcategorization information in the former two experiments. Notice, however, that in the experiments of the present study types of complements were varied, while subcategorization frames were kept constant (see Section 2.3, pp. 7).

4.8 A model of sentence comprehension

Friederici (1995, 1999) and Friederici and Mecklinger (1996) proposed a model of sentence comprehension based on neurophysiological and neuropsychological data which assumes sentence comprehension to take place in three stages, each with its own temporal and functional signature in the event-related brain potential. The model proposes a first phase, an early syntactic parsing stage, followed by a stage of lexical integration, followed by a late stage during which secondary language processes take place (see Figure 4.1).

A first stage involves an autonomous and automatic ”first pass parse” during which an initial syntactic structure is built up on the basis of word category information exclusively and independent of lexical-semantic information. At this level, expectations concerning a word’s syntactic category but not its meaning are possible. This stage is reflected by the early left anterior negativity (ELAN) occurring between 150-250 ms, at least in the auditory domain (see Section 4.5.1 on page 43).

Lexical integration takes place during Phase 2. In this phase other lexical syntactic, morphosyntactic and lexical semantic processes are carried out. Left anterior negativities (LAN) between 300-500 ms are observed with morphosyntactic violations such as subject-verb agreement errors and with errors concerning the verb argument structure (see Section 4.5.2 on page 44).

This latter time window is identical to the one in which processes correlated with lexical-semantic violations reflected by a N400 take place (see Section 4.5.3 on page 45).

Friederici (1995) has claimed that these two types of violations, although functionally different and eliciting negativities with different distributions, might fall in the same time window as they both require access to the lexical element, be it to retrieve information about meaning of a word or to retrieve specific grammatical information such as case, gender, number, tense or mode of a bound morpheme.

During Phase 3 processes of reanalysis, correction or repair occur if necessary. Within this model interaction takes place only at the third stage during which semantic and syntactic information are mapped onto each other for interpretation. If no direct mapping is possible at this stage, the system has to undergo processes of reanalysis (when the sentence is grammatical but follows an unpreferred structure) or repair (when the sentence is ungrammatical). This process is reflected by the late positivity called P600 (see Section 4.5.4 on page 45).

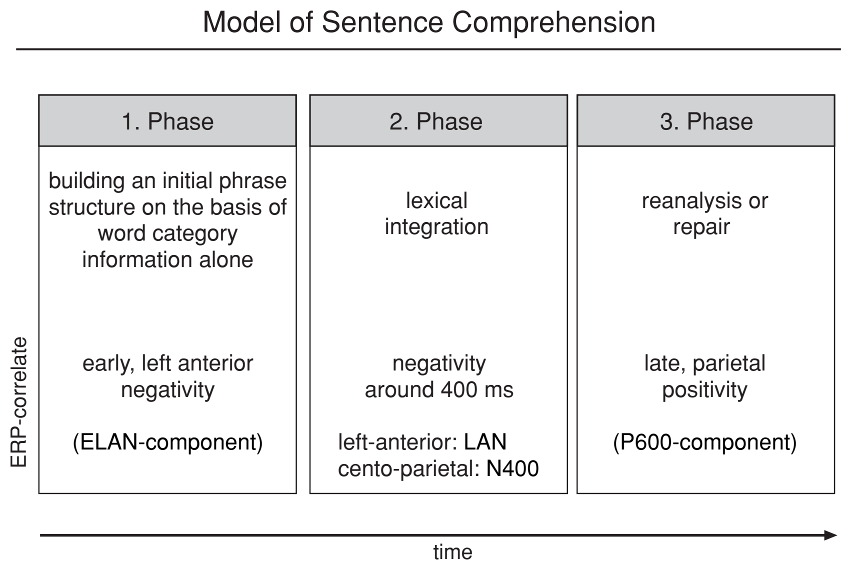

Figure 4.1: A model of sentence comprehension after Friederici (1995).

This model is compatible with modular views on language comprehension. A modular theory predicts that syntactic and semantic processes should be independent at least during the early stages of processing, but not necessarily during the later stages of processing. Thus, interaction between syntactic and semantic aspects can take place during a later stage. If the question of modularity versus interactivity boils down to the temporal structure of different subprocesses during language comprehension, the ERP method with its high temporal resolution should allow a clear description of these subprocesses.

This model provides the basis for the predictions presented in the next chapter.

4.9 Summary

The present chapter introduces the electrophysiology of the brain in general and of language comprehension in particular. To this end, a brief introduction to the method of the electroencephalogram (EEG) and event-related brain potential (ERP) technique is provided. In the past two decades, a number of ERP components have proven to reflect processes of language comprehension or their disruption. The early left anterior negativity (ELAN) is elicited by phrase structure violations occurring during sentence comprehension. The left anterior negativity (LAN) is mainly induced by morphosyntactic violations such as verb tense, number or other aspects of inflectional morphology. In sentence comprehension, the N400 is correlated with the ease of lexical semantic integration of a new word into the existing sentence structure. Finally, the P600 is an indicator of processes of reanalysis and revision of the Sentence structure.

The present work is based on a neurobiological model of language comprehension (Friederici, 1995, 1998b). In this three-stage model an autonomous first-pass parse is carried out exclusively on the basis of word category information and general parsing principles. Processing problems are indicated by the ELAN. During a second stage other lexical syntactic information is used for syntactic structure building. Disruptions are indicated by the LAN. At the same time lexical integration takes place (N400). Finally, at the third stage processes of reanalysis or revision of the sentence structure are carried out, indicated by the P600.

Chapter 5

Research Questions and Preview

The present chapter is structured as follows. First, the research questions and goals of this study are developed. Then a preview of the experiments is given.

5.1 Research questions and goals

In theoretical linguistics a number of levels of analysis can be distinguished (see Chapter 2). Within linguistic syntax, case is an indispensable device of theoretical syntactic analysis (see Section 2.6 on page 9). Structural and inherent as well as morphological and abstract case were theoretically distinguished. In the psycholinguistic literature, structural case has been demonstrated to be processed during sentence comprehension (see Section 3.8 on page 33). This is done in a time frame small enough to affect naming latencies in the 500ms range. In addition, structural and inherent case were implicated as being dissociated on a structural dimension in the human language faculty. Complementary aphasic performance patterns on regular active and passive versions of sentences were interpreted in terms of Case Theory in the Government and Binding framework (see Section 3.8). Furthermore, ERP studies revealed effects of subcategorization violations during sentence comprehension (see Section 2.3 on page 7).

The approach of the present study was to pull these strings of knowledge from different scientific disciplines together in investigating characteristics of processing morphological structural and inherent case in language comprehension.

Three main issues were addressed in order reach the goal of this study:

- Processing characteristics as measured by off-line tasks
- Processing characteristics as measured by on-line tasks
- Converging empirical evidence for the concepts of structural and inherent case

In the following paragraphs these three main questions are presented each in turn. Empirical hypotheses are developed for each question. More detailed hypotheses will be presented in the individual experiment chapters.

This study does not particularly aim at contributing evidence in the autonomist versus interactive debate. As a consequence, the experiments were not designed to deliberately test specific models of word recognition or syntactic processing. Rather, theoretical background and models established in the literature were adopted as a basis and working model to explore characteristics of processing structural and inherent case. Results of the present study, if they proved to be reliable, could, however, serve as constraints for empirical models of sentence processing.

Case processing characteristics as measured by off-line tasks Regarding the first main question, the term ”off-line” refers to the fact that recording of the dependent measure takes place after the critical processes of sentence comprehension are completed or that no control about the time course is possible in the specific task. Structural (accusative) and inherent (dative) object case information coded in the complement structure of a verb and marked on a pronominal sentence constituent was used in all experiments. It was investigated whether or not this case information is processed, and to what extent it is processed correctly. The grammatical acceptability judgment task (GAJT, see Section 2.1 on page 5) as well as a sentence completion task were used. These tasks were employed varying the time pressure imposed on the participants as well as the sensory input modality (sentence completion). In particular, empirical reflections of the theoretical case concepts were of interest.

Given the fact that German has a rich morphological case system, that case is an omnipresent feature in German language usage, the following hypothesis is posed.

(5.1) H. I: In general, morphological case information is processed correctly.

It was particularly important to establish that the particular variation of structural and inherent case that was planned to be used throughout this study was processed reliably. Hypothesis (5.1) was tested in a number of the subsequent experiments using the GAJT and sentence completion.

The theoretical distinction of structural and inherent case, the notion of a default case for verb objects in particular led to postulating Hypothesis (5.2). If there is a processing default, it should be processed more reliably than the non-default.

(5.2) H. II: Processing structural case is more reliable than inherent case.

In experimental terms, Hypothesis (5.2) is a main effect prediction. It extends to performance parameters such response latencies, error percentages and ERP characteristics.

Given results about case syncretisms, predominantly in English, it can be speculated that there is a greater tendency of inherent case to be absorbed by structural case than vice versa (see case syncretism in Section 2.6).

(5.3) H. III: Processing interaction between both case types.

In experimental terms, Hypothesis (5.3) is a prediction of an interaction effect. It also extends to performance parameters such response latencies, error percentages and ERP characteristics.

Case processing characteristics as measured by on-line tasks Regarding the second main question, the term ”on-line” refers to tasks tapping into the sentence comprehension process, i. e., recording of the dependent measure takes place during sentence comprehension. On the one hand, the cross-modal naming task (CMNT) was used in a task variant that had participants listen to an auditory sentence fragment followed by a sentence-completing verb target. The second task used was sentence reading in a serial word-by-word setting while the EEG was recorded. Two levels of temporal resolution need to be distinguished regarding these two tasks. (see Section 4.3 on page 4.3). While the ERP method records electrophysiological activity during word reading, the response latencies recorded in the CMNT are affected via third processes, e. g., the output of a postlexical checking mechanism (see Section 3.7.2 on page 28). This renders the ERP technique likely to be the method with the higher temporal resolution.

Online tasks were used in Experiments 4 and 5 (CMNT) as well as Experiments 6 and 7 (ERP).

(5.4) H. IV: On-line case congruency effect: Violation conditions cause longer RTs.

Qualitative distinctions and processing characteristics can be captured using the ERP method (see Section 4.3). Based on the model by Friedrici (see Section 4.8 on page 51) a syntactically triggered negativity effect, most likely a LAN, possibly followed by a P600 was predicted for Experiment 6.

(5.5) H. V: LAN / P600 pattern in violation conditions.

Furthermore, a dissociation of the processing of structural and inherent case was predicted. Given that structural case as the default case is processed more reliably, larger, quantitative as well as qualitative, violation effects were expected.

(5.6) H. VI: Dissociation of structural and inherent case.

The temporal resolution was expected to be higher in the ERP experiments (see above).

Converging empirical evidence The third main question posed in this study is concerned with evaluating converging empirical evidence for the theoretical linguistic concepts of structural and inherent case. This question can be considered the feedback loop from empirical research to linguistic theory in the study.

The theoretical distinction of structural and inherent case should become apparent in the lexical frequency analysis, the sentence completion experiments, the grammatical acceptability judgments and potentially also in the ERPs.

In the former, the concept of accusative as the default case for verb objects should be reflected in the frequency of occurrence of different verb complement structures (see Experiment 1 in Chapter 6).

No further particular hypotheses were generated. Rather, empirical results obtained were considered in the light of theory.

5.2 Experiment Preview

The purpose of the following section is to provide a preview of the experiments and introduce their common ground.

As mentioned above, in theoretical linguistics a number of levels of analysis are distinguished (see Chapter 2). This study focused on syntactic aspects of language processing, in particular processing morphological structural and inherent case. As a consequence, for all experiments influences from semantics, irrelevant morphology, other non-syntactic influences or other syntactic aspects were avoided. In order to achieve the best possible experimental control the experiments were operationalized based on linguistic theory. Linguistic sources were used for material generation, the CELEX lexical database in particular (Burnage, 1990). By using verb complement structures the level of case processing was experimentally isolated. In all experiments, the factors case (structural (accusative) vs. inherent (dative)) and correctness (correct vs. incorrect) were crossed in a two by two design.

Additions to and alterations from this general scheme, if they exist, are reported in the experiment chapters.

5.2.1 Participants

Participants were healthy young adults. All were native speakers of German who had no contact with another language prior to the age of six. They were students at a Leipzig university, with an age range from 18 to 30 years. All participants reported normal or corrected-to-normal visual and auditory acuity. New participants that were naive regarding the purpose of the study were recruited for each experiment. They received course credit or were paid for their participation.

5.2.2 Material

All experiments used wh-sentence constructions. Morphological case marking of accusative (structural) and dative (inherent) case was realized on pronouns. Wh-question pronouns and personal pronouns were used. Accusative and dative verbs were used according to their CELEX complement structures as case-assigning verbs. Sentence were constructed such that the level of case was experimentally isolated. Common first names were used for the Agent role in sentence construction in order to render predictions based on semantic grounds impossible.

Also, pronouns were used in the sentence material in order to preclude semantic effects, like e. g. predictions, based on the meaning of the words used, like social roles for instance.

Within each experiment the general phrase structure, the syntactic sentence structure, of the stimulus sentences was identical for all sentences. No sentences featuring different phrase structures were included in the experiments. Thus, sentence complexity was kept constant. Also, all sentences of an experimental set have an identical argument structure, there is no variation in terms of number of arguments. There were arbitrary relations between type of case a verb requires and the thematic roles it assigns (as there was no reliable source for thematic roles; see also Section 2.6).

In sum, the focus was on verb complement structures, in particular, accusative versus dative obligatory NP complements. Two arguments, i. e., two-place predicates, were used in the critical clause of the sentences. No manipulation of number of arguments or thematic roles was carried out.

5.2.3 Apparatus

The experiments were run on a PC-type computer using the ERTS experiment programming shell (unless otherwise noted Beringer, 1993; Iwanek, 1994). Digitized sound files were played using a ”SoundBlaster 16” sound board and standard headphones. Visual stimuli were presented on a ”Sony Multiscan 17 se” SVGA computer monitor. Participants’ voice responses were captured by a head-mounted microphone and fed into a voice key that triggered the reaction time clock.

5.2.4 Procedure

All experiments constituted fully crossed two by two design with the factors case and correctness. Fifty percent of all critical trials used accusative and the remainder dative verbs. Also, half the sentences were grammatically correct and the other half were incorrect. Item repetition was used in mixed between- / within-subject designs. For the correctness factor, critical words served as their own controls, i. e. different experimental conditions where realized using identical items. In experiments with between-subject manipulations of blocks (Experiments 4-8) participants gender was counter-balanced across blocks. Filler sentences were used in the questionnaires of Experiments 1 and 2. No fillers were used in the other experiments.

Variations of several experimental standard tasks were employed. Grammatical acceptability judgments, sentence completion, word naming and sentence reading. The GAJT was used as an identical secondary task for all online sentence comprehension experiments (Experiments 4, 5, 6 and 7).

All experiments featuring auditory stimulation (Experiments 3-5) used physically identical sound files presented at the same highly audible volume setting.

In all experiments in which participants were tested individually, post-experimental questions were used to probe for suspicion and determine whether or not participants were aware of the purpose of the experiment.

5.2.5 Data analysis

Greenhouse-Geisser (Greenhouse & Geisser, 1959) corrected error percentages are reported where applicable.

Part II

Empirical Section

Chapter 6

Lexical Frequency Analysis

6.1 Introduction

In this chapter an empirical frequency analysis of German verbs that subcategorize for either or both accusative and dative objects is presented. Its purpose was to add to the theoretical linguistic analysis given in the introduction (see Chapter 2, pp. 5). There, the concept of verb complement structures and a distinction between accusative as the default case for verb objects and dative as the lexical inherent case were introduced. It was expected that this dissociation could also be found on the level of lexical frequencies.

Note that the present chapter is concerned with lexical frequencies, i. e., frequencies of use of individual lexical items, and verb categories in particular. A frequency analysis of syntactic frames, i.e., different sentence types, could not be provided, because the respective corpus data were not available for German at the time of this analysis (Institut für Deutsche Sprache, personal communication). Presumably, these two types of information are correlated, but not identical.

6.2 Method

6.2.1 Source

The CELEX lexical database was used as the data source for this analysis (Centre for Lexical Information, 1995; Burnage, 1990). CELEX codes nine different types of possible complements in the subcategorization information of lexical verbs (Burnage, 1990, pp. 5-92). See Appendix A.1 for a complete listing. For the purposes of the present study, a CELEX lemma lexicon of all German verbs was created. The complementation codes for Accusative complements and Dative complements were used to extract the verbs that subcategorize for these complements. A verb can feature one complement structure exclusively or more than one complement structure. Only verbs were considered that feature either an accusative or a dative complement or both.

Accusative and Dative complements can either be obligatory or optional. Combining the latter feature with type of complement results in eight different complement structures. Only verbs that take obligatory or optional noun phrase complements were analyzed, since they were of particular importance for the experiments reported in this thesis. [1]

6.2.2 Apparatus

The CELEX lexical database was used in the internet interface version (Centre for Lexical Information, 1995; Burnage, 1990). It was accessed via the telnet application using accordingly configured Xterminals. The remote system at CELEX, Nijmegen, was a HP9500 running Unix and the ”flex” interface. CELEX lexica were created on the remote system, transferred using the ftp application and analyzed mainly using self-written special purpose software on DEC Alphas running Unix.

6.3 Results

Sixteen separate frequency counts were conducted according to the following scheme. A verb can feature one complement structure exclusively or more than one complement structure. These sets of verbs were analyzed separately. Only verbs were considered that feature either an accusative or a dative complement or both. Accusative and Dative complements can either be obligatory or optional. Combining the latter feature with type of complement results in eight different complement structures. The results are given in Table 6.1.

CELEX showed 4101 verbs featuring an obligatory accusative object as the only complement structure, but only 98 verbs featuring an obligatory dative object as the only complement structure. Hence, the default accusative occurs more than 40 times more frequently as the object case in verbs featuring a single obligatory noun phrase object. Thus, the notion of accusative being the default case for verb complements was also demonstrated on lexical frequency basis.

Dative is structural case in ditransitive structures. The dative case occurs more often in three argument verbs in conjunction with accusative case. Hence, it seems fair to state that for dative case the ”default” is co-occurring with accusative case in three argument verbs rather than being used as case for verb objects in two-argument verbs.

6.4 Discussion

The results of the lexical frequency analysis showed that the theoretical linguistic concepts of structural and lexical case correlate strongly with the frequency distributions of the respective

[1] In addition to these analyses on noun phrases, other analyses that investigated all possible types of complements (e. g., prepositional phrases) were conducted. They are not reported in detail here because they did not yield qualitatively different results.

Table 6.1: Frequency of occurrence of German verb complement structures according to CELEX: Accusative and Dative noun phrase complements only.

exclusively		not exclusively	
structure	count	structure	count
ACCUSATIVE	4101	ACCUSATIVE	6454
accusative	92	accusative	337
DATIVE	98	DATIVE	265
dative	15	dative	58
ACC & DAT	177	ACC & DAT	686
ACC & dat	105	ACC & dat	331
acc & DAT	2	acc & DAT	13
acc & dat	0	acc & dat	0

Note. Upper case letters code obligatory verb complements. Lower case letters code optional verb complements.

verbs.

Furthermore, the dissociation of frequencies shown in this chapter had to be considered during the planning of the subsequent experiments. Here two types of frequencies are to be distinguished: type frequency of word subcategories, investigated in this chapter, and token frequency, the frequency of occurrence of a given verb. In order to avoid possible effects of word frequency on the processes under investigation, the token frequencies of the experimental verbs were matched for frequency of occurrence. This, however, had to be done independently of the investigation of type frequency of word subcategories.

6.5 Summary

A lexical frequency analysis of German dative and accusative verbs was conducted to investigate the correspondence between the theoretical linguistic distinction of structural and lexical case (Chapter 2) and the frequency distribution of the verbs' subcategories. The default accusative occurs more than 40 times more frequently as the object case in verbs featuring a single obligatory noun phrase object.

Chapter 7

Experiment 1 - Grammatical Acceptability Judgments

7.1 Introduction

The goal of Experiment 1 was to investigate the extent to which accusative and dative case information morphologically marked on a sentence-initial wh-pronoun is processed in an off-line grammatical acceptability judgment task by German native speakers.

Note that while it is necessary to process different instances of structural case, e. g., nominative versus accusative, correctly in order to build syntactic structure (see Section 2.6), this does not apply to the same extend to structural versus inherent object case. Here it would be sufficient to determine that a constituent features an object case, furhter discrimination is not necessary, because the appropriate case will also be provided by the case-assigning verb. Checking this coreference between verb and its object was central to the task used in this experiment. Experiment 1 was a test of Hypothesis (5.1).

Setting the stage for the subsequent experiments, it was necessary to find an experimental manipulation that participants could flawlessly perform. Note that the verb was the critical case assignor in the sentences used (see Chapter 2). It was predicted that German native speakers should not have difficulties performing this task, since German has a rich morphological system overt case marking is an omnipresent feature in everyday language use (Chapter 2).

7.2 Method

7.2.1 Participants

Fifty-four young adults (18 males) volunteered to participate in Experiment 1. All were native speakers of German and second-year psychology students at the University of Leipzig. Their mean age was 21 years (standard deviation 1.7), ranging from 18 to 27. Participants reported normal or corrected-to-normal visual acuity. They received course credit for their participation.

7.2.2 Material

In this subsection first the selection of critical verbs is described. Then the construction of experimental sentences using these verbs is explained.

Selection of verbs The material selection was based on the CELEX lemma lexicon of German verbs material reported in Chapter 6 (pp. 63). In order to achieve maximal clarity and distinctness between the accusative and the dative item sets, only verbs that feature one and only one complement structure with a single accusative or dative object complement were selected. (In CELEX notation (see Appendix A.1) accusative verbs were 00N000000 only and dative verbs were 0000N0000 only. As reported in Chapter 6, CELEX showed 4101 verbs featuring an obligatory accusative object as the only complement structure, but only 98 verbs featuring an obligatory dative object as the only complement structure.

However, a number of additional constraints had to be regarded for item selection:

- Animacy: A verb had to work perfectly well with a person in the object role. For this reason a number of verbs that require an inanimate object could not be used.
- Auxiliary: Verbs had to subcategorize for the auxiliary ”haben” (”to have”). Whereas verbs subcategorizing for the auxiliary ”sein” (”to be”) could not be used.
- Ambiguity: Verbs that can be used in past participle form in an active as well as as an adverb in a passive notion could not be selected for the following reason. The verb ”einschüchtern” (”intimidate”) for instance is an accusative verb and would thus qualify for a sentence like ”Wen hat Lutz eingeschüchtert, als er mit der Polizei drohte?” (”Whom has Lutz intimidated, when he threatened to call the police.”) But it can also be used as an adverb in participle form in a passive notion with dative case in a sentence like ”Wem hat Lutz eingeschüchtert zugehört, als er mit der Polizei drohte?” (”To whom has Lutz intimidatedly listened, when he threatened to call the police”). This renders this verb form case-ambiguous and it, along with all other verbs of this type, could thus not be used in this and the subsequent experiments.
- Passive: Verbs that exclusively feature a passive notion in past participle form (e.g., ”mißfallen” (”disliked”)) could not be selected for reasons of consistency of the types of sentences used in the experiment.
- Length: Verbs featuring more than three orthographic syllables in infinitive form were not selected, because they were considered to be too long for presentation in subsequent on-line experiments.

- Prefixation: In German, there is only a very small number of non-prefixed dative-only verbs, not enough to sufficiently fill an experimental condition. Hence, exclusively prefixed verbs were used for consistency reasons.

- Miscellany: Verbs that sounded odd or feature a meaning too offending for the purposes of this experiment were excluded.

As a consequence of the above selection constraints only 22 dative verbs could be selected. For the experiment, half the critical verbs were to be accusative verbs and half were to be dative verbs (50%/50% conditions). As a consequence, equal numbers of dative-only and accusative-only verbs had to be selected. The accusative verbs had to match the dative verbs with respect to all above criteria plus their frequency of occurrence based on the CELEX lemma frequency.

Furthermore, an attempt was made to match the frequency of occurrence of verb prefixes over both conditions. This could not be achieved. It appeared to be the case that certain prefixes occur with certain complement structures more often than with others. [1] After the attempt to match the frequency of prefix occurrence for both conditions had been dropped, accusative verbs were selected that matched the dative verbs with respect to all above mentioned criteria and that sounded particularly odd when presented accompanied by the wrong, the dative, case. This was done based on two independent German native speakers' linguistic intuition. Using this procedure 27 accusative and 22 dative verbs were selected. This unequal number was accepted in order to be able to use the maximal number of CELEX entries for purposes of material selection for the subsequent experiments. It was supplemented by filler items in order to construct a fully counterbalanced design. The verbs are listed in Appendix B.1.

Sentence construction A basic sentence was constructed for each critical verb using the template given in (7.1). A syntactically correct and an incorrect sentence version were derived from each basic sentence (e.g. (7.2) & (7.3), the critical words are underlined). Only common German first names were used (half male, half female). A different first name was employed for each basic sentence.

(7.1) $< wh - pronoun >< auxiliary"have" >< name >< verb >< subord.clause >$

(7.2) "Wen hat Maria gesehen, bevor sie ging."

"Whom has Mary seen, before she left."

(7.3) *"Wem hat Maria gesehen, bevor sie ging."

*"To whom has Mary seen, before she left."

[1] This would result in probabilistic verb complement structure information that could be processed well before the uniqueness point of an auditorily presented word. Note that all experiments reported in thesis used visual target presentation.

(7.4) ”Wem hat Maria geholfen, bevor sie ging.”

”To whom has Mary helped, before she left.”

(7.5) *”Wen hat Maria geholfen, bevor sie ging.”

*”Whom has Mary helped, before she left.”

A set of 20 additional 3-argument-verbs was used to construct 40 filler sentences (50% correct), in order to prevent monotony of the sentence constructions. Finally, a total of 22 control items using 11 new accusative verbs were constructed based on the same template. 11 sentences featured number agreement errors. They served as control items to monitor participants' performance. A total of 160 sentences resulted. Half the sentences were syntactically correct. Also, about half the sentences featured dative verbs (42 dative and 38 accusative). The critical sentences are given in Appendix B.1.

7.2.3 Procedure

The participants received a booklet containing instructions and the 160 sentences. Instructions were given on the cover page. Participants were asked to fill in personal information. They were instructed to indicate for each of the sentences whether it was syntactically correct or incorrect (see Appendix C.1 for the complete instructions).

The sequence of the sentences in the questionnaire was as follows. The complete set of sentences was split into halves according to the verbs, since each verb occurred twice, once in a correct and once in an incorrect condition. Both correctness conditions occurred equally often in both halves. Items were pseudo-randomized within the halves with the constraint that a given condition could not occur more than three times in a row.

All participants were tested in a single group session.

7.3 Results

Four participants who produced more than 2 errors on the control items were excluded from further analysis. The remaining 50 participants showed on average 98% hits and 98% correct rejections on the control items. The results are given in Table 7.1. Missing and indifference responses combined were below one percent for both accusative and dative conditions.

Accusative and dative case information overtly marked on a sentence-initial wh- question pronoun was correctly processed in this off-line grammatical acceptability judgment task. Descriptively, there was a tendency to accept dative verbs preceded by incongruently case-marked pronouns. This issue and the grammatical acceptability judgment task were investigated in more detail in subsequent experiments.

Table 7.1: Performance data of the grammatical acceptability judgment task.

	accusative		dative	
correct judgments	hit 98	miss 1	hit 97	miss 5
incorrect judgments	false alarm 2	correct rej. 99	false alarm 3	correct rej. 95

Note. All values in percent of type of response (correct/incorrect) by case condition (accusative/dative).

7.4 Discussion

Experiment 1 clearly showed that accusative and dative case information marked on a sentence-initial wh-pronoun is processed correctly in a grammatical acceptability judgment task.

These results indicate that German native speakers process morphological case information correctly in an off-line task. While Experiments 2 and 3 also used off-line procedures, Experiment 4 to 7 used on-line measures to investigate characteristics of case processing.

In Experiment 1, the grammatical acceptability judgment task proved to be suitable to function as a secondary task in subsequent experiments.

7.5 Summary

An off-line grammatical acceptability judgment task was used to investigate the processing of accusative and dative case information marked on a sentence- initial wh-pronoun. Results indicated that German native speakers process this information correctly.

Chapter 8

Experiment 2 - Sentence Completion I: Questionnaire

8.1 Introduction

The lexical-statistical analysis of the CELEX data on verb-complement structures reported in Chapter 6 added to the theoretical distinction between structural and inherent case reported in the introduction (Chapter 2). Experiment 1 (Chapter 7) provided clear evidence that native speakers of German process accusative and dative case marking correctly in an off-line grammatical acceptability judgment task. The main question investigated in Experiment 2 was to what extent case information morphologically marked on the sentence-initial wh-pronoun is used, if the the case assigning verb is not presented.

Experiment 2, reported in this chapter, and Experiment 3, reported in the next chapter (pp.85), were designed to investigate fundamental aspects of the processing of morphological case marking from a production, rather than a mere reception, perspective. In using a verb generation task, these experiments left more possibility for characteristic and thus informative errors to occur.

The sentence completion experiments reported in the present and the following chapter investigated aspects of the processing of morphological case marking using sentences that also featured initial wh-question pronouns. The participants of the experiments were presented with initial fragments of wh- question sentences and asked to complete them with a single word in a syntactically correct and also meaningful way. All sentence fragments were of the structure given in (8.2). An accusative (8.3) and a dative case marking condition (8.4) were used (see below).

Again, the main question was to what extent the case information is processed in these conditions. Furthermore, the question was posed whether or not characteristic answering patterns would emerge in cases where participants completed sentences in a syntactically incorrect manner.

The following paragraphs provide a brief informational analysis of the task and also an analysis of the hypothetical mental processing path, i.e., a task analysis.

8.1.1 Informational analysis

First, the informational analysis examines the types of information that were provided to the subject for completing the task. Informationally, the task can be regarded as a search task with a number of constraints narrowing the search space. Three different informational elements were provided to the subjects by the sentence fragment that was presented to them: the argument structure of the verb that was searched for, the auxiliary verb associated with it as well as the case of the verb's object. For example, the sentence fragment (4) exclusively prompted the participants to scan their linguistic memory/mental lexicon for a 2-argument dative verb that combines with the auxiliary verb ”haben”(to have), not ”sein” (to be). Informationally, these three elements can be considered constraints narrowing the search space for each sentence fragment.

Under a linguistic perspective, the three constraints could be assigned a hierarchical internal structure (see Chapter 2). Case information can be viewed as nested within verb complement structure information. Whereas, the latter and verb auxiliary information rest on an equal level (4).

(8.1) Types of information provided

- verb complement structure
- case information
- verb auxiliary information

The specific information provided for each sentence narrows the search tree of the lexical search. The constraints have to be satisfied in order to produce a correct sentence completion.

If, for a given reason, the system has to perform the search for a sentence completion under limited capacity conditions, performance patterns that are specific for the system's architecture can be expected. For example, a deterministically operating serial search processor could not produce sentence completions violating the constraints provided. It simply would not produce a completion if no matching element could be retrieved (in the given time window). Its processing time would be determined by the organization of the lists it performs its search upon (given the search was self- terminating) If, for example, the search lists were ordered according to frequency of real-world occurrence of the listed items, then finding a correct sentence completion for low frequency items would result in longer search times than vice versa. Moreover, in order for the system to be able to produce any kind of error, it has to be operating in some sort of probabilistic fashion. Some kind of noise has to be allowed in the system. As a consequence, characteristic error patterns would be informative with regard to the system's processing characteristics. In particular, it would be interesting to determine whether or not one specific of the three constraint is relaxed more easily than others under the given experimental conditions.

8.1.2 Task analysis

The following paragraphs provide a sketch of a task analysis. The mental processing path underlying the sentence completion task used in this study is investigated. From a cognitive perspective, the task involved, first, the processing of a sentence fragment, followed by a lexical search based on the syntactic information provided by the fragment. The process of determining whether or not a verb is associated with a given complement structure may be considered a judgment task. Finally, the system has to determine whether the retrieved lexical item currently under consideration meets the constraints or not. A decision process has to be employed. Furthermore, since participants were instructed to use a given word only once, the task - to a certain extent - contained a secondary memory component, i.e. keeping track of previous completions. The latter, however, was kept as small as possible (see below).

Given the analyses of lexical frequencies that is reported in Chapter 6, accusative is the default case for verb objects in German, Dative is lexical case. Accusative verbs feature a distinguishedly higher frequency than dative verbs. Within the set of dative verbs, 3-argument-verbs are a lot more frequent that 2-argument-verbs. Dative is the default case for the second verb object. Based on this analyses, it was expected that, if case is processed appropriately, the accusative condition should be easier than the dative condition. Furthermore, it was an empirical question whether or not a characteristic error pattern would emerge.

Moreover, it is tempting to speculate about how well different theories of word recognition, or lexical processing in general (see Chapter 3) are capable of accommodating sentence completion data that feature characteristic error patterns. However, this is not done here for the following reasons: A verb generation task was used, not a comprehension task. This task can be considered to be rather artificial. It occurs only very seldom in everyday language use and is an off-line task. It is beyond the scope of this thesis, to pursue these speculations in an appropriate and sufficient manner.

In the following sections the sentence completion questionnaire study is reported. An auditory version is reported in the next chapter.

8.2 Method

8.2.1 Participants

Forty-two young adults (eighteen males) volunteered to participate in Experiment 2. None of them had participated in Experiment 1. All were native speakers of German, their minimal level of education was a German ”Abitur” (baccalaureate), usually perceived to be equivalent to bachelor of science degree (BS). Most of them were students of the University of Leipzig. Their mean age was 25 years (standard deviation 4.7), ranging from 19 to 39. Participants reported normal or corrected-to-normal visual acuity. They received course credit or were paid for their participation.

8.2.2 Material

Seventy-two sentence fragments were constructed using the following procedure. 18 common female and 18 common male first names were selected. Each of the 36 names was combined with the accusative as well as the dative wh-question pronoun and the auxiliary ”hat” (have) to form a sentence fragment of the type (2). Thus 36 accusative (3) and 36 dative sentences (4) were constructed. See Appendix B.2 for a complete material list.

(8.2) $< wh - pronoun >< auxiliary"have" >< name >$

(8.3) ”Wen hat Maria ...”

”Whom has Mary ...”

(8.4) ”Wem hat Maria ...”

”To whom has Mary ...”

The sentence fragments contained three types of information (see (8.1) above): verb complement structure, case information and verb auxiliary information. Only the case information differed between conditions, whereas complement structure and auxiliary information were kept constant.

8.2.3 Procedure

The participants received a booklet that contained instructions, the 72 sentence fragments and 60 filler sentences that were used for a different study (see Ferstl & Friederici, 1998). Instructions including examples were given on the cover page. Participants were asked to fill in personal information including information about their place of birth. This information was recorded in order to be able to control for potential regional differences in dialect. They were instructed to complete each sentence using a single word such that a syntactically well-formed and meaningful completion resulted. They were asked to use any given word only once throughout the questionnaire (see Appendix C.2 for the complete instructions).

Both subsets of sentences, criticals and fillers, were pseudo-randomized separately. The critical set was pseudo-randomized as follows. The complete set of sentences was split into halves according to the first names, since each name occurred twice, once in the dative and once in the accusative condition. Both case conditions occurred equally often in both halves. Items were randomized within the halves with the constraint that a given condition could not occur more than three times in a row.

The randomized lists of critical and filler items were then merged into one list according to the constraint of not more than three items of one kind (critical or filler) in a row. There were five final lists differing only in the version of the filler item

Participants were tested individually or in small groups. An experimental session lasted about 40 minutes.

8.3 Results

In this section the error coding procedure, the frequency results and a temporal split-half analysis are reported. [1]

8.3.1 Error coding procedure

In the first paragraphs of this subsection the error coding procedure that was employed in this study is described. Here, a first goal was to establish objective criteria for determining which sentence completions had to be considered syntactically correct and which incorrect.

A coding scheme for the data had been projected that included codes for violations based on all three types of information provided by the sentence fragments as described above.

The data were prepared in the following way: German umlauts (”ä”,”ö” and ”ü”) and ”ß” were resolved, unambiguous orthographic spelling errors were corrected and the spelling of a small number of verbs, e.g. ”photographieren/fotografieren” (”taking a picture”), was unified. These steps were necessary in order to accommodate a subsequent automated processing of the data.

A first inspection of the data revealed that the vast majority of the items could easily be categorized into syntactically correct and incorrect answers, whereas a subset of answers of considerable size could not. Because this first analysis was based on linguistic intuition, and hence on subjective clinical judgment, a tool for an objective classification of all items was needed. In principle, a number of sources containing information about verb complement structures of German verbs could be used for this purpose. On the one hand there were printed sources like Helbig and Schenkel (1973), Mater (1971), the ”Duden” (Drosdowski, 1996) or the ”Langenscheidt” (Götz, Haentsch & Wellmann, 1993) and on the other hand the electronic lexical database CELEX (Centre for Lexical Information, 1995).

[1] I am very grateful to Karsten Steinhauer for his help with the first inspection of the data and to Martin Trautwein for assistance during error coding.

While evaluating the potential utility of the different sources, it turned out that one major problem was the scope of coverage of a given source. Since different meanings of a verb might be reflected in different complement structures, all meanings of a verb would have to be covered in the source in order to allow a correct error coding. Helbig and Bucha (1973), which can be considered the standard in German linguistic research on verb-argument structures (see Chapter 2), unfortunately was not extensive enough. Practically, only the basic verbs (”Grundverben”), usually with a high frequency of occurrence, were contained in the Helbig. As a consequence, this source was of very limited use for disambiguating most of the verbs with respect to their possible complement structures. As a matter of fact, none of the available sources was complete.

This situation called for two variants of error coding of the data. On the one hand, a conjoint analysis was based on the printed sources. It was mainly based on the Langenscheid, but also on the Mater, the Duden and the Helbig. And on the other hand an automated analysis based on the CELEX database was carried out. Initially, both these two options were pursued independently.

A first analysis based on the printed sources was primarily based on the Langenscheidt. The employed strategy of a conjoint analysis based on the printed sources still left a very low number of ambiguities for low frequency verbs. The latter were resolved based on two independent German native speakers' linguistic intuition.

A second analysis was based on the CELEX database, which codes all possible complement structures of each German verb. [2] The CELEX verb complement structure coding was based on Wahrig (Piepenbrock,1997, personal communication). Computer programs were developed for the automated error analysis of the sentence completion data based on the CELEX lexical database, that automatically evaluated a sentence's correctness.

Subsequently, both types of analyses were compared. A computer program for cross-checking revealed incongruencies between the error codes based on the two different procedures. Most of these incongruencies could be resolved for various reasons (e.g., errors in a source or missing animacy selection restrictions) on the basis of available sources. Even after an extensive search, a very small number of verbs were hard to classify (e.g., ”nachforschen”, ”servieren”, ”spenden”, ”zurufen”). The different sources left us with unresolved ambiguities. The verbs ”schneidern, töpfern” for example were coded differently by the Langenscheid and Mater. Finally, a very low number of remaining ambiguities were resolved based on two German native speakers' linguistic intuition.

[2]Since German has the possibility of extensive prefixing, not every German verb in the literal sense could be listed in CELEX (a number of missing non- prefixed verbs was encountered during the course of the data analysis). Furthermore, CELEX was missing a number of verb entries, complement structures (e.g., ”durchschauen”, ”erschrecken” & ”schützen”) and also featured a number of errors (e.g., for ”auswischen” in a dative use and ”nachäffen” in a dative and optional accusative use). These issues were discussed in detail with CELEX.

8.3.2 Details of error coding

In the following paragraphs a number of issues encountered while establishing error codes are described in more detail. However, these issues, although they seem to be quite a few, can be considered of minor importance. They did not affect the over-all data pattern and changes in their evaluation would not significantly alter the results. Nevertheless, they were added here for a comprehensive documentation of the analysis procedure. First, doubtful cases that were coded as correct are reported. Then, those that were considered incorrect are given.

Correct:

- A small number of instances of ”Dativus commodi” occurred in the study. For example, ”Jemandem einschenken” (”to pour for somebody.”) or ”Jemandem öffnen” (”to open for somebody.”). These were counted as correct (p. 289, Helbig & Buscha, 1996).

- Also, metonymies were considered syntactically correct (Schwarz & Chur, 1996). The questions ”Wen hat Peter gelesen?” (”Whom has Peter read?”) and ”Wen hat Peter relativiert?” (”Whom has Peter relativized?”) can serve as examples.

- Another issue that was important to notice was a reflexive use of verbs versus the use of obligatorily reflexive verbs. The reflexive pronoun is considered part of the lexical entry of an obligatorily reflexive verb. It cannot be omitted or substituted. For questions like ”Wen hat Peter rasiert?” it would make sense to expect the reflexive pronoun as an answer. However, in this case it is an argument of the verb and hence the sentence is correct. Further examples are the verbs ”verschätzen” (”to misjudge”), ”behelfen” (”to make do”), ”zulegen” (”to get oneself something.”)

- Very rarely used were words that simply modified the sentence, e.g., ”nie” (”never”), they were not counted as errors, (although they represented a disregarding of the instructions).

Incorrect:

- In a number of cases participants came up with violations of animacy selection restrictions. For instance, the verb ”abhelfen” (”to remedy”) was assigned an error when used to complete a dative sentence fragment, because it cannot be used with a person in the dative object role. CELEX as well as Mater (1971) do not provide animacy information. As a consequence, an evaluation of sentence completion entirely based on these sources was impossible. This fact was the major source of incongruency between the two types of analyses, since the automated CELEX analysis could not take animacy information into consideration. The verb ”beglaubigen” (”to witness/authenticate”), for example, requires an inanimate accusative object. Therefore, it had to be counted as an incorrect completion. CELEX on the other hand, only provided a complement structure information that allows an accusative object, which is not sufficient information to assess the correctness of a given completion.

- Furthermore, on the use of obligatorily reflexive verbs: Since the reflexive pronoun cannot be substituted with true reflexive verbs, a question like "*Wen hat Peter betrunken?" ("*Whom has Peter drunk?") cannot be posed (p. 65, Helbig & Buscha, 1996). Hence, these completions had to be considered as syntactically incorrect.

Furthermore a number of subjects developed the strategy of filling in more than one word as an answer. Most of the times they filled in a second argument and a participle of an obligatorily ditransitive verb. Example: Wem hat Maria etwas geschickt "To whom has Mary sent something". In doing so, they disregarded the instruction and - mostly - made the task easier for themselves, because it was easier for them to come up with 3-argument-verbs than to come up with 2-argument-verbs. These sentences were not counted as errors in the first place, if they were syntactically correct, rather they were assigned to a special category of errors (see below). The strategy of filling in a second word and at the same time a third verb argument can be considered closely related to using an obligatorily ditransitive verb as a completion of a sentence fragment used in this experiment. Example: *"Wem hat Maria geschickt?" *"To whom has Mary sent?" However, they are not identical since filling in a second word did (most of the times) not constitute a syntactic error, whereas omitting an obligatory argument does, although the same subcategory of verbs was used (3-argument dative verbs).

Elliptic expressions (a complete sentence featuring missing constituents) were coded incorrect as "missing second argument". The sentence "Wem hat Peter erzählt" is an example. The complete sentence would contain an accusative and a dative object.

8.3.3 Establishing categories of error

One of the error categories projected above were the pure "case errors". This error type occurred very seldom in the data set. A genitive verb, e.g., "gedenken" ("recall"), was used three times to complete a dative sentence. This was coded as incorrect.

Also, the auxiliary verb errors (see above) were empirically not important.

Only once, a verb that requires the auxiliary "sein" ("to be"), e.g., "Wem hat Jan aufgesessen", ("To be taken in by sbd. / sth."), (Vp26, 108), was used as a sentence completion. Surprisingly, these error types could be fully neglected although, given the logical analysis of the task's informational content (see above), they are possible errors.

Based on the types of errors and their frequency of occurrence the following data codes were established:

- 1 - Correct completions
- 2 - Third argument error - syntactically correct obligatory two-word completions
- 3 - Missing third argument - omission of an obligatory verb complement
- 4 - All other errors (including animacy violation, auxiliary and case error)

- 5 - Missing answers

Due to the very rare occurrence of pure case errors and auxiliary verb errors ($k\langle 5$; see above) no separate categories for these error types were established. Rather, they were pooled into the common rest error category. Cell counts of less than five under either condition were considered to be not informative enough to form a separate category of errors.

8.3.4 Frequency distributions

The frequency of these data categories for both case conditions is shown in Table 8.1. The 2 x 5 cell chi-square statistic ($\chi^2, 4 = 559; p\langle .0001$) revealed that the accusative and the dative conditions yielded highly significantly different data patterns.

Table 8.1: Frequencies and percent of data category by case

Data Category	Frequency Percent	CASE accusative	dative	Total
correct completions		1457 96	944 62	2401
additional 3rd.argument		10 1	160 11	170
missing argument error		4 0	250 17	254
error (all others)		22 1	36 2	58
missing answers		19 1	122 8	141
	Total	1512	1512	3024

The results showed that case information is processed correctly. The participants very seldom flipped the case information, that is changed a ”wem” into a ”wen”. Whereas, the complement structure of the dative verbs appeared to be more vulnerable than auxiliary or case information. Also, the data pattern suggests a specific vulnerability verb argument structure information.

Table 8.2 shows the data categories divided into the first and the second half of the questionnaire session. There was no practice effect. In the second half, the participants produced more missing data and missing complement errors. Whereas, they did not produce more additional complement sentences in the second half than in the first half of the questionnaire. This clearly indicates that the task was more difficult in the second half. Nevertheless the same types of errors as in the first half occurred there. The 2 x 5 cell chi-square statistic ($\chi^2, 4 = 43; p\langle .001$) revealed a highly significant difference between the first and the second half pooled over both case conditions. Overall, the participants produced more errors and missing data during the second half of the experiment.

Table 8.2: Frequencies and percent of data category by half

Data Category	Frequency Percent	HALF 1.half	2.half	Total
correct completions		1260 83	1141 75	2401
additional 3rd. argument		84 6	86 6	170
missing argument error		105 7	149 10	254
error (all other)		24 2	34 2	58
missing answers		39 3	102 7	141
	Total	1512	1512	3024

Note that this effect was not dependent upon time pressure. The participants could not improve their performance although they were not set under time pressure. [3]

In general, complex, abstract verbs featured more errors than simple concrete verbs.

Interindividual differences with regard to the breakdown error pattern were observed for the dative verbs which are not reported in detail here. These indicated that there are interindividual differences in the exactness of the mental representation.

[3] So far, the interaction between the two case marking conditions and the two halves of the experiment was not tested. A hierarchical log- linear analysis of the data could be computed in order to be able to test this interaction, but this is not necessary for the aim and in the scope of this thesis.

8.4 Discussion

The results of experiment 2 showed clearly that case information carried by wh-pronouns is processed correctly. The completions of the dative sentences, however, featured significantly more errors than those of the accusative sentences. Most of these errors were due to the subjects' using 3-argument- dative-verbs in a 2-argument sentence frame. Prior case information and auxiliary information is not violated in a sentence-final verb generation task if the system is not set under pressure, whereas the verb argument information is violated. Participants had difficulties accessing adequate completions for dative sentence fragment with no time pressure inflicted upon them. The representations of dative verbs' complement structures appeared to be more vulnerable in the above mentioned sense than the complement structure accusative verbs. The resulting pattern (third argument errors) might be due to a strategy like ”It is not really complete, but it is still kind of okay." Clearly, case and auxiliary information (see (8.1)) were not violated in this task. Verb argument structure information, in particular specification of a third argument, on the other hand, was violated.

For a more detailed and combined discussion of both sentence completion experiments see the combined discussion section of Experiments 2 and 3 (Chapter 9)

8.5 Summary

In Experiment 2 sentence completions of German wh-questions featuring accusative and dative case marking were investigated. Results showed that subjects processed the case information encoded in the wh-pronoun correctly. The completions of the dative sentences, however, featured significantly more errors than those of the accusative sentences. Most of these errors were due to the subjects' using 3-argument-dative-verbs in a 2-argument sentence frame.

Chapter 9

Experiment 3 - Sentence Completion II: Auditory

9.1 Introduction

The main goal of Experiment 3 was to investigate the use of structural and inherent case information in an auditory sentence completion experiment. It tested whether or not the case information marked on the sentence-initial wh-question pronoun is processed equally well under auditory presentation conditions. In particular, identical presentation conditions as in the subsequent RT experiments were used.

In addition to the sentence completion experiment in questionnaire format, an auditory version was run which is presented in the present chapter. This experiment constitutes a modified replication of Experiment 2. The same sentence fragments were used to investigate the extent to which case is processed under auditory presentation conditions. These conditions were used subsequently in Experiments 4 and 5.

In addition to the previous experiment, response latencies were recorded for Experiment 3. Given the results of the linguistic analysis, the lexical frequency statistics and the questionnaire study, a reaction time advantage for completions of the structural case, the accusative was predicted.

9.2 Method

9.2.1 Participants

Twenty-four young adults (12 males) volunteered to participate in Experiment 3. None of them had participated in Experiments 1 or 2. All were native speakers of German and students at the University of Leipzig. Their mean age was 23 years (standard deviation 2.8), ranging from 18 to 30. Participants reported normal or corrected-to-normal visual and normal auditory acuity.

They were paid for their participation. One additional participant, who turned out to be a highly trained professional translator, was excluded from the sample.

9.2.2 Material

The sentence fragments used in Experiment 3 were identical to Experiment 2 (see Appendix B.3). For the purposes of auditory material recording, the fragments were completed to syntactically well-formed sentences. A trained female speaker read these sentences in a normal intonation at normal speech rate. At least three tokens of each sentences were recorded and digitized. The best variant of each sentence was selected and clipped after the first name using a speech wave editor.

9.2.3 Apparatus

Experiment 3 was carried out on an IBM compatible computer controlled by a program written in the PASCAL language. [1] The PC was equipped with a standard ”Soundblaster SB16” audio board. The sound files were presented to the participants via conventional Sennheiser headphones. The sound tokens were recorded, digitized and edited using the Kay computerized speech lab 4300B installed on an IBM compatible computer running DOS.

9.2.4 Procedure

The participants were tested individually, in a dimly lit, sound- attenuated experimental booth. As in Experiment 2, they were instructed to complete each sentence fragment using a single word such that a syntactically well-formed and meaningful completion resulted. Responses were typed in using a standard computer keyboard. Participants were instructed to work continuously (”zügig”) but without time pressure. They were instructed to exclusively use syntactically correct completions and to use a given word only once. However, if they were not sure whether or not they have already used a word they were allowed to use it (again). The latter part of the instruction served to reduce memory load for the participants, since there was no way for them to look up the words they had already used, as there was in the questionnaire of Experiment 2.

The trial structure of Experiment 3 was as follows: The participants initiated a trial by pressing the space bar. After that there was a brief pause of 500 ms followed by a warning tone (ascii character 7) from the system speaker. After an ISI of 700 ms a sentence fragment was presented to the participant via headphones with a standard soundblaster volume setting of 220. After the playing of the sound file terminated the response time clock was started and the participants were given a time window of maximally 30 seconds for their response. A

[1] I am very grateful to Erdmut Pfeifer for providing key routines of the software program that controlled the experiment and to Katja Kühn for reading the sentences.

completed response (or the end of the response window) terminated the response time measure. Subsequently a warning tone was played again. After this the subjects were free to initiate the next trial. The experiment software only allowed for one-word completions. Since two-word entries were impossible, third-argument-errors (see Experiment 2, Chapter 8) were prevented, and thus more experimental control was achieved.

Using the same pseudo-randomization procedure as in Experiment 2, trials were individually randomized for each participant. The set of sentence fragments was split into halves according to the first names. Both conditions occurred equally often in both halves. Items were randomized within the halves with the constraint that a given condition could not occur more than three times in a row. In addition to Experiment 2, there were eight practice trials. They were chosen pseudo-randomly from a set of 16 in a fully counter-balanced fashion. The occurrence of all tokens was counter-balanced across participants.

An experimental session lasted approximately one hour.

9.3 Results

The error coding procedure for Experiment 3 was identical to Experiment 2 (Chapter 8), with the exception of the category of two-word completions. In this experiment the set-up did not allow this type of disregarding the instructions, hence participants were forced to make a missing argument error or leave the space blank if they could only think of 3-argument dative verbs. The frequencies of the data categories are shown in Table 9.1. The 2 x 4 cell chi-square statistic $(\chi^2, 3 = 530; p\langle .0001)$ proved that the results for the accusative and the dative condition differed highly significantly from each other. [2]

As predicted, the participants also retrieved accusative completions faster than datives from linguistic memory. The mean response times for correctly completed trials only are given in Table 9.2. An analysis of variance $(F = (1, 23) = 12, 9; p\langle .0015)$ revealed a significant response time advantage for the accusative condition. In a second analysis, trials that featured complement errors (data category 2), time outs (data category 4) and correct trials were included. This followed the rationale that specific difficulties to retrieve an appropriate item were also reflected in these trials. Mean RTs and standard deviations are given in Table 9.3. Again, an analysis the of variance $(F = (1, 23) = 32.8; p\langle .0001)$ revealed, that responses in the accusative conditions were significantly faster than in the dative condition.

Finally, Pearson correlations between participants' age (r = .21; p = .41) or gender (r = .18; p = .47) and time on task were not substantial.

[2]The one participant who was excluded from the group analysis performed flawlessly on every single trial. This might indicate that her particular professional training as a translator equipped her with a special skill that could be used to access linguistic memory in this verb generation task. Indicating that this special kind of knowledge and its retrieval can be trained and be brought to perfection. Which furthermore illuminates the aspect of interindividual differences.

Table 9.1: Frequencies and percent of data category by case

Data Category				
	Frequency Percent	CASE accusative	dative	Total
correct completions		808 94	374 43	1182
missing argument error		11 1	262 30	273
error (all others)		27 3	46 5	73
missing answers		18 2	182 21	200
	Total	864	864	1728

Table 9.2: mean response times in ms and standard deviations for correct answers only

CASE	Mean	Std Dev
accusative	10737	5358
dative	12938	6976

Table 9.4 shows the data categories divided into the first and the second half of the experimental session. As in Experiment 1, there was no practice effect. The participants produced more missing data and missing complement errors in the second half than in the first half of Experiment 2. This clearly indicates that the task was more difficult in the second half. Nevertheless the same types of errors as in the first half occurred here. The 2 x 4 cell chi-square statistic $(\chi^2, 3 = 13; p\langle .004)$ revealed a highly significant difference between the first and the second half of Experiment 2 pooled over both case conditions.

Post-experiment questions revealed that the reduction in performance from first to second

Table 9.3: mean response times in ms and standard deviations including missing answers and complement errors

CASE	Mean	Std Dev
accusative	10739	5353
dative	13601	6980

Table 9.4: Frequencies and percent of data category by half

Data Category				
	Frequency Percent	HALF 1.half	2.half	Total
correct completions		625 72	557 64	1182
missing argument error		114	159	273
		13	18	
error (all other)		34 4	39 5	73
missing answers		91 11	109 13	200
	Total	864	864	1728

half was not due to a loss of motivation but rather to increased difficulties of accessing linguistic memory and coming up with new words.

9.4 Discussion

Experiment 3 clearly replicated the findings of Experiment 2 extended for an auditory presentation of the stimuli. Results showed that subjects processed the case information correctly. Response latencies and error rates were significantly higher for dative verbs. As in Experiment 2, most of the errors were due to the subjects' using 3-argument-dative-verbs in a 2-argument sentence frame.

9.5 Summary

In Experiment 3 participants were auditorily presented with the 72 sentence beginnings featuring accusative or dative case marking used in Experiment 2. They were asked to enter sentence completions using a computer keyboard. Besides this difference, instructions equaled those of Experiment 2. Results showed that subjects processed the case information correctly. Response latencies and error rates were significantly higher for dative verbs than for accusative verbs. As in Experiment 2, most of the errors were due to the subjects' using 3-argument-dative-verbs in a 2-argument sentence frame.

9.6 General Discussion of Experiments 2 and 3

Both sentence completion experiments clearly showed that German participants process case information to guide verb processing in this off-line verb generation paradigm. Moreover, they indicate that the access of accusative case is easier than the access of dative case during verb processing. An analysis of errors showed that the violation of verb-argument-structure occurred far more often than a violation of case information.

In both experiments participants performed less well in the second half of the experiment. Postexperimental questions helped to determine that this performance effect was largely due to increased difficulty of the task and not a decline in motivation of the participants. Dative verbs, in particular became harder to generate with increased duration of the experiment.

Both experiments involved self-paced tasks on the one hand, but differed with respect to two features. One, a sentence fragment could be read more than once in the paper and pencil version, whereas no repetition was possible in the auditory version. And two, the paper and pencil version enabled subjects to backtrack to previously completed sentences in order to check for accuracy or other features, whereas the auditory version did not permit doing so. The more rigid experimental setting of Experiment 3 affected performance in a negative fashion. In particular, the number of correct dative completions declined. Anecdotally, it can noted that participants made use of (and reported postexperimentally) the cognitive strategies of verb invention (mainly by prefixing) and association within semantic fields in order to meet the task requirements.

It can be speculated that the ”default” 3-argument dative verbs kept ”blocking” the ”non-default” 2-argument verbs. There seems to be no separate lexical bin for 2-argument dative verbs. Furthermore, the participants were not able to generate a sufficient strategy to exclusively access the 2-argument dative verbs.

Experiments 2 and 3 used off-line cued verb-generation tasks which obviously do not speak directly to theories of on-line word recognition. But they illuminate the issue of the mental representation of verb complement structure to an extent. The analysis procedure was based on state-of-the-art linguistic information, however, the large number of minor problems in establishing what had to considered as syntactically correct and as incorrect, might lead to the question whether or not binary error coding was adequate. Or rather whether a probabilistic concept would be more adequate. The terms ”syntactically correct” and ”incorrect” can be seen from both a prescriptive and a descriptive linguistic perspective. The question could be posed which one has to be considered adequate here. The problems with finding a unambiguous error coding procedure as well as the data at hand indicated that, at least for low frequent words, there is a considerable degree of fuzziness as well as arbitrariness implicated in the representation. For this subset of verbs, discrete localist representations in the mental lexicon might not be adequate. More speculation and analysis concerning this issue would be possible but is beyond the scope of this thesis.

Chapter 10

Experiment 4 - Cross-Modal Verb Integration I

10.1 Introduction

The previous experiments established that morphologically marked accusative and dative case information, in general, are processed correctly by German native speakers. This holds for the visual (Experiments 1 & 2) as well as for the auditory stimulus modality (Experiment 3).

After having established that structural and lexical case are processed correctly under normal reading and listening conditions under the tasks used, which can be considered off-line tasks, the goal of the present experiment was to investigate the use of case information during on-line sentence comprehension. To this end, a cross-modal word naming procedure was used. Since cross-modal priming was introduced (Swinney, 1979) it has been successfully used to investigate a number of issues in psycholinguistics (see Chapters 3 & 3.7.2). The variant employed in the present experiment used simple auditory sentence fragments as primes identical to those used in Experiment 3 and visually presented verbs as naming targets. Structural and lexical case marking was provided by case-marked wh-question pronouns prior to the presentation of an accusative or dative verb as naming target. Grammatical acceptability judgments were used as a secondary task following the naming task to ensure proper processing of the entire sentence.

Since this was an initial exploratory experiment, no attempt was made to create a neutral baseline in order to assess potential facilitation or inhibition independently (see Section 3.7.2). For the same reason, no attempt was made to control the locus of the effect experimentally, as to whether the effect was clearly lexical or post-lexical in nature (see Section 3.7.2). Based on the syntactic priming literature, a post-lexical locus of the effect was assumed (see Section 3.7.2 for a discussion and the deduction of the locus of the effect).

The following predictions were derived for the present experiment. If the case information marked on the sentence-initial wh-question pronoun is processed in coreference to the type of complement that the critical verb requires while the utterance of the verb can still be influenced, then a case violation should result in longer response latencies and possibly higher error rates. The assumption is that the processes leading to the utterance of the verb are disturbed and slowed down by the case incongruency (see e.g. West & Stanovich, 1986; Traxler & Pickering, 1996).

Furthermore, a result pattern comparable to Experiment 1 was predicted for the secondary grammatical acceptability judgment task. Lexical case should prove to be harder to judge than structural case. Given also the results of Experiments 2 and 3 an interaction between the two factors was predicted driven by the incorrect dative condition. Participants were expected to accept incorrect dative case as correct more often than making other errors.

10.2 Method

10.2.1 Participants

Twenty-four young adults (12 males) volunteered to participate in Experiment 4. None of them had participated in any of the previous experiments. All were native speakers of German, right-handed and students at the University of Leipzig. Their mean age was 22.9 years (standard deviation 2.94), ranging from 19 to 30. Participants reported normal or corrected-to-normal visual and normal auditory acuity. They received course credit or were paid for their participation. One additional participant had to be excluded from the sample for technical reasons, that is triggering of the voice key by extraneous noise etc. .

10.2.2 Material

18 critical accusative and 18 critical dative verbs (plus 4 fillers for each case) were selected from the verbs used as material of Experiment 1. Verbs were selected such that both sets were matched for verb lemma frequency (Centre for Lexical Information, 1995) and word length in terms of both number of orthographic syllables as well as number of letters in their past participle forms. All datives were used. Of the latter, those verbs that proved to be the hardest to process in Experiment 1 were used as fillers in the present experiment. The best fitting 18 accusative verbs from Experiment 1 were used (plus 4 fillers).

These were combined with the initial sentence fragments from Experiments 1 - 3 according to the template given in (10.1), using the same sound files as in Experiment 3. In (10.2) the accusative verb "ermorden" ("murder") is preceded by the syntactically correct accusative marked wh-pronoun. In (10.3) the dative-marked question pronoun is used resulting in an incorrect sentence. (10.4) and (10.5) constitute the dative analogs. In the examples the critical target verbs are underlined. See Appendix B.4 for the complete material.

(10.1) $\langle wh - pronoun\rangle\langle auxiliary\text{"}have\text{"}\rangle\langle name\rangle\langle participle\rangle$

(10.2) ”Wen hat Maria ermordet?” ”Whom has Maria murdered?”

(10.3) *”Wem hat Maria ermordet?” *”To whom has Maria murdered?”

(10.4) ”Wem hat Maria zugenickt?” ”To whom has Maria nodded?”

(10.5) *”Wen hat Maria zugenickt?” *”Whom has Maria nodded?”

10.2.3 Apparatus

The experiment was run on an IBM compatible computer running DOS using the ”ERTS” experiment programming shell (Beringer, 1993; Iwanek, 1994). Digitized sound files were played using a ”SoundBlaster 16” sound board and standard headphones. The targets were presented on a ”Sony Multiscan 17 se” SVGA computer monitor. The participants’ voice responses were captured by a head-mounted microphone and fed into a voice key that triggered the reaction time clock via the ”ERTS” ExKey-Logic. Voice responses and voice key triggers were recorded on separate channels on DAT in order to have the option of later off-line accuracy checking. Judgment responses and latencies were captured using the right and left buttons of a three-button response keyboard triggering the ”ERTS” reaction time clock via the ”ERTS” ExKey-Logic.

10.2.4 Procedure

In this subsection the session structure is described first, followed by a description of the design and the trial structure of the main experiment.

Session structure A session consisted of the following parts.

1. Training of the targets. Participants were asked to read the participles (critical and practice verbs) aloud from a list. The latter contained the items in pseudo-randomized sequence under the constraint that a given verb onset could not occur twice in a row. Participants were then asked to repeat this procedure with two more differently randomized lists. The sequence in which the three lists were administered to a reader was counter-balanced across participants in order to control for possible sequence effects of this training. Using this procedure the participants had processed each verb three times prior to the main experiment.

2. A voice key calibration was conducted (See Appendix C.4 for details).

3. The main experiment followed. First, a sequence of 10 practice trials was delivered. Then there was a brief break for questions, repeating instructions or once more adjusting the voice key if necessary. Then six more practice trials were given, immediately followed (no break) by the 72 trials of the main experiment.

4. Finally, participants were debriefed.

An experimental session lasted approximately one hour.

Design of the main experiment The two sets of verbs (18 accusative and 18 dative, see Material section and Appendix B.4) were each divided into two equally large subsets (k = 9) such that word onsets and lengths (number of letters and orthographic syllables) were about equally distributed. Then the participles from the four subsets were combined with their respective basic sentences in a correct as well as in an incorrect version resulting in eight subsets of sentences. Each of these was then assigned to one of two equally large item sets in the following way: All verbs were contained once per item set. A given subset occurred once and only once per item set. An item set consisted of half accusative and half dative subsets as well as half correct and half incorrect subsets. Such an item set contained the items for one of two experimental blocks. A block constituted a complete counterbalanced design with equal frequencies of both case and correctness realized across items. The sequence of items within an experimental block was pseudo-randomized with the following constraints. Accusative, dative, correct and incorrect items could each occur no more than three times in row. A given verb target onset could not occur twice in a row (in order to avoid phonetic priming). There was a buffer of a minimum of six items between target repetitions across blocks. The sequence of blocks was counterbalanced across participants. Thus a completely counterbalanced between-subject design was realized for both the first and the second presentation of an item. Furthermore, a completely counter-balanced within- subject design was realized across item repetitions. Practice trials were pseudo-randomized according to the same constraints. Assignment of yes/no judgment responses to the right and left response keys and participants gender were counterbalanced across block sequences.

The participants were tested individually while seated in a dimly lit room in front of a computer screen. The viewing distance was 110 cm resulting in a vertical visual angle of about one degree and horizontal visual angles ranging between about 3.5 and 5.5 degrees for the stimuli.

Participants were instructed to maintain fixation throughout the trial after the warning tone occurred to listen to the sentence carefully and to name the target word accurately and as quickly as possible as soon as it appeared on the screen. Then they were to wait until the question mark appeared as the prompt for the judgment task. See Appendix C.4 for complete instructions.

Trial structure of the main experiment The trial structure of the main experiment was designed as follows. A 200-ms-long 1000-Hz warning tone was presented. With an ISI of 300 ms after tone offset, a sentence fragment was presented. A screen-centered fixation cross onset simultaneously with the warning tone and persisted until sentence fragment offset. The target word followed, also centered on screen (ISI 0 ms). The actual ISI was 14 ms due to synchronization to the refresh rate of the computer screen. The target word was presented for 100 ms. Naming response and latency were recorded. There was an ISI of 1700 ms between naming target offset and onset of response prompt. The latter was a screen-centered question mark presented for 500 ms. Followed by an ITI of 2700 ms plus a variable, exponentially distributed interval with a mean length of 400 ms and a maximum length of 800 ms.

10.3 Results

This results section is structured as follows. First, the results of the naming task, the primary task, are reported. Then, the results of the grammatical acceptability judgment task, the secondary task, are covered. For both tasks response time and error analyses were conducted.

10.3.1 Naming task

Subject and item analyses were performed on the data. Erroneous naming responses were excluded from further analysis. In addition a cut-off procedure based on Ratcliff (1993) was applied. A low-cut was set at a 250ms response latency, affecting 0.3% of the data. A high-cut was set at 1200ms affecting 0.7% of the data. Furthermore, trials that featured incorrect judgment responses preceded by a correct naming response were also excluded from further analysis. [1]

Mean word naming latencies, standard deviations and error percentages for the conditions repetitions of presentation, case and syntactic correctness are given in Table 10.1.

Table 10.1: Mean word naming latencies, standard deviations (in parenthesis) and naming errors (second row) for the conditions: repetitions of presentation, case and syntactic correctness. The two rightmost columns show mean values over both repetitions.

	1st presentation		2nd presentation		mean of presentations	
	accusative	dative	accusative	dative	accusative	dative
correct	624 (115)	663 (119)	616 (120)	643 (105)	620 (117)	653 (112)
	1.9	2.8	1.4	4.2	1.6	3.5
incorrect	670 (143)	698 (114)	648 (119)	663 (118)	659 (131)	681 (116)
	4.2	6.0	2.3	3.2	3.2	4.6

Note. Naming latencies in ms and naming errors in %.

Naming latencies There were no effects of block sequence ($F\langle 1$) or response key assignment (right-left / left-right), ($F\langle 1$). Therefore, these factors were not included in subsequent analyses.

[1] A control ANOVA on the data set not excluding these trials revealed comparable results and did not change the overall pattern.

A repeated measures analysis of variance (ANOVA) revealed significant within-subject main effects of: Syntactic congruency, $F(1, 22) = 83.55, MSE = 548, p\langle.0001$ and Case, $F(1, 22) = 15.98, MSE = 2082, p\langle.001$. There was no effect of repeated presentation, $F(1, 22) = 3.30$, $MSE = 5883, p\rangle.08$. None of the three two-way interactions nor the three-way interaction were significant: Case by correctness, $F(1, 22) = 3.99, MSE = 735, p = .0583$, Repetition by correctness, $F(1, 22) = 2.31, MSE = 932, p\rangle.14$, all other $Fs\langle 1$.

The item ANOVA revealed an effect of the between-item factor case, $F(1, 34) = 8.56$, $MSE = 2390$, $p = .0061$, and within-item effects of syntactic correctness, ($F(1, 34) = 42.12, MSE = 931, p\langle.0001$), and repetition ($F(1, 34) = 10.54, MSE = 872, p = .0026$). None of the three two-way nor the three-way interaction were significant: Case by correctness, $F(1, 34) = 2.11, MSE = 931, p\rangle.15$, Repetition by correctness, $F(1, 34) = 2.33, MSE = 1133, \rangle.59$, all other $Fs\langle 1$.

As predicted, naming the verb target was significantly delayed in the incorrect case condition. At the descriptive level processing structural case seemed to be disrupted more than processing lexical case. This interaction, however, was not significant. The training was effective as there was no effect of item repetition.

Naming errors 96.8 percent of all naming responses were correct. Error percentages for the conditions repetitions of presentation, case and syntactic correctness are given in Table 10.1.

A repeated measures analysis of variance (ANOVA) of the error percentages revealed a within-subject main effect of syntactic correctness, $F(1, 23) = 5.31, MSE = 17, p = .0306$. No other effect was significant: Main effect of case, $F(1, 23) = 3.36, MSE = 37, p = .0796$, repetition by correctness, $F(1, 23) = 2.56, MSE = 36, p\rangle.12$, all other $Fs\langle 1$.

The analysis showed that the disruption of target naming was evident also on the level of naming errors.

10.3.2 Grammatical acceptability judgment task

In the following subsection response time and error analyses of the grammatical acceptability judgment task are reported. Mean judgment latencies, standard deviations and judgment errors for the conditions case and syntactic correctness are given in Table 10.2.

Judgment latencies A repeated measures analysis of variance (ANOVA) over the judgment latencies revealed effects of case, $F(1, 23) = 11.56, MSE = 11493, p = .0025$, syntactic correctness, $F(1, 23) = 13.64, MSE = 3770, p = .0012$ and a significant interaction, $F(1, 23) = 11.13, MSE = 4235, p = .0029$.

As predicted, lexical case took longer to judge than structural case and incorrect lexical case was markedly slower than the other three conditions.

Table 10.2: Mean judgment latencies, standard deviations (in parenthesis) and judgment errors (second row) for the conditions case and syntactic correctness.

	accusative	dative
correct	639 (254) 8.8	669 (283) 9.5
incorrect	641 (247) 8.1	760 (301) 21.8

Note. Judgment latencies in ms and judgment errors in %.

Judgment errors 88.0 % of all judgment responses were correct. Error percentages for the conditions case and syntactic correctness are given in Table 10.2.

An ANOVA over the judgment errors also revealed effects of case, $F(1, 23) = 18.25, MSE = 68, p\langle .0003$, correctness, $F(1, 23) = 10.80, MSE = 74, p = .0032$, and a significant interaction, $F(1, 23) = 7.38, MSE = 137, p = .0123$.

Confirming the results of Experiment 1 and the predictions, lexical case was harder to judge than structural case. Incorrect lexical case stood out, accounting for the effect of correctness and the interaction entirely.

10.4 Discussion

The results of the present experiment clearly showed that the training prior to the main experiment was effective, there was no repetition effect. Verbs preceded by incorrect case information were harder to process than vice versa. The incorrect condition resulted in longer naming latencies and a higher rate of naming errors. Dative verbs were harder to integrate - harder to process.

Grammatical acceptability judgments were harder for lexical case (dative) than for structural case (accusative). In addition, they were harder for incorrect lexical case than for correct lexical case, while judging correct or incorrect structural case was equally fast. Note that only overt morphological case marking was manipulated as each verb served as its own control.

The case information was retrieved from the complement structure of the target word as it was processed. This information was checked in coreference with the case information marked on the sentence-initial wh-pronoun. This post-lexical check was carried out before the word was uttered. Naming of the word was delayed in the incorrect conditions relative to the correct conditions. This checking mechanism, or production editor, was involved in an obligatory fashion, because it was not part of the participants' task to make a congruency judgment prior to target naming. It could also be conceptualized as a failure of selective attention, since this syntactic congruency check was not required prior to uttering the target word. The issue of obligatory congruency checking is investigated more closely in the following experiment.

While Hypotheses (5.1), (5.2) and (5.4) could clearly be confirmed in this experiment, Hypothesis (5.3) was only confirmed at the level of the secondary tasks. Judgment latencies as well as errors revealed the interaction predicted by Hypothesis (5.2) This might serve as a hint that the checking mechanism requires about an equal amount of time for both case types. Descriptively, however, the effect was 11 ms larger in the accusative condition and the interaction of case and correctness was marginally significant.

This result is consistent with other effects reported in the literature and discussed in Section 3.8. While Trueswell et al. (1993) reported a study that investigated structural case exclusively and used a critical element presented after the case-assigning verb, structural as well as inherent case were investigated in the present study with the verb itself being the target. This provided a further narrowing of the temporal extension of the effect.

Note that the overall performance level in the grammatical acceptability judgment task was three to four times worse in the present experiment than in Experiment 1, while still showing the same overall pattern. This can be accounted for by the higher task demand in the present experiment. Participants had to name the critical verb under speeded conditions prior to performing the judgment, while Experiment 1 was conducted as a self-paced questionnaire study.

In the present experiment no neutral baseline condition was employed in an attempt to isolate facilitation from inhibition (see Section 3.6). As discussed above, given the results in the literature it could be assumed that a case congruency effect has a post-lexical locus.

See also the combined discussion of Experiments 4 and 5 at the end of the following chapter

10.5 Summary

In the present syntactic priming experiment the effects of prior morphological structural and lexical case information on the processing of a participle verb in a cross-modal naming task was investigated

A cross-modal naming task (CMN) using continuous auditory presentation of a sentence fragment featuring an accusative or dative case-marked wh-question pronoun and a visually presented verb target (SOA 0ms) was employed. 50% were dative and 50% accusative verbs. Half of the sentences were syntactically correct, the other half were syntactically incorrect. There were no fillers. There was a list training of target words (reading three times) and 16 practice trials were delivered prior to the main experiment. Every trial was concluded by a secondary task. Grammatical acceptability judgments were used to ensure proper processing of the sentences and directed participants attention partly on syntax.

Training prior to the main experiment was effective, there was no repetition effect. Verbs preceded by incorrect case information were harder to process than vice versa. Dative verbs were harder to integrate - harder to process. Grammatical acceptability judgments were harder for lexical case (dative) than for structural case (accusative). In addition, they were harder for incorrect lexical case than for correct lexical case, while judging correct or incorrect structural case was equally fast.

Chapter 11

Experiment 5 - Cross-Modal Verb Integration II

11.1 Introduction

The goal of Experiment 5 was to determine whether or not the case congruency effects observed in Experiment 4 emerged under processing conditions without a secondary task.

The following predictions were derived. For the condition including the secondary grammatical acceptability judgment task a replication of the results of Experiment 4 was expected. If the case information marked on the sentence-initial wh-question pronoun is processed in coreference with the type of complement that the critical verb requires while the utterance of the verb can still be influenced, than a case violation should result in longer response latencies and possibly higher error rates then in the correct case conditions. Furthermore, it was expected to find this case marking effect also in the condition without the secondary judgment task, under the assumption that the processes of syntactic structure building, that when violated lead to the observed effect, take place obligatorily.

The present experiment constitutes an extended replication of Experiment 4. The design of the latter was extended such that processing of morphological case information could additionally be investigated without a potential influence from a secondary response task, i.e., the grammatical acceptability judgment task.

11.2 Method

11.2.1 Participants

Twenty-four young adults (12 males) volunteered to participate in Experiment 5. None of them had participated in any of the previous experiments. All were native speakers of German, right-handed and students at the University of Leipzig. Their mean age was 23.5 years (standard deviation 2.57), ranging from 19 to 29. Participants reported normal or corrected-to-normal visual and normal auditory acuity. They received course credit or were paid for their participation. Five additional participants had to be excluded from the sample due to a very high error level (three; more than 15% incorrect responses) or technical errors (two).

11.2.2 Material

The Material used in Experiment 5 was identical to the material of Experiment 4 (See Appendix B.5 for the complete material).

11.2.3 Apparatus

The Apparatus and the experiment room were identical to Experiment 4.

11.2.4 Procedure

In this subsection the session structure is described first, followed by a description of the design and the trial structures.

Session structure A session consisted of the following parts.

1. The training of the targets was identical to Experiment 4 (participants were asked to read the participles aloud from a list three lists were used).

2. A voice key calibration was conducted which was identical to Experiment 4 (See Appendix C.5 for details).

3. In contrast to Experiment 4, an additional training of the naming task including a fourth presentation of the experimental items was conducted in Experiment 5. This was done in order to further reduce error variance (due to the unusual task) in an experiment with less statistical power (smaller N per condition) and more item repetitions than Experiment 4. All participles (criticals and practice) were presented under the same presentation conditions as in the main experiment in a pseudo- randomized sequence with the constraint that a given verb onset could not occur twice in a row. There were six variants counterbalanced across participants. Note that this additional training is the only experimental parameter (in the condition including a grammatical acceptability judgment) that was changed between Experiments 4 and 5.

4. The main experiment followed. It consisted of two parts. One of which was identical to Experiment 4 in the conditions including the grammatical acceptability judgment task. The other part was identical with the exception that trials omitted the grammaticality judgment. A part was constructed as follows: First, a sequence of 10 practice trials was delivered. Then there was a brief break for questions, repeating instructions or adjusting the voice key. Then six more practice trials were given, immediately followed (no break) by the 72 trials of the

main experiment. After a break of two to five minutes the second part of the main experiment followed.

5. Finally, participants were debriefed.

An experimental session lasted approximately one hour and twenty minutes.

Design of the main experiment The procedure of creating an experimental block was identical to Experiment 4 (Chapter 10). [1] The sequence of experiment parts (with or without judgment task) was counterbalanced across participants. Thus realizing an identical replication of Experiment 4 with the subgroup doing the part with judgment first.

The participants were tested under the same presentation conditions as in Experiment 4: individually while seated in a dimly lit room in front of a computer screen. The viewing distance was 110 cm resulting in a vertical visual angle of about one degree and horizontal visual angles ranging between about 3.5 and 5.5 degrees for the stimuli.

Participants were instructed to maintain fixation throughout the trial after the warning tone occurred and to listen to the sentence carefully and to name the target word accurately and as quickly as possible as soon as it appeared on the screen. Then they were to wait until the question mark appeared as the prompt for the judgment task. See Appendix C.5 for complete instructions.

Trial structures Training trials consisted of a 200-ms-long 1000-Hz warning tone which onset simultaneously with a screen-centered fixation cross presented for 500 ms. Following fixation cross offset the target word (ISI 0ms) was presented for 100 ms in black on a gray background (RGB 60, 60, 60) at screen center. Naming response and response latency were recorded. The ITI was 1200 ms plus a variable, exponentially distributed interval with a mean length of 400 ms and a maximum length of 800 ms.

The trial structure of the main experiment was designed as follows. Again, a 200-ms-long 1000-Hz warning tone was presented. With an ISI of 300 ms after tone offset, an auditory sentence fragment was presented. A screen-centered fixation cross onset simultaneously with the warning tone and persisted until sentence fragment offset. The target word followed, also centered on screen (ISI 0 ms). The actual ISI was 14 ms due to synchronization to the refresh rate of the computer screen. The target word was presented for 100 ms. Naming responses and latencies were recorded. For the trials without grammaticality judgment the ITI was 2700 ms plus a variable, exponentially distributed interval with a mean length of 400 ms and a maximum length of 800 ms. The trials with grammaticality judgments featured an ISI of 1700 ms between naming target offset and onset of response prompt. The latter was a screen-centered question mark presented for 500 ms, followed by an ITI of 2700 ms plus a variable, exponentially distributed interval with a mean length of 400 ms and a maximum length of 800 ms. The structure of the latter class of trials was identical to Experiment 4.

[1] With the exception that the assignment of verbs to subsets according to their onset was slightly improved.

11.3 Results

This results section is structured as follows. First, the results of the complete design are reported. As for the previous experiment, starting with the naming task followed by the grammatical acceptability judgment task. Then, the results of the new experiment part without secondary task are reported. Finally, the replication of Experiment 4 is reported in the last two subsections.

11.3.1 The complete design - Naming task

The results for the naming task in the complete design are reported in this subsection. Response time and error analyses were conducted. Subject and item analyses were performed on the naming data. Erroneous naming responses were excluded from further analysis. In addition, a cut-off procedure based on Ratcliff (1993) and identical to Experiment 4 was applied. The low-cut affected 0.1% of the data and the high-cut affected 0.5% of the data. Furthermore, trials that featured incorrect judgment responses preceded by a correct naming response were also excluded from further analysis. [2]

Mean word naming latencies, standard deviations and error percentages for the conditions repetitions of presentation, case and syntactic correctness are given in Table 11.1.

Table 11.1: Mean word naming latencies, standard deviations (in parenthesis) and naming errors (second row) for the conditions: repetitions of presentation, case and syntactic correctness. The two rightmost columns show mean values over all four repetitions.

	1st & 2nd presentation		3rd & 4th presentation		mean of presentations	
	accusative	dative	accusative	dative	accusative	dative
correct	556 (123)	599 (140)	519 (81)	560 (102)	537 (104)	579 (122)
	1.4	3.3	0.3	1.0	0.8	2.1
incorrect	580 (145)	609 (143)	534 (77)	570 (104)	556 (117)	589 (125)
	1.9	2.8	1.3	0.3	1.5	1.5

Note. Naming latencies in ms and naming errors in %.

Naming latencies There were no effects of block sequence ($F\langle 1$) or response key assignment (right-left / left-right), ($F\langle 1$). Therefore, these factors were not included in subsequent analyses.

A repeated measures analysis of variance (ANOVA) revealed significant within-subject main effects of: Syntactic congruency, $F(1, 23) = 13.10, MSE = 1049, p = .0014$,

[2]A control ANOVA on the data set not excluding these trials revealed comparable results and did not change the overall pattern.

Case, $F(1,23) = 32.01, MSE = 1958, p\langle .0001$ and repetition of presentation, $F(1,23) = 6.96, MSE = 2867, p = .015$. The interaction of presentation by congruency was significant, $F(1,23) = 6.63, MSE = 546, p = .017$. No other interaction was significant: Case by correctness, $F(1,23) = 1.84, MSE = 1141, p = .18$, all other $Fs\langle 1$.

The item ANOVA revealed an effect of the between-item factor case, $F(1,34) = 19.79, MSE = 1832, p = .0001$, and within-item effects of syntactic correctness, ($F(1,34) = 13.57, MSE = 705, p\langle .001$), and repetition ($F(1,34) = 13.96, MSE = 666, p = .0007$). None of the three two-way nor the three-way interaction were significant: Case by correctness, $F(1,34) = 2.99, MSE = 705, p\rangle .09$, all other $Fs\langle 1$.

Naming errors 98.5 % of all naming responses were correct. Error percentages for the conditions repetitions of presentation, case and syntactic correctness are given in Table 11.1.

A repeated measures analysis of variance (ANOVA) of the error percentages revealed no significant effect. Main effects of repetition, $F(1,23) = 3.76, MSE = 44, p = .065$, and of case, $F(1,23) = 3.63, MSE = 25, p = .0693$. Interaction: Repetition by case, $F(1,23) = 1.64, MSE = 25, p\rangle .21$, and repetition by correctness, $F(1,23) = 2.87, MSE = 14, p\rangle .10$, all other $Fs\langle 1$.

11.3.2 Partial design without secondary task

In this subsection the results for the experiment part without grammatical acceptability judgments are reported. Mean word naming latencies, standard deviations and error percentages for the conditions repetitions of presentation, case and syntactic correctness are given in Table 11.2.

Table 11.2: Mean word naming latencies, standard deviations (in parenthesis) and naming errors (second row) for the conditions: repetitions of presentation, case and syntactic correctness. The two rightmost columns show mean values over all levels of repetition.

	1st & 2nd presentation		3rd & 4th presentation		mean of presentations	
	accusative	dative	accusative	dative	accusative	dative
correct	486 (55)	518 (67)	546 (99)	607 (116)	516 (83)	562 (102)
	0.0	0.9	0.0	1.0	0.0	0.9
incorrect	496 (65)	524 (66)	559 (93)	620 (120)	527 (85)	572 (106)
	1.4	0.0	0.5	0.0	0.9	0.0

Note. Naming latencies in ms and naming errors in %.

Naming latencies There were no effects of block sequence ($F\langle 1$) or response key assignment (right-left / left-right), ($F\langle 1$). Therefore, these factors were not included in subsequent analyses.

A repeated measures analysis of variance (ANOVA) revealed significant within-subject main effects of: Syntactic correctness, $F(1,23) = 10.80, MSE = 488, p = .0032$ and Case, $F(1,23) = 43.23, MSE = 2375, p\langle.0001$, as well as an effect of repeated presentation, $F(1,23) = 7.27, MSE = 1307, p = .013$. None of the three two-way interactions nor the three-way interaction were significant: Repetition by correctness, $F(1,23) = 1.32, MSE = 608, p\rangle.26$, all other $Fs\langle 1$.

The item ANOVA revealed an effect of the between-item factor case, $F(1,34) = 24.26$, $MSE = 1334, p\langle.0001$, and within-item effects of syntactic correctness, ($F(1,34) = 4.11$, $MSE = 708, p\langle.05$), and repetition ($F(1,34) = 12.37, MSE = 711, p = .0013$). None of the three two-way nor the three-way interaction were significant: Repetition by correctness, $F(1,34) = 1.72, MSE = 1757, \rangle.20$, all other $Fs\langle 1$.

Naming errors Naming error percentages for the conditions repetitions of presentation, case and syntactic correctness are given in Table 11.2.

A repeated measures analysis of variance (ANOVA) of the error percentages revealed no significant within-subject main effects: Repetition of presentation: $F(1,23) = 3.29, MSE = 7, p\rangle.08$. There was a significant interaction of case by syntactic congruency, $F(1,23) = 6.57, MSE = 6, p = .0174$, all other $Fs\langle 1$.

11.3.3 Partial design - Replication - Naming task

In this subsection the results for the partial design that replicated Experiment 4 are reported. Mean word naming latencies, standard deviations and error percentages for the conditions repetitions of presentation, case and syntactic correctness are given in Table 11.3.

Table 11.3: Mean word naming latencies, standard deviations (in parenthesis) and naming errors (second row) for the conditions: repetitions of presentation, case and syntactic correctness. The two rightmost columns show mean values over all levels of repetition.

	1st presentation		2nd presentation		mean of presentations	
	accusative	dative	accusative	dative	accusative	dative
correct	626 (134)	679 (149)	498 (47)	509 (60)	559 (119)	596 (139)
	2.8	5.6	0.5	0.9	1.6	3.2
incorrect	663 (156)	693 (149)	513 (49)	521 (53)	586 (137)	607 (141)
	2.3	5.6	1.9	0.5	2.1	3.0

Note. Naming latencies in ms and naming errors in %.

Naming latencies There were no effects of block sequence ($F\langle 1$) or response key assignment (right-left / left-right), ($F\langle 1$). Therefore, these factors were not included in subsequent analyses.

A repeated measures analysis of variance (ANOVA) revealed significant within-subject main effects of: Syntactic correctness, $F(1,23) = 15.54, MSE = 1134, p\langle .001$, Case, $F(1,23) = 18.76, MSE = 2182, p\langle .001$ and repeated presentation, $F(1,23) = 6.89, MSE = 2769, p\langle .05$. None of the three two-way interactions nor the three-way interaction were significant: Case by correctness, $F(1,23) = 2.20, MSE = 1263, p = .15$, Repetition by correctness, $F(1,23) = 2.29, MSE = 572, p\rangle .14$, all other $Fs\langle 1$. [3]

The item ANOVA revealed an effect of the between-item factor case, $F(1,34) = 13.39, MSE = 4343, p\langle .001$, and within-item effects of syntactic correctness, ($F(1,34) = 10.27, MSE = 2367, p\langle .001$), and repetition ($F(1,34) = 8.40, MSE = 1842, p\langle .001$). None of the three two-way nor the three-way interaction were significant: Case by correctness, $F(1,34) = 1.22, MSE = 1267, p\rangle .27$, all other $Fs\langle 1$.

Naming errors Naming error percentages for the conditions repetitions of presentation, case and syntactic correctness are given in Table 11.3.

A repeated measures analysis of variance (ANOVA) of the error percentages revealed no significant effect. Main effects of case $F(1,23) = 2.76, MSE = 28, p = .11$,and repetition, $F(1,23) = 2.53, MSE = 43, p = .13$,as well as interactions of repetition by correctness, $F(1,23) = 1.88, MSE = 17, p\rangle .18$, and interactions of repetition by case, $F(1,23) = 4.05, MSE = 27, p\rangle .05$, and all other $Fs\langle 1$.

11.3.4 Partial design - Replication - Judgment task

The results for the grammatical acceptability judgment task of the partial design replicating Experiment 4 are reported in this subsection. Grammatical acceptability judgment latency and error analyses were conducted. Mean judgment latencies, standard deviations and judgment errors for the conditions case and syntactic correctness are given in Table 11.4.

Judgment latencies A repeated measures analysis of variance (ANOVA) over the judgment latencies revealed an effect of case, $F(1,23) = 12.90, MSE = 2500, p\langle .0015$. The other effects were not significant: Correctness, $F(1,23) = 3.67, MSE = 5583, p = .068$, and the interaction, $F(1,23) = 2.31, MSE = 1423, p = .14$.

Inherent case took longer to judge than structural case. The main effect of syntactic congruency observed in Experiment 4 is only marginally significant. This suggested that the GAJT

[3] A control ANOVA on the data set not excluding trials showing an incorrect grammatical acceptability judgment response revealed comparable results and did not change the overall pattern.

Table 11.4: Mean judgment latencies, standard deviations (in parenthesis) and judgment errors (second row) for the conditions case and syntactic correctness.

	accusative	dative
correct	479 (235) 3.2	504 (237) 3.2
incorrect	497 (241) 2.8	545 (258) 9.0

Note. Judgment latencies in ms and judgment errors in %.

is selectively susceptible to practice effects, because target and experimental sentences were presented more frequently in the present experiment.

Judgment errors 95.4 % of all judgment responses were correct. Error percentages for the conditions case and syntactic correctness are given in Table 11.4.

An ANOVA over the judgment errors revealed effects of case, $F(1,23) = 13.28, MSE = 18, p = .0014$, correctness, $F(1,23) = 20.31, MSE = 8, p = .0002$, and a significant interaction, $F(1,23) = 9.62, MSE = 24, p = .0050$.

As in the previous experiment and also confirming the results of Experiment 1 and the predictions, lexical case was harder to judge than structural case. Incorrect lexical case stood out, accounting for the effect of correctness and the interaction entirely.

11.4 Discussion

It is concluded that postlexical processes of syntactic congruency checking are carried out irrespective of a secondary task.

Interaction of repetition and correctness in the complete design revealed that the congruency effect was larger when a secondary task was used. Note that the complete design comprised blocks with and without secondary task.

The accuracy data of the GAJT replicated the performance pattern of Experiment 4.

See also the combined discussion of Experiments 4 and 5 below.

11.5 Summary

The goal of Experiment 5 was to determine whether or not the case congruency effects observed in Experiment 4 emerged under processing conditions without a secondary task.

A replication of Experiment 4 was carried out. In addition, the identical experiment was run without a secondary grammatical acceptability judgment task. This experiment part showed smaller but still reliable case congruency effects. It was concluded that postlexical processes of syntactic congruency checking are carried out irrespective of a secondary task.

11.6 General Discussion of Experiments 4 and 5

Experiment 4 revealed that structural and inherent case information coded in a verb's complement structure is processed fast enough to delay the naming of the word itself under appropriate conditions. The fact that naming is delayed in syntactically incongruent conditions shows that case information is processed immediately in the sense of Traxler and Pickering (1996). Post-lexical checking is fast enough to affect naming of a verb target itself. In addition, Experiment 5 showed that the case congruency effect was also observed when there was no secondary task.

In both experiments there was a main effect of case on the naming latencies. This effect can be accounted for in terms of different item sets or type frequency of wh-sentence construction. These two alternative explanations cannot be differentiated without additional data. This issue, however, does not lie at the heart of this study. Note also that the case main effects did not contaminate the congruency effects.

Furthermore, the main effects of case on the judgment latencies (Experiment 4) and error percentages confirmed Hypothesis (5.2). The interaction effects of case and correctness confirmed Hypothesis (5.3). Experiment 5 featured more repetitions of the critical target and of the experimental sentences. This resulted in an improved level of overall performance and also in a slightly shifted pattern of results. For instance, no correctness effect on judgment latencies was observed in Experiment 5. From this pattern of results it is concluded that the effects observed are susceptible to practice and repetition.

On the basis of Experiments 4 and 5 results about the on-line processing of structural and inherent case in sentence comprehension were obtained. The time-course of the availability of complement structure information and its use in processes of sentential coindexation could be narrowed down. However, the RT results of Experiments 4 and 5 still do not allow statements about the exact time-course of the use of case information. As a consequence, this study turns to the ERP method in order to investigate the time course and other processing characteristics of structural and inherent case more closely. The high temporal resolution of the ERP method was of particular interest (see also Swinney, Nicol & Rieber, 1998).

Chapter 12

Experiment 6 - ERP I: Participles

12.1 Introduction

The goal of the present experiment was to investigate processing of structural and inherent case information associated with verb participles during the processing of object-subject-verb constructions. Processing characteristics as revealed by ERP and the processing time-course were of particular interest.

In the previous, chapters experiments were reported that established behavioral effects of processing structural and lexical case using off-line and on-line experimental techniques. The present and the following final experiment used an on-line measure with high temporal resolution, the event-related brain potential technique (ERP).

In the present chapter an ERP study is described that investigated the effects of accusative and dative case information during sentence processing. The question was what effects does structural and inherent case information, morphologically marked on the verb object and presented prior to the case-assigning verb in a sentence context, have on verb processing and what is its time-course. These questions were investigated using a syntactic violation paradigm. One goal was, again, to make use of pure case errors. Expectations of the critical verb based on semantics were ruled out.

Sentences, that were either syntactically correct or featured a case violation, were presented in a word by word serial visual presentation (SVP) setting. In one half of the sentences an accusative verb was used as the main verb. The other half used dative verbs. Type of verb and syntactic correctness were completely counterbalanced.

Based on the literature at the time of the design of this experiment a LAN around 400 ms after onset of the critical verb reflecting disruption of syntactic processes during second pass-parsing and possibly a P600/SPS were predicted as electrophysiological correlates for processing case violations of the kind used in the present experiment.

In the meantime, other studies using variations of case information became available (see the discussion section of this experiment).

12.2 Method

12.2.1 Participants

Sixteen young adults (nine males) volunteered to participate in Experiment 6. None of them had participated in any of the previous experiments. All were native speakers of German, right-handed and students at the University of Leipzig. Their mean age was 24.1 years, ranging from 19 to 29. Participants reported normal or corrected-to-normal visual acuity and no known neurological condition. They received course credit or were paid for their participation. Two additional participants were be excluded from the analysis due to a high rate of EEG artefacts (at least one condition featuring more than 40% of the trials excluded).

12.2.2 Material

The material of Experiment 6 was similar to that of the previous experiments in that it followed the same design principles. A number of adjustments that resulted in an extension of the list of critical verbs of the previous two experiments were required by the ERP method.

Two hundred critical sentences were constructed. Fifty per cent of which featured verbs requiring an accusative complement, fifty per cent a dative complement. Of each subset, half of the sentences were syntactically correct, the other half incorrect. A violation was constructed via agreement between the case of a wh-pronoun and required case of verb complement. For sentence construction a modification of template 10.1 of Experiment 4 was used. In addition, lead-in and lead-out phrases were used to ensure that critical elements were neither in sentence-initial nor sentence-final position. Sentence examples are given in (12.1), accusative correct, (12.2), accusative incorrect, (12.3), dative correct, and (12.4), dative incorrect (the critical word is underlined). The complete set of verbs is listed in infinitive and participle form in Appendix B.6.1.

(12.1) Er wußte, wen Nina <u>gesehen</u> hat, bevor sie ging.

He knew, whom Nina seen has, before she left.

(12.2) *Er wußte, wem Nina <u>gesehen</u> hat, bevor sie ging.

He knew, *to whom Nina seen has, before she left.

(12.3) Er wußte, wem Nina <u>geholfen</u> hat, bevor sie ging.

He knew, to whom Nina helped has, before she left.

(12.4) *Er wußte, wen Nina <u>geholfen</u> hat, bevor sie ging.

He knew, *whom Nina helped has, before she left.

In the following passages the process of material construction is described in more detail.

Selection of sentence frame The selected variant of experimental sentences 12.1 - 12.4 differs from the initial sentence template 10.1 with respect to the lead-in and lead-out phrases as well as the word order of the critical subordinate clause. Sentence variants constructed according to 10.1, featuring a lead-out only (”Wen hat Meike gesehen, bevor sie ging?”) or a lead-in only (”Er wußte, wen Nina gesehen hat?”) were also considered. The present sentence variant was selected, because the critical information under investigation is neither presented at sentence onset nor offset. Possible sentence initial or sentence wrap-up processes cannot occur while the critical verb is being processed (see, e.g., Connolly & Phillips, 1994). Furthermore, due to the auxiliary ”hat” (”have”) the critical participle was not in clause-final position.

Selection of verbs The ERP method required a larger number of trials than the experimental techniques used in the previous experiments of this study. As a consequence, 50 dative and 50 accusative verbs were selected for the experiment. The composition of the set of verbs was largely determined by the number of available (possible) dative verbs. Prefixed as well as non-prefixed verbs had to be used. Other than this the same selection criteria as in the previous experiments were used.

50 accusative verbs were selected in a way that they matched the selected dative verbs as well as possible. Matches included: Length, frequency, prefix vs. no prefix, onset and all other constraints considered for the datives. While the datives could not be kept constant in terms of complement/argument structure complexity this was kept constant for the accusative verbs for reasons of simplicity, resulting in the only non-matched difference between the sets. All accusative verbs allowed one and only one accusative object.

The following possible influence factors were also considered:

- All dative verbs that also allow for an optional accusative object were omitted, even if this object had to be inanimate. The animacy violation might have different effects than the pure case violation - only unambiguous participles were selected.
- Verb participle forms like ”bewundert” (”admired”) or ”berichtet” (”reported”) were excluded. The latter words would result in complete sentences before the auxiliary occurs.
- Mostly ”ge”-participles were selected.
- no foreign words (these - all ”...ieren”-verbs - are always ambiguous)
- Selected participles cannot be used as an adjective, e.g., ”entäuscht. They featured no 3rd person singular present tense ambiguity.

It was not possible to exclude all possible factors influencing verb processing from the study due to the relatively small number of available dative verbs (see Chapter 6). Note that these possible confounds would only affect effects of case. For effects of syntactic correctness each verb served as its own control. Factors that were not varied in the study were: verb complement structure complexity, verb argument structure complexity, mono-morphemic words vs. not mono-morphemic words and prefixed vs. non-prefixed verbs.

Selection of sentence elements The lead-in phrases were constructed according to the following template: $\langle pronoun \rangle \langle verb \rangle$. 10 different verbs were selected: erfuhr ("got to know"), wußte, ("knew"), erzählte ("told"), bemerkte ("noticed"), erkannte ("noticed"), beschrieb ("described") erwähnte ("remarked") beobachtete ("observed"), zeigte ("showed") and berichtete ("reported"). They were combined systematically with two personal pronouns ("er" ("he") & "sie" ("she")) resulting in 20 different lead-in phrases. See (12.1) for an example lead-in phrase.

As grammatical subjects of the subordinate clauses, ten different proper names were selected, five of each gender. Only two different codas were used (for reasons of the ERP baseline): Anja, Tobias, Anna, Thomas, Lisa, Lukas, Nina, Jonas, Vera and Andreas.

Finally, lead-out phrases were constructed according to the following template: $\langle adverb \rangle \langle pronoun \rangle \langle verb \rangle$.

Two temporal adverbs (bevor ("before") & "nachdem" ("after")) were systematically combined with the two different personal pronouns and five different verbs, resulting in 20 different lead-out phrases completely counterbalancing all three constituents. Verbs were ging ("left"), zurückkam ("came back"), losfuhr ("took off"), ankam ("arrived") and abfuhr ("departed"). See (12.1) for an example lead-out phrase.

Sentence construction The sentences were systematically and algorithmically generated using the lead-in phrases, the names and the lead-out phrases as a "building kit". In doing so, the gender of the subjects of the subordinate clause (proper name) determined the gender of the pronoun of the adjunct (lead-out) clause, because it can be argued that there is an attachment preference for this reading in German. On the other hand, the gender of the subject of the matrix clause (personal pronoun) of the lead-in clause was kept in the opposite gender in order to facilitate the comprehension of the sentences.

A number of procedure and design factors influenced the material construction: The accusative and the dative verb sets were each divided into two equally large subsets such that the onsets of the verbs of each subset represented the full alphabetical range (a-z). 4 subsets consisting of 25 verbs each resulted. The verbs of each of these sets were then inserted into both a syntactically congruent and an incongruent sentence frame of the type ("wen"/"wem" $\langle name \rangle \langle participle \rangle$ "hat"; "whom"/"to whom" $\langle name \rangle \langle participle \rangle$ "has"). This way eight different sets resulted. These were then merged into two combinations of four of these sets each, such that each combination featured one quarter accusative verbs in a correct frame, one quarter in an incorrect one, one quarter dative verbs in a correct frame, one quarter in an incorrect one. This way all critical verbs were contained once in Combination 1. The second combination was a mirror image of the first also containing all critical verbs, but in the other correctness conditions.

Lead-in phrases, names, lead-out phrases were then added to each frame in a systematic, algorithmic fashion. Thus ensuring that occurrences and repetitions of the latter were unrelated to those of the critical elements. 200 hundred sentences resulted. 14 manual changes to the automatically generated sentences were made in order to prevent semantic anomalies. Subsequently a manual check for plausibility, temporal consistency, other semantic anomalies etc. was carried out by two additional, independent judges. See Appendix B.6.2 for a complete listing of the experimental sentences.

Practice sentences Twenty additional filler sentences were created using the same procedure described above for use in practice trials. All four conditions, lead-in, lead-out phrases and proper names were contained in a counterbalanced fashion in these sentences.

12.2.3 Apparatus

The experiment was run on an IBM compatible computer running DOS using the ”ERTS” experiment programming shell (Beringer, 1993; Iwanek, 1994). The stimuli were presented on a ”Sony Multiscan 17 se” SVGA computer monitor. Judgment responses and latencies were captured using the right and left buttons of a three-button response keyboard triggering the ”ERTS” reaction time clock via the ”ERTS ExKey-Logic”. An electrically shielded and sound-attenuated experimental chamber (International Acoustic Company, IAC) was used.

A 120-channel EEG was recorded using tin Electrodes attached to a cap (Electrocap Inc.). Four 32-channel NeuroScan SynAmps EEG amplifiers were used for EEG signal amplification and digitizing. The NeuroScan ”Acquire” software was used for recording and run on a PC-type computer. Off-line signal processing was carried out on DEC Alpha work stations running UNIX and EEP 3.0 (Nowagk & Pfeifer, 1996).

12.2.4 Procedure

In this subsection the session structure is described first, followed by a description of the experimental design and the trial structure of the main experiment. Finally, the electrophysiological recordings are described.

Session structure A session consisted of the following parts.

1. Participants received training on the target verbs in order to reduce any repetition effect. They were asked to read the critical and practice verbs aloud from a list. The latter contained the items in a pseudo-randomized sequence under the constraint that a given verb onset could not occur twice in a row (see Appendix B.6.1).

2. General EEG instructions were given. Participants were told to move their head and body as little as possible, make no eye movements or blinks while the fixation cross or experimental

sentences were presented on the screen. They were also instructed to make eye movements and blinks during response execution.

3. A block of 20 practice trials was administered using the practice sentences and the trial structure of the main experiment. Participants were instructed to maintain fixation throughout the trial after the fixation cross occurred, to read the sentence carefully and to execute a grammatical acceptability judgment accurately and as quickly as possible as soon as a question mark appeared on the screen as the prompt for the judgment task. See Appendix C.4 for complete instructions. All four conditions were contained in a counterbalanced design using the practice sentences. Participants questions were answered, advice given or corrections made if necessary.

4. The main experiment followed. Four blocks of 50 trials each were administered. Breaks were taken between blocks (ranging from one to five minutes if necessary).

5. Finally, participants were debriefed.

The participants were tested individually while seated in a dimly lit experimental chamber in front of a computer screen. The viewing distance was 115 cm resulting in a vertical visual angle of about one degree and horizontal visual angles ranging between about 1.5 and 5.5 degrees for the stimuli.

An experimental session lasted approximately one hour not including electrode application and cleaning up after the experiment.

Experimental design The two mirror image combinations of material subsets (see section 12.2.2 page 115) were split into halves such that all four conditions were presented equally frequently in each half, and a specific verb was assigned to the corresponding half of each mirror combination. This was done in order to gain more control over the distance between repetitions of a critical participle. Four items lists resulted from this procedure. The item sequence was pseudorandomized according to the following constraints: no more than three trials of a given case or syntactic correctness level or featuring a given proper name in a row, a given onset syllable of a critical verb not twice in a row (exception ”ge” participles, not more than three times in row). Four experimental blocks resulted from this manipulation. An additional set of four blocks was created by reversing the item sequence of the first four blocks. Eight participants saw blocks one through four and the other eight participants saw the other four blocks. The sequence of blocks was counterbalanced across participants.

Trial structure The trial structure of Experiment 6 was designed as follows. A screen-centered asterisk appeared as a fixation mark for 300 ms. Followed by an ISI of 500 ms (blank screen). Then each word was presented individually, screen-centered for 500 ms (ISI 0ms). [1] Punctuation was included. After sentence presentation an ISI of 800 ms occurred followed by a screen-centered question mark presented for 2000 ms, as a prompt for the grammatical

[1] An ISI of 0 ms was chosen in order to have exogenous i.e., stimulus-driven off-set and on-set components in the ERP fall together.

acceptability judgment. The response time window was 3000ms starting with the presentation of the response prompt. The next trial was started after a 1500 ms ITI. All characters were presented in black on a gray background. The trial structure is shown in Figure 12.1.

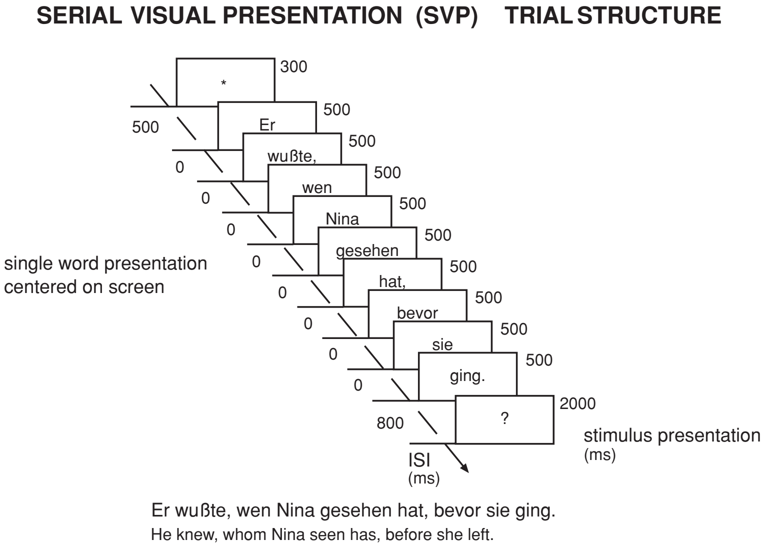

Figure 12.1: Trial structure of Experiment 6

Electrophysiological Recordings The electroencephalogram (EEG) was recorded from 120 sites according to the ElectroCap Inc. electrode configuration shown in Figure 12.2 using tin electrodes attached to a cap. The EEG was recorded continuously referenced to an electrode placed on the tip of the nose. The ground electrode was placed posterior to the nasion at ca. 30% of the distance between nasion and inion. Additionally, electrical activity at both matoids was recorded. The vertical and horizontal electrooculogram (EOG) were recorded for the control of eye movements. Electrooccular activity was recorded from six monopolar channels also referenced to the nose. The vertical EOG was recorded from a montage above and below both eyes. The horizontal EOG was recorded from electrodes on the outer canthi.

All electrodes showed an impedance below 3kΩ. The signal was amplified using DC amplifiers. On-line filtering was carried out using a 0.1 Hz high-pass, a 30 Hz low-pass and 50 Hz notch filter. The amplifier gain was set to 10.000. The signal was digitized with a 16bit resolution at a sampling rate of 250 Hz. All continuous EEG records were off-line filtered high-pass with a finite impulse response filter (FIR) with the following specifications: 2001 points, critical frequency of 0.4 Hz and a corner frequency (3db attenuation) of 0.5 Hz. The data were rereferenced to linked mastoids. Artefacts were rejected using a standard deviation criterion in a sliding window of 200ms (vertical EOG (right and left), 40; horizontal EOG, electrode 18 (see Figure 12.2) and both mastoids, 30). Contaminated epochs were excluded from further analysis.

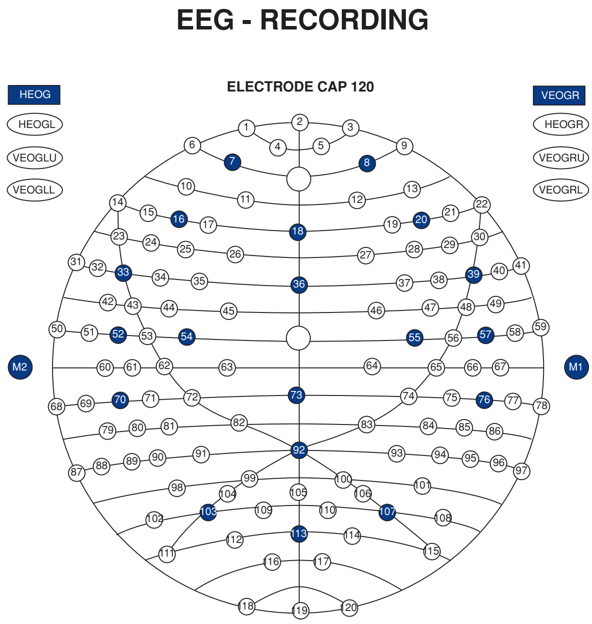

Figure 12.2: EEG recording of Experiment 6. Electrode configuration; view from top; frontal sites are at top of the figure. Highlighted electrode positions are presented in the results section.

12.3 Results

The results section is structured into two subsections. First, the performance data of the grammatical acceptability judgment task are reported and then the event-related brain potential data are described.

12.3.1 Grammatical acceptability judgment task

In the following subsection response time and error analyses of the grammatical acceptability judgment task are reported. Mean judgment latencies, standard deviations and judgment errors for the conditions case and syntactic correctness are given in Table 12.1.

Table 12.1: Mean judgment latencies, standard deviations (in parenthesis) and judgment errors (second row) for the conditions case and syntactic correctness.

	accusative	dative
correct	400 (108)	402 (109)
	2.1	3.3
incorrect	392 (104)	393 (105)
	2.5	7.3

Note. Judgment latencies in ms and judgment errors in %.

Judgment latencies Trials that featured incorrect grammatical acceptability judgments were excluded from further analysis (including ERP derivation). A repeated measures analysis of variance (ANOVA) over the judgment latencies revealed no significant effects: Syntactic correctness, $F(1,15) = 2.41, MSE = 438, p = .14$, all other $Fs\langle 1$.

No differences in judgment latencies were observed. Participants were faster overall than in the previous experiments. Both null effects might be accounted for by the longer preparation period between encountering the violation and response execution that was available in the present experiment.

Judgment errors 96.2 % of all judgment responses were correct. Error percentages for the conditions case and syntactic correctness are given in Table 12.1.

An ANOVA over the judgment errors revealed effects of case, $F(1,15) = 6.45, MSE = 21, p\langle .05$, syntactic correctness, $F(1,15) = 7.63, MSE = 10, p = .0145$, and a significant interaction, $F(1,15) = 6.66, MSE = 8, p = .0209$.

Confirming the results of the previous experiments and the predictions, lexical case was harder to judge than structural case. Incorrect inherent case stood out, accounting for the effect of correctness and the interaction entirely.

12.3.2 Event-related potentials

Event-related potentials of 1200ms length starting with onset of the critical participle and featuring a 200ms prestimulus baseline were computed separately for the four conditions for each individual participant. Subsequently, group averages (grand average, N = 16) were computed for the four conditions. Grand averages for the conditions accusative correct, accusative incorrect, dative correct and dative incorrect are shown in Figure 12.3. Figure 12.4 shows the ERPs for the accusative verbs only. Figure 12.6 shows the ERPs for the dative verbs.

The ERPs to all four conditions equally showed a N1 component followed by a P2 component. The ERPs start to differ at approximately 450 ms after the onset of the critical participle. ERPs elicited by both incorrect conditions revealed more negative going waveforms than the respective correct conditions. The effects are found while all four ERPs are on a positive going, descending ramp. They were broadly distributed over the scalp.

In addition to the negativity starting after 450ms, a later positivity was found for the incorrect structural case condition. Starting after 750ms after participle onset, the ERP elicited by the incorrect accusative condition revealed a more positive going waveform than the the correct condition. The effect was descriptively largest over centro-posterior sites.

ERP quantification The ERP quantification routine consisted of several steps. First, two exploratory analyses using separate ANOVAs in 30ms time windows were used to identify substantial effects. Second, subsequent analyses were carried out in the identified time windows and and over regions of interest (ROI).

An initial exploratory analysis using separate ANOVAs in 30ms time windows over five midline electrode sites was used to identify substantial effects, their time windows and topographical variations. Midline electrodes were 18, 36, 73, 92 and 113 according to the configuration shown in Figure 12.2.

In case of topographical variations of effects of case, correctness or interaction of the two, a second exploratory series of 30ms time window ANOVAs over ROIs was carried out. ROI classification was according to the factors hemishere and anterior/posterior. Four equal-sized ROIs of six electrode sites each were defined (see Figure 12.2):

- Left anterior, electrodes 10, 15, 16, 17, 24, 25.
- Right anterior, electrodes 13, 19, 20, 21, 28, 29.
- Left posterior, electrodes 89, 90, 91, 98, 102, 103
- Right posterior, electrodes 93, 94, 95, 101, 107, 108

ERP effects were taken to be substantial, if they resulted in significant effects in three consecutive 30ms time windows in both exploratory analyses. Using this procedure two time windows were identified: a negativity in the time window between 480 and 780ms and a later positivity between 850 and 1000ms after stimulus onset.

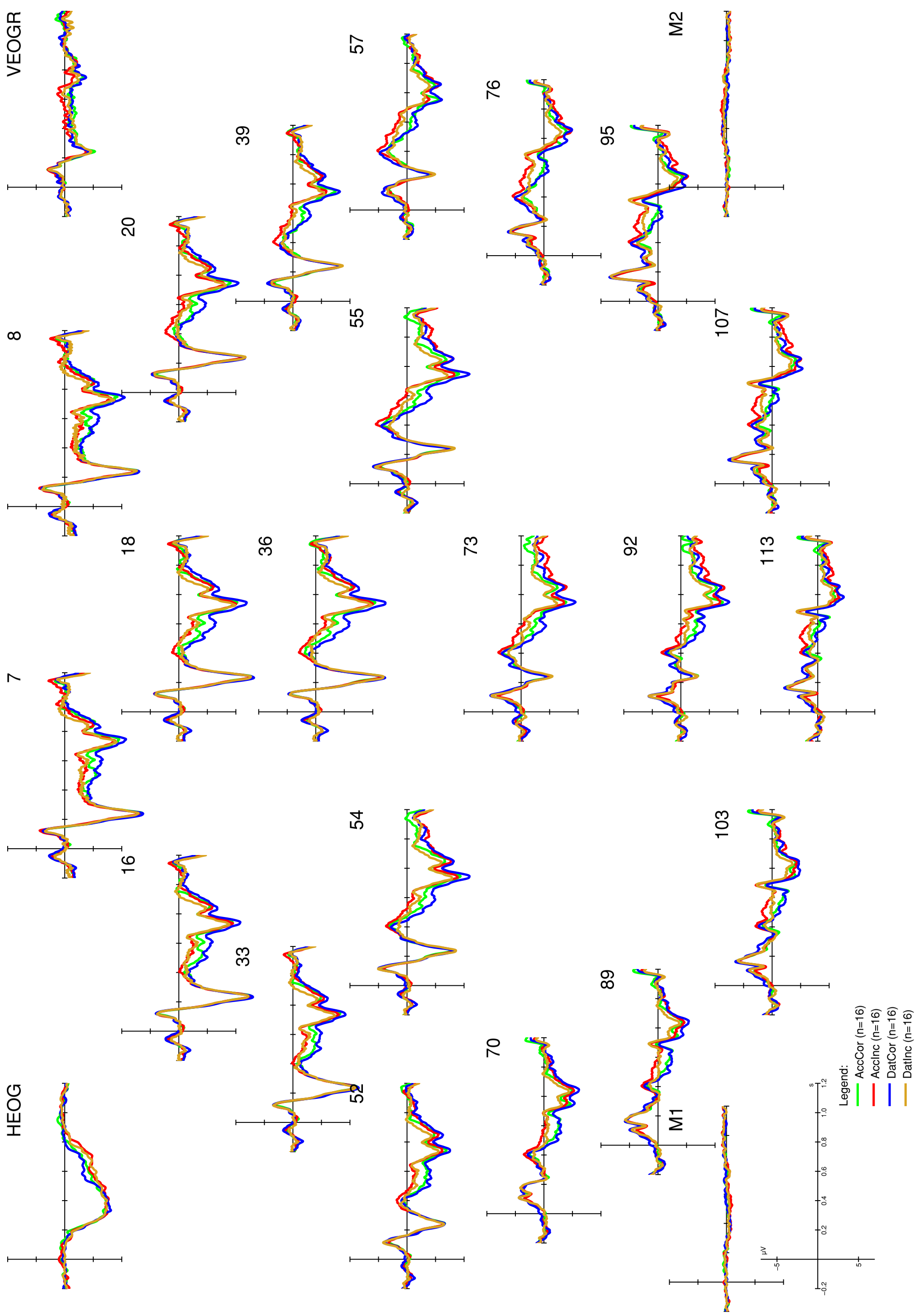

Figure 12.3: Event-related brain potentials for the critical participles in all four conditions.

Figure 12.4: Event-related brain potentials for the critical participles in the accusative conditions (correct vs. incorrect).

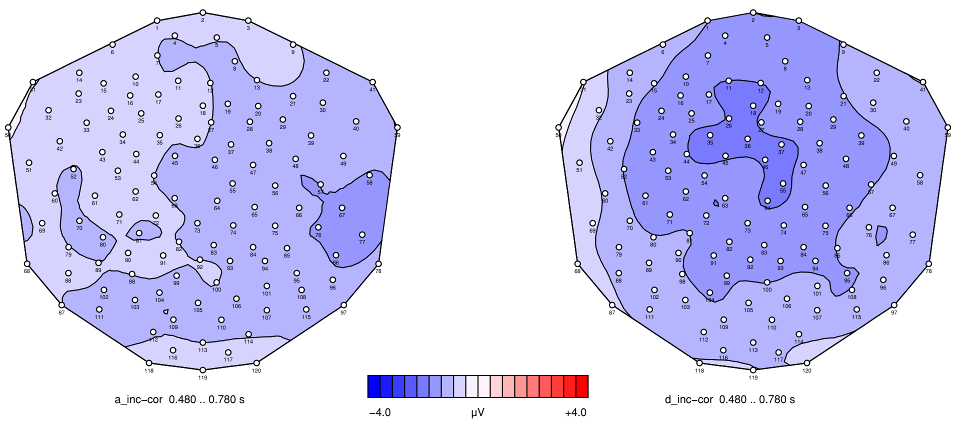

Figure 12.5: Negativity. Potential maps of the correctness effects for accusative (left panel) and dative (right panel). Mean difference potentials (incorrect minus correct) in the time window between 480 and 780 milliseconds were plotted.

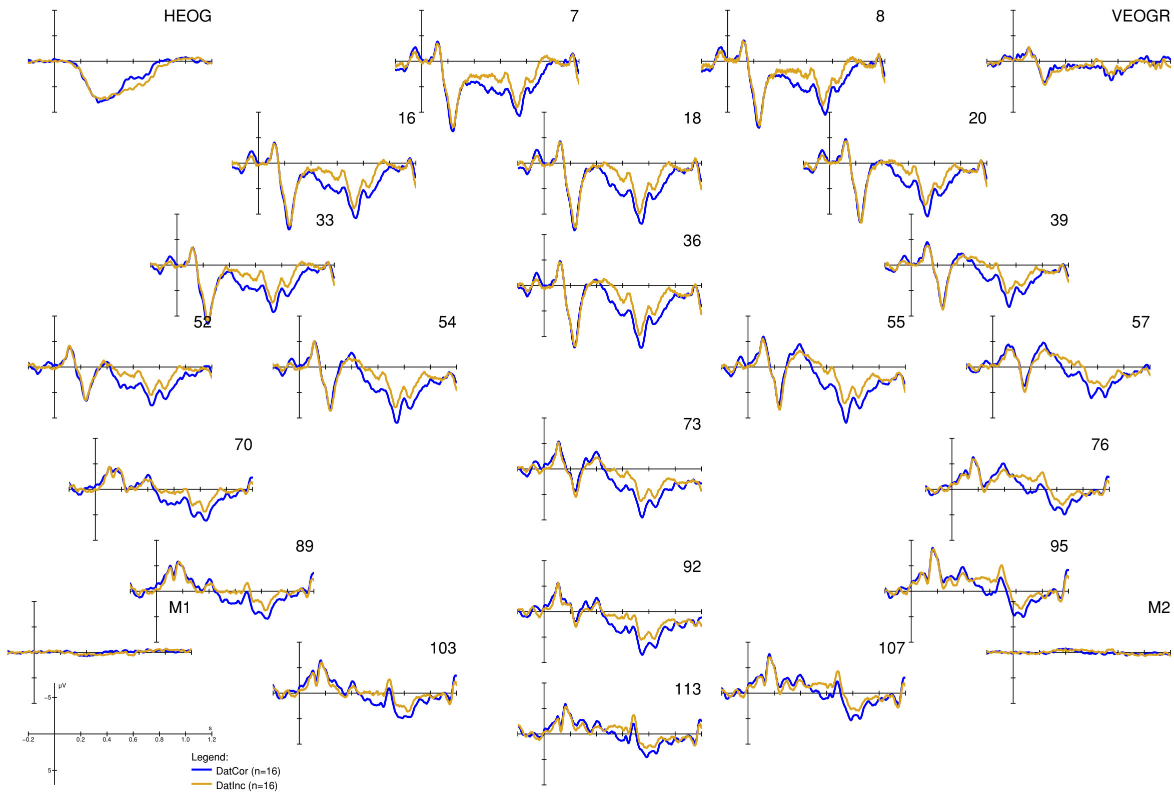

Figure 12.6: Event-related brain potentials for the the critical participles in the dative conditions (correct vs. incorrect).

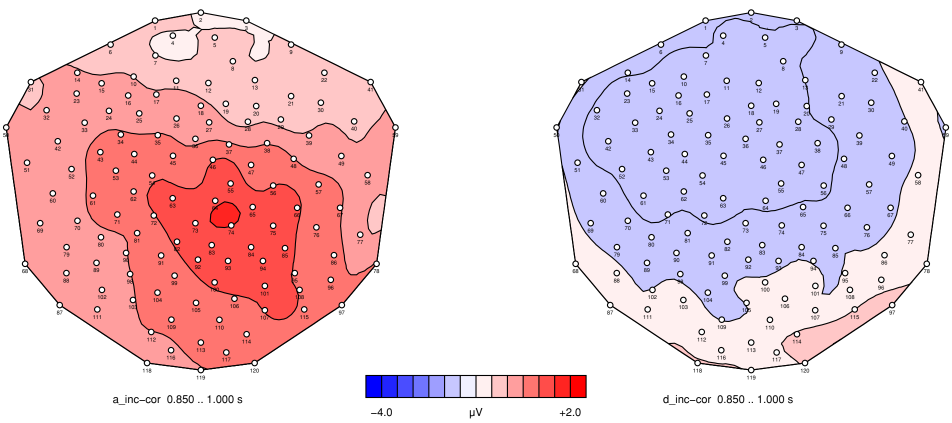

Figure 12.7: Late positivity. Potential maps of the correctness effect of the accusative condition (left panel). The Dative condition is shown in the right panel. Mean difference potentials (incorrect minus correct) in the time window between 850 and 1000 milliseconds were plotted.

Negativity Potential maps of the correctness main effects for accusative and dative are given in Figure 12.5. An ANOVA over mean amplitudes in the time window between 480 and 780ms after onset of the participle with the factors case (accusative & dative), syntactic correctness, hemishere and anterior/posterior was carried out. The analysis revealed a significant main effect of correctness ($F(1, 15) = 14.43, MSE = 7.80, p\langle.0017$) as well as main effects of hemishere ($F(1, 15) = 19.12, MSE = 3.22, p\langle.0005$) and anterior/posterior ($F(1, 15) = 16.47, MSE = 23.59, p\langle.001$). No other effect was significant: Case $F(1, 15) = 2.03, MSE = 3.68, p = .17$, case by correctness, $F(1, 15) = 1.75, MSE = 3.01, p = .21$, case by hemisphere, $F(1, 15) = 1.62, MSE = 0.09, p = .22$, case by anterior posterior, $F(1, 15) = 1.36, MSE = 0.70, p = .26$, correctness by hemisphere, $F(1, 15) = 3.14, MSE = 0.12, p = .10$, hemisphere by anterior/posterior, $F(1, 15) = 1.06, MSE = 1.60, p = .32$, case by correctness by hemisphere, $F(1, 15) = 2.09, MSE = 0.23, p = .17$, case by hemisphere by anterior/posterior, $F(1, 15) = 3.96, MSE = 0.04, p = .07$, the four-way interaction, $F(1, 15) = 3.2.41, MSE = 0.03, p = .14$, and all other $Fs\langle 1$.

The results for the negativity between 480 and 780ms after onset of the critical participle were clear-cut. There was a strong main effect of syntactic correctness. The case violations in this experiment elicited more negative going waveforms for both violation conditions. The onset of this effect was located in time after the N400 peak of all conditions and could be found entirely on the descending ramps of the ERPs. This negativity effect started slightly later than a typical N400 and was widely distributed over the scalp, that is, it was present in all four ROIs and there were no interactions of correctness and ROI. It was not confined to left anterior scalp sites and thus did not qualify as a typical LAN. Furthermore, it was relatively low in amplitude and set in after the N400 peak and therefore did not qualify as a N400. This effect was clearly elicited by the experimental manipulation, reflecting the detection of the case violation after the N400 peak. Also, the negativity effect was found relatively late which might reflect long lexical access times due to low frequency of the nouns and relatively high length.

The material matching procedure worked sucessfully, as there was no main effect of case and no interaction of case and correctness. The syntactic correctness effect was broadly distributed over the scalp. The absence of significant interactions of the correctness factor and any of the two topographical factors indicates the there were no topographical effects. No further analyses were necessary in this time window.

Late positivity Potential maps of the correctness main effect for accusative and the corresponding dative computation are given in Figure 12.7. An ANOVA over mean amplitudes in the time window 850 and 1000 with the factors case (accusative & dative), syntactic correctness, hemisphere and anterior/posterior was carried out. The analysis revealed no significant main effect: correctness, $F(1, 15) = 2.42, MSE = 5.39, p = .14$, the Fs for other main effects were $\langle 1$. There were significant interactions for: case by correctness, $F(1, 15) = 7.80, MSE = 5.54, p = .013$ and correctness by anterior/posterior $F(1, 15) = 8.16, MSE = 0.98, p = .012$.

No other effect was significant: case by anterior posterior, $F(1,15) = 1.12, MSE = 1.35, p = .31$, case by hemisphere by anterior/posterior, $F(1,15) = 4.19, MSE = 0.10, p = .06$, and all other $Fs\langle 1$.

The interaction of case by correctness was resolved for case. The ANOVA for the accusative conditions revealed no significant main effect of syntactic correctness $F(1,15) = 2.13, MSE = 2.05, p = .16$. The interaction of correctness and anterior/posterior was, however, marginally significant in this analysis, $F(1,15) = 4.22, MSE = 1.28, p = .057$, indicating, given an inspection of the data, that there was a syntactic correctness effect for accusative verbs over posterior sites (see below). No other effect was significant. The ANOVA for the dative conditions also revealed no significant main effect of syntactic correctness.

Secondly, the interaction of correctness by anterior/posterior sites was resolved for sites. The ANOVA for the posterior ROIs revealed no significant main effect of syntactic correctness, $F\langle 1$. There was, however, a significant interaction of case by correctness. No other effect was significant in this analysis. Tracing the latter interaction, a significant main effect for correctness for accusative verbs over posterior sites was found, $F(1,15) = 5.98, MSE = 1.63, p = .027$. The ANOVA for the anterior ROIs revealed no significant main effect nor interactions of syntactic correctness.

This late posterior positivity elicited by structural case verbs in the incorrect condition is interpreted as a late P600/SPS reflecting late processes of repair or reanalysis of the syntactic sentence structure.

These results indicated that structural case is processed differently than inherent case at the point during sentence comprehension when the case assignor (verb) is currently processed.

12.4 Discussion

The ERPs results as well as the performance results of Experiment 6 were clear-cut.

As in the other experiments of this study, a relatively fine-grained syntactic violation was used that can be labeled a pure case error. In contrast to other studies of syntactic processing, verb object case was varied against verb object case (see below).

Participants showed good overall performance in the secondary grammatical acceptability judgment task. Incorrect inherent case stood out in that it accounted for the correctness effect entirely. The performance pattern of the GAJT, again, replicated the previous experiments. The finding that no effect on the judgment latencies was observed can be accounted for by the fact that participants had several seconds time to prepare for the judgment. Another hint is that mean latencies were substantially shorter than in Experiments 4 and 5.

In this experiment, the subordinate clause of interest had an OSV structure, that is, the case-assigning verb was processed after the verb-object, that case is being assigned to, was encoun-

[1]The subordinate ANOVAs are not reported in full here for reasons of readability.

tered. A more negative ERP deflection elicited by violations of case information was observed for both incorrect conditions in the time window between 480 and 780ms after participle onset. These effects are taken to reflect difficulty of lexical integration of the incoming verb into the syntactic sentence structure. No case differences were observed for the negativity effect. A late posterior positivity was observed for the incorrect structural case condition. Reflecting repair processes on the violated sentence structure. Here, structural and inherent case differed in that the sentence comprehension mechanism does not engage in such processes in the inherent case condition.

One issue that deserves discussion is the question of the time course of case processing as reflected by the ERP effects obtained in the present experiment. The case that a verb assigns to its object is syntactic lexical information. If a verb assigns accusative, the structural case for verb objects, the minimum entry in the mental lexicon must state ”use the default” whereas the dative case must be specified. This particular information must be retrieved by processes of lexical access and selection during the course of sentence comprehension before case can be processed on the sentential level. This poses the question: When does lexical access occur? If the LAN is taken to reflect working memory processes, the word recognition must be completed before that. For semantic integration effects - like the N400 - the word must be fully recognized. Also, in order for effects of inherent case to occur, word recognition must be completed prior to the effect arising. Thus, the negativity observed in this experiment is taken to reflect disruption / difficulties in lexical integration of the participle into the syntactic structure projected on the basis of the case information provided by the object wh-pronoun. This relates to the second phase of the sentence comprehension model of Friederici (1995).

In the following passage the late positivity effect obtained in this experiment is discussed. There was a late posterior positivity effect for accusative verbs presented in the syntactically incorrect condition, whereas this effect was absent for dative verbs. Indicating that the sentence comprehension mechanism engages in reanalysis or repair operations for the default case featuring higher type frequency, the structural case for verb objects. For verbs featuring inherent case, on the other hand, such an operation is not carried out, although the syntactic violation was reliably detected (negativity) and reported by the participants. It is worth adding, however, that precisely the condition in focus here, the incorrect inherent case condition produced the highest error rates (7.3%) in the secondary control task accounting for the significant case by correctness interaction. This relates to the third phase of the sentence comprehension model by Friederici (1995).

Recent ERP research using manipulations of case marking to investigate syntactic processing has yielded a diverse pattern of effects.

Hopf, Bayer, Bader and Meng (1998) investigated accusative dative case ambiguities. They used object subject verb declarative sentences of the following kind: ”Dirigenten, die ein schwieriges Werk einstudiert haben, kann ein Kritiker ruhig umjubeln (acc) /applaudieren (dat).” (”Conductors who a difficult opus rehearsed have can a critic safely cheer / applaud”). The sentence-initial NP is not case-marked and thus creates an ambiguity that is not resolved until the sentence-final verb is encountered.

The authors found a N400 effect for sentence-final dative verbs in German case-ambiguous sentences that they labeled pure case ambiguities. No P600 was obtained. They interpreted their finding of an N400 as a re-access to the mental lexicon.

There are, however, potential problems with this study. For one, no secondary behavioral task was employed to assure proper sentence reading and control participants' performance. In addition, the critical verbs were presented in sentence-final positions which might have resulted in a contamination by sentence wrap-up effects. Thirdly, additional effects might have occurred due to the length of the sentence. Furthermore, there is a preference to read the sentence-initial object of the matrix sentence as the subject of the sentence, this might also have resulted in an effect on the processing of the sentence-final matrix verb.

Also in German, Friederici and Frisch (submitted), investigated verb-argument structure processing, by presenting incongruent accusative case marked NPs preceding dative verbs in sentence-final position. They obtained a N400 followed by a small P600 for the verbs (see (12.5)).

(12.5) *"Anke weiß, daß der Tourist den Wirt drohte."

"Anke knows that the tourist the landlord threatened"

In a second experiment the SOV structure was changed to VSO declarative sentences. Accusative verbs were used instead of dative verbs (see 12.6). Solely a P600 was obtained, indexing processes of reanalysis.

(12.6) *"Vorhin überzeugte der Arbeiter dem Direktor im Gespräch."

"A short while ago convinced the worker the director in a conversation"

There were a number of experimental parameters that differed between their study and the present study: declarative sentences, accusative and dative not counter-balanced, phrase-wise presentation, potential semantic predictions based on nouns they used. These issues deserve further investigation.

Rösler, Pechmann, Streb, Röder and Hennighausen (1998) used ditransitive verbs in German to investigate effects of canonical versus non-canonical word order in sentences with overtly accusative and dative case marked constituents. They found an LAN/P600 pattern for the case-marked articles of the NPs contingent on the degree of diversion from the canonical word order. In using only ditransitive structures, it can be argued that Rösler et al. investigated structural case exclusively (see Chapter 2). Note that their study focused on processing preferences in the realm of ordering sentence constituents. This resulted in differing structural complexeties and processing load between experimental conditions, two parameters that were kept constant in the present study. Furthermore, this study used syntactic violations whereas their study used ambiguities.

Coulson, King and Kutas (1998) found a biphasic LAN/P600 ERP pattern for morphologically incorrectly case-marked personal pronouns by trading accusative and genitive marked personal pronouns (us/his) for nominative ones (we/he). That is, they investigated structural case marking in the remnants of the English morphological case system (see Table 2.1). These differences might account for the different pattern of results. It would be interesting to study this issue in an experimental study deliberately designed to address it (see open issues in the general discussion).

Both latter studies take the LAN to reflect processes of working memory. But note that both studies obtained local LAN / P600 pattern elicited by violations of syntactic processing expectations based on structural case.

N400 effects are usually interpreted to reflect semantic processes, whereas the P600 effects are seen in correlation with late syntactic processes. All prior studies differed in combinations of experimental conditions.

The negativity effect of the present experiment cannot easily be reconciled with the classical language-related ERP effects (see Chapter 4). It could be: (1) induced by the linguistic processing of case violations during sentence comprehension. The detection of the mismatch (certain) other syntactic operations on the current partial phrase marker (repair) (speculation), (2) a language-related ERP not seen before elicited by processing of case violation while processing the case assignor in a highly case-marked language as German. or (3) an interaction of case incongruency and the secondary task used. Still it would reflect case-specific processing.

The negativity effect obtained was not an N400. Thus, it is concluded that an atypical syntactic LAN reflecting difficulties of lexical integration on the basis of case information was obtained. See also the discussion of Experiments 6 and 7 at the end of the following chapter.

12.5 Summary

The present event-related brain potential (ERP) study investigated effects of overt structural and inherent case information on the processing of verbs. Accusative and dative case-marked wh-pronouns were used to constrain processing of the verb. The VP including the critical participle verb was presented in clause-final position, realizing a violation between the case information given by the pronoun and the argument structure of the verb in half of the sentences. The other half consisted of correct sentences. A 120 channel EEG was recorded while participants (N=16) read 200 sentences in a word-by-word SVP setting at 500 ms per word. Grammatical acceptability judgments were used to ensure sentence reading. The ERPs for the clause final past participles revealed effects of syntactic correctness. Incorrect case led to more negative going waveforms for both case violation conditions compared to correct sentences in the time range of 480 to 780 ms after onset of the participle. This negativity effect is interpreted in terms of difficulty of lexical integration of the participle verb into the syntactic structure of the sentence in the incorrect conditions. Furthermore, a late posterior positivity was found for structural case in the incorrect condition. This P600/SPS is taken to reflect processes of repair of the violated syntactic sentence structure. The observed ERP effects suggest that case marking provided by prior context affects the lexical integration of verbs.

Chapter 13

Experiment 7 - ERP II: Pronouns

13.1 Introduction

The goal of Experiment 7 was to investigate processing structural and inherent case in verb-subject-object (VSO) constructions. Pronouns were used as critical elements. This variation of sentence structure resulted in a reversed word order of case assignor and assignee as compared to Experiment 6. The variation was tested using the identical set of verbs, design and sentence contents. Thus, the two ERP studies (Experiment 6 & 7) differ with respect to the sequence in which the case assigning verb and the verb object that case is being assigned to occur as constituents in the experimental sentences. In sentences 12.1 to 12.4 of Experiment 6 the case-marked NP is encountered before the case-assigning verb during sentence comprehension.

Based on the results of the previous experiment a larger negativity for the incorrect conditions in the LAN time range - appropriate for the very short and highly frequent target words - was expected.

13.2 Method

13.2.1 Participants

Sixteen young adults (eight males) volunteered to participate in Experiment 7. None of them had participated in any of the previous experiments. All were native speakers of German, right-handed and Students at the University of Leipzig. Their mean age was 23.1 years, ranging from 20 to 30. Participants reported normal or corrected-to-normal visual acuity and no known neurological condition. They received course credit or were paid for their participation. Five additional participants had to be excluded from the analysis due to technical errors (two), poor performance (more than fifteen percent errors in at least one condition of the secondary task - two) or a high rate of EEG artefacts (at least one condition featuring more than 40% of the trials excluded).

13.2.2 Material

The material was highly comparable to Experiment 6. The critical verbs, logic and algorithm of sentence construction were identical to the previous experiment. The only significant difference was a reversal of the sequence of case assigning verb and verb object, resulting in a different word order and making an additional word necessary. Sentence examples are given in (13.1), accusative correct, (13.2), accusative incorrect, (13.3), dative correct, and (13.4), dative incorrect (the critical words are underlined). See Appendix B.7.2 for a complete listing of the experimental sentences.

(13.1) Klaus wußte, sehen würde Nina ihn erst, wenn diese ging.

Klaus knew, see would Nina him not until, when she left.

(13.2) *Klaus wußte, sehen würde Nina ihm erst, wenn diese ging.

Klaus knew, see would Nina *him not until, when she left.

(13.3) Klaus wußte, helfen würde Nina ihm erst, wenn diese ging.

Klaus knew, help would Nina him not until, until she left.

(13.4) *Klaus wußte, helfen wurde Nina ihn erst, wenn diese ging.

Klaus knew, help would Nina *him not until, when she left.

13.2.3 Apparatus

The apparatus was highly similar to the previous experiment. The same type of computer, monitor, software and additional hardware was used for stimulation and response capture. The EEG was recorded using 59 tin electrodes mounted in a cap (Electro Cap Inc.). Signals were amplified and digitized by two 32-channel Synamps (NeuroScan) Recording and subsequent data processing was carried out using equivalent or the same equipment as in Experiment 6.

13.2.4 Procedure

In this subsection the session structure is described first, followed by a description of the experimental design and the trial structure of the main experiment. Finally, the electrophysiological recordings are described.

Session structure The session structure of Experiment 7 was identical to Experiment 6.

Experimental design The trial structure of Experiment 7 was identical to Experiment 6.

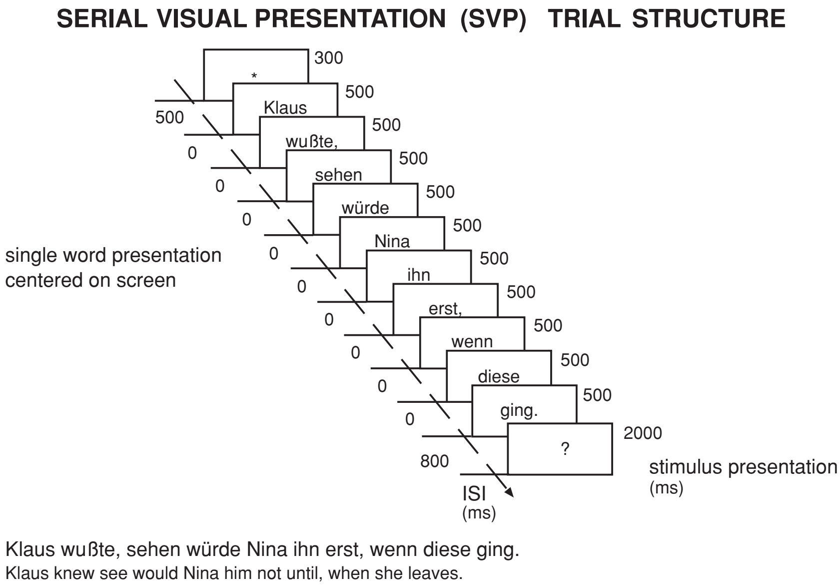

Figure 13.1: Trial structure of Experiment 7

Trial structure The trial structure was identical to Experiment 6 with the exception that it contained one additional word.

Electrophysiological Recordings The electroencephalogram (EEG) was recorded from 59 sites according to the extended 10-20 system (American Electroencephalographic Society, 1991) using tin electrodes attached to a cap. The electrode configuration is shown in figure 13.2. The EEG was recorded continuously referenced to an electrode placed on the left mastoid. The ground electrode was placed at C2. Additionally, electrical activity at the tip of the nose and the right mastoid was recorded. The vertical and horizontal electrooculogram (EOG) were recorded for the control of eye movements. Electrooccular activity was recorded from four bipolar channels. The vertical EOG was recorded from a montage above and below the right eye. The horizontal EOG was recorded from electrodes on the outer canthi.

Aquisition settings, registration and off-line processing of the continuous EEG were identical or equivalent to Experiment 6.

13.3 Results

The results section is structured into two subsections. First, the performance data of the grammatical acceptability judgment task are reported and then event related brain potential data are described.

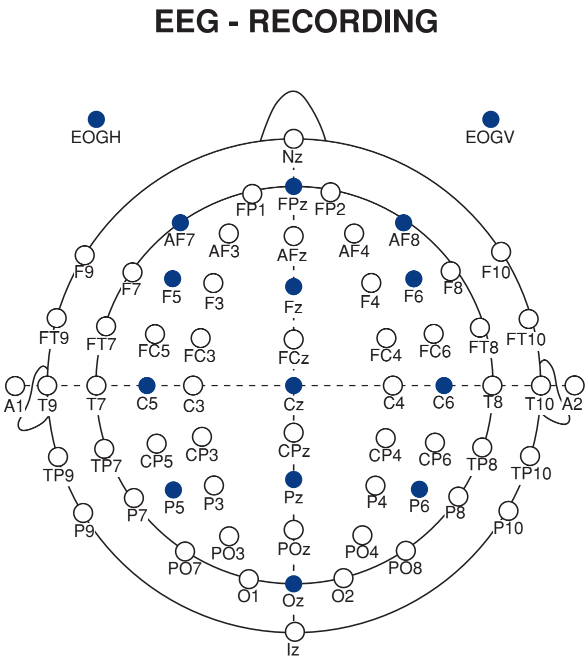

Figure 13.2: Electrode configuration. Highlighted electrodes are presented in the results section

13.3.1 Grammatical acceptability judgment task

In the following subsection response time and error analyses of the grammatical acceptability judgment task are reported. Mean judgment latencies, standard deviations and judgment errors for the conditions case and syntactic correctness are given in Table 13.1.

Table 13.1: Mean judgment latencies, standard deviations (in parenthesis) and judgment errors (second row) for the conditions case and syntactic correctness.

	accusative	dative
correct	399 (116)	397 (111)
	2.9	4.4
incorrect	409 (105)	407 (116)
	3.0	4.9

Note. Judgment latencies in ms and judgment errors in %.

Judgment latencies A repeated measures analysis of variance (ANOVA) over the judgment latencies revealed no significant effects: Syntactic correctness, $F(1, 15) = 2.87, MSE = 531, p = .11$, all other $Fs\langle 1$.

No differences in judgment latencies were observed. Participants were as fast as in the previous experiment. As in Experiment 6, the absence of latency effects effects might be accounted for by the longer preparation period that was available in the present experiment.

Judgment errors 96.2 % of all judgment responses were correct. Error percentages for the conditions case and syntactic correctness are given in Table 13.1.

An ANOVA over the judgment errors revealed no significant effects: case, $F(1, 15) = 1.67, MSE = 27, p = .21$, all other $Fs\langle 1$.

In contrast to the previous experiments, no significant effects were found in the judgment error analysis.

13.3.2 Event-related potentials

As for Experiment 6, event-related potentials of 1200ms length starting with onset of the critical pronoun and featuring a 200ms prestimulus baseline were computed separately for the four conditions for each individual participant. Subsequently, group averages (grand average, N = 16) were computed for the four conditions. Grand averages for the conditions accusative correct, accusative incorrect, dative correct and dative incorrect are shown in Figure 13.3. Figure 13.4 shows the ERPs for the accusative verbs only, and Figure 13.5 shows the ERPs for the dative verbs.

The ERPs to all four conditions showed a N1 component followed by a P2 component. The ERPs start to differ at approximately 300 ms after the onset of the critical pronoun. ERPs elicited by both incorrect conditions revealed more negative going waveforms than the respective correct conditions. In contrast to Experiment 6, the effects were not entirely found on a descending ramp. They were broadly distributed over the scalp. Also, they were descriptively larger over centro-posterior sites.

ERP quantification The ERP quantification routine was identical to Experiment 6. As the electrode montage differed from the previous experiment, new ROI definitions were required. Four equal-sized ROIs of eight electrode sites each were defined (see figure 13.2):

- Left anterior, electrodes AF7, AF3, F7, F5, F3, FT7, FC5, FC3.
- Right anterior, electrodes AF4, AF8, F4, F6, F8, FC4, FC6, FT8.
- Left posterior, electrodes TP7, CP5, CP3, P7, P5, P3, PO7, PO3.
- Right posterior, electrodes CP4, CP6, TP8, P4, P6, P8, PO4, PO8.

In the exploratory 30ms window analyses a critical time window was identified. The time range was between 300 and 500ms past onset of the critical pronoun.

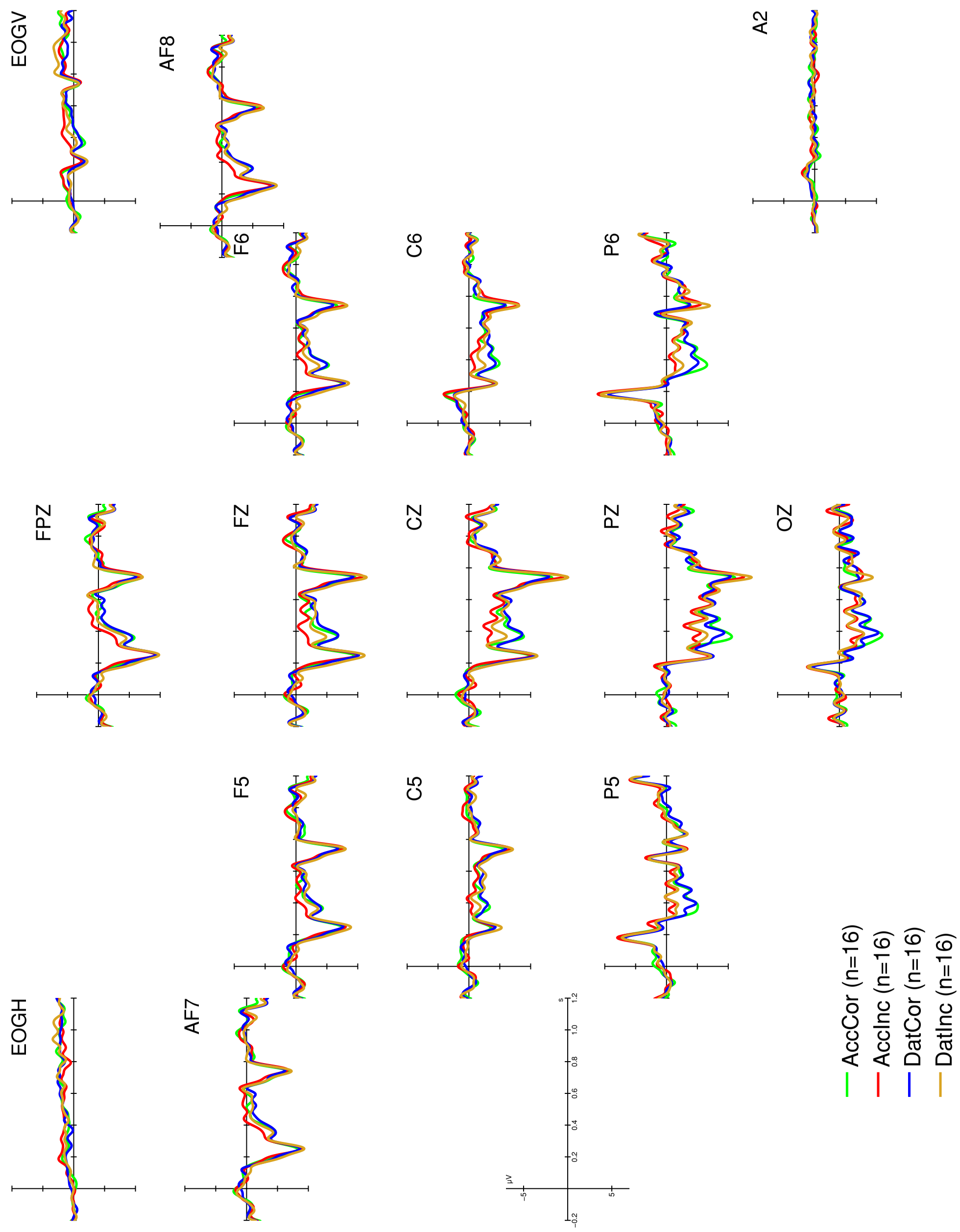

Figure 13.3: Event-related brain potentials for the pronouns in all four conditions.

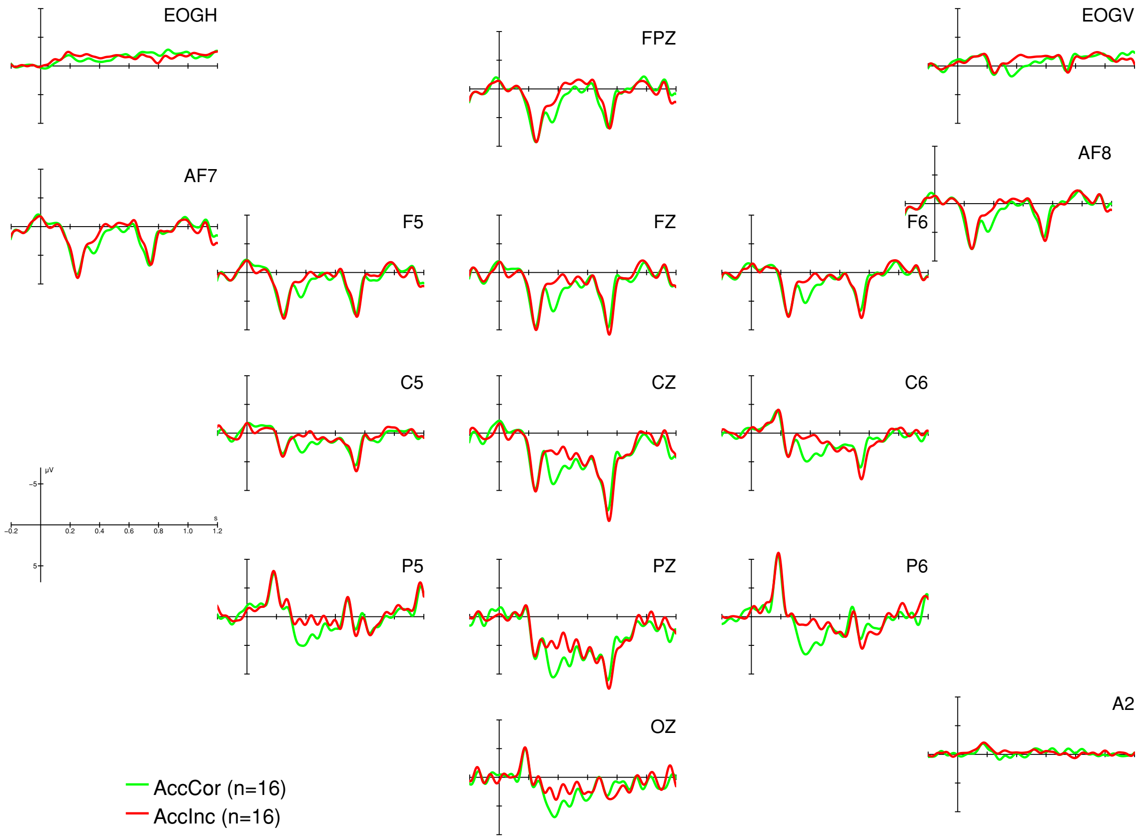

Figure 13.4: Event-related brain potentials for the pronouns in the accusative verb conditions (correct vs. incorrect).

Negativity Potential maps of the correctness main effects for accusative and dative are shown in Figure 13.6. An ANOVA over mean amplitudes in the time window between 300 and 500 ms with the factors case (accusative & dative), syntactic correctness, hemisphere and anterior/posterior was carried out. The analysis revealed a significant main effect of correctness ($F(1, 15) = 26.07, MSE = 4.67, p\langle.0001$) and the following significant interactions: case by correctness, $F(1, 15) = 4.72, MSE = 1.40, p\langle.05$ case by anterior posterior, $F(1, 15) = 6.80, MSE = 0.54, p\langle.05$ and correct by anterior/posterior, $F(1, 15) = 16.31, MSE = 1.16, p\langle.002$. No other effect was significant: Case, $F(1, 15) = 1.07, MSE = 3.70, p = .31$, correctness by hemishere, $F(1, 15) = 3.99, MSE = 0.40, p = .07$, case by correctness by hemishere, $F(1, 15) = 2.14, MSE = 0.26, p = .16$, all other $Fs\langle 1$.

The three significant interactions where delineated by subsequent analyses. The interaction of case and correctness was resolved for case. The ANOVA for the accusative conditions revealed a significant main effect of syntactic correctness $F(1, 15) = 19.52, MSE = 4.74, \langle.0005$

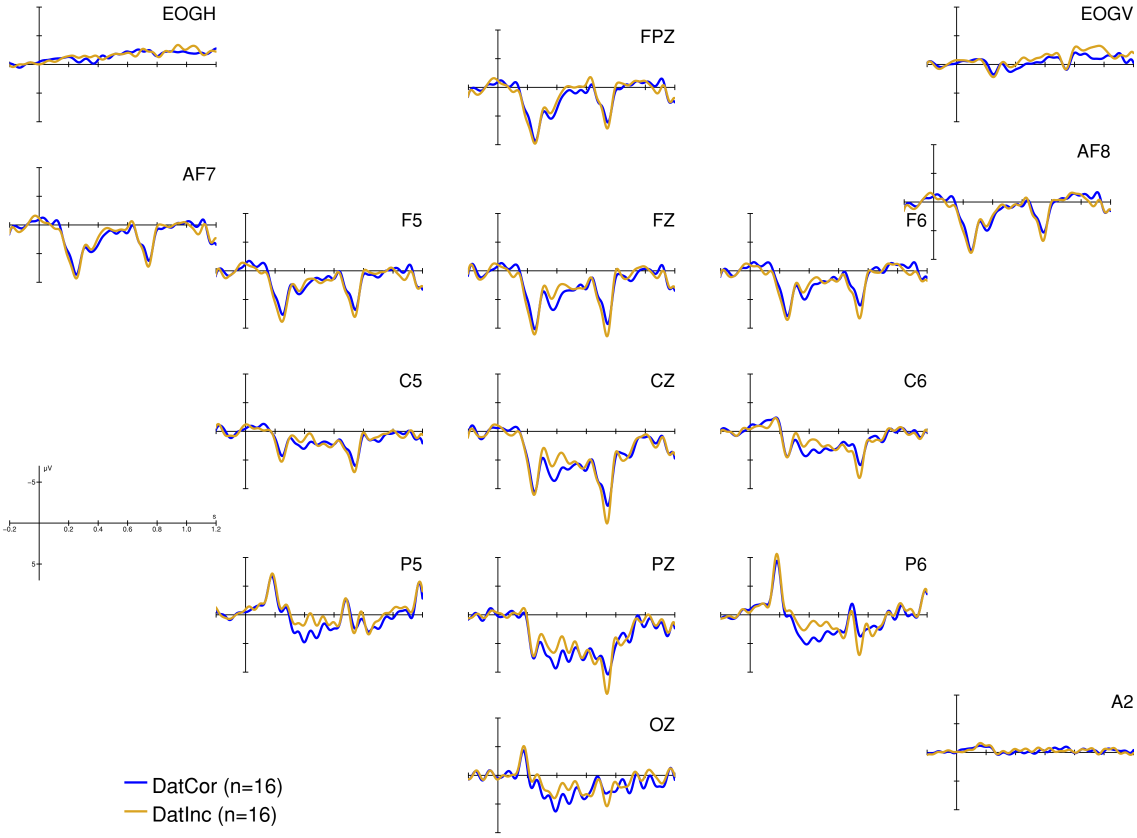

Figure 13.5: Event-related brain potentials for the pronouns in the dative verb conditions (correct vs. incorrect).

and a significant interaction of correctness and anterior/posterior $F(1,15) = 8.92, MSE = 1.04, p = .01$. No other effects were significant. The ANOVA for the dative conditions also revealed a significant main effect of syntactic correctness $F(1,15) = 26.92, MSE = 1.33, p = .0001$, and a significant interaction of correctness and anterior/posterior $F(1,15) = 11.27, MSE = 0.63, p\langle .01$. No other effects were significant. These results show that the correctness effect, present for both cases, is descriptively larger for the structural case accusative. Furthermore, the effect is larger over posterior sites for both case conditions.

The interaction of correctness by anterior/posterior sites was resolved for sites. The ANOVA for the anterior ROIs revealed a significant main effect of syntactic correctness $F(1,15) = 11.58, MSE = 2.11, p\langle .004$. No other effect was significant. [1] The ANOVA for the posterior ROIs also revealed a significant main effect of syntactic correctness $F(1,15) = 30.52, MSE = 3.72, p\langle .0001$. No other effect was significant. The correctness effect was larger over posterior sites while being broadly distributed over scalp as shown by its presence in all four ROIs.

[1] the subordinate ANOVAs are not reported in full here for reasons of readability.

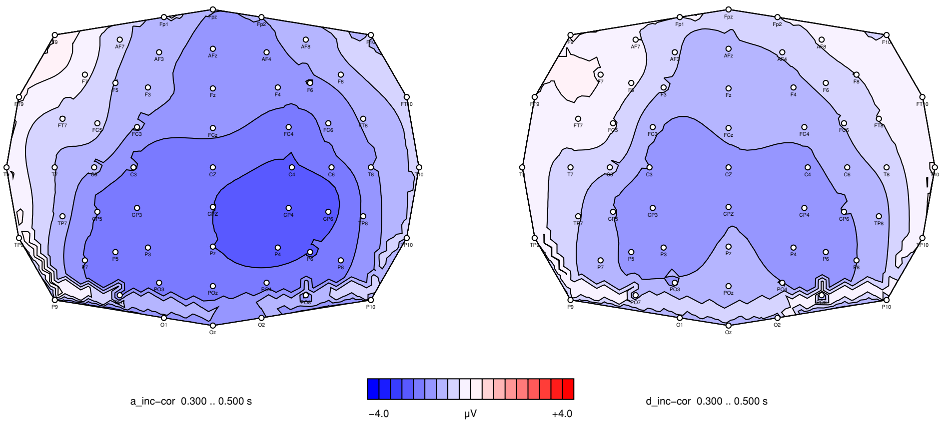

Figure 13.6: Potential maps of the correctness effects for accusative (left panel) and dative (right panel). Mean difference potentials (incorrect minus correct) in the time window between 300 and 500 milliseconds were plotted.

Finally, the interaction of case by anterior/posterior was resolved for sites. No significant effects were found in this subordinate analysis.

In sum, in this experiment with its reversed word order of case-assigning verb and object that case is assigned to, a broadly distributed, but posteriorly larger, negativity effect was found but no P600/SPS. There was a strong effect of syntactic violation, reflected in more negative going waveforms, present for both case conditions but stronger for the structural case accusative. The effect was broadly distributed, present in all four ROIs but for both cases larger over posterior sites.

This comparable negativity effect was found, despite the fact that an argument that case is assigned to instead of the case assignor and a function word instead of a content word were processed. It occurred a lot earlier than in Experiment 6. Here, a highly frequent lexical element had to be processed repeatedly instead of one out of 40 relatively low frequent and much longer verbs. Nevertheless, the same gross pattern of effects in terms of negativity effects resulted.

13.4 Discussion

The results of Experiment 7 were clear-cut. A broadly distributed, posteriorly larger, non-lateralized negativity was found for both incorrect case conditions. The effect was larger for violations of structural case than violations of inherent case.

This experiment constitutes a first replication of the syntactically elicited, broadly distributed negativity effect found in the previous experiment. In Experiment 7, the effect was, however, larger over posterior sites than over anterior ones and stronger for violations of structural case (see Figures 12.5 & 13.6). This difference can be viewed as an effect of the word order change. Furthermore, the waveforms followed a function word morphology.

The more negative going waveforms in the violation conditions than the correct conditions can be taken as an electrophysiological marker of disrupted processes of lexical integration of the incoming element into the existing structure based on a detection of the case violation. Whether or not this is based on a violation of an expectation of an element or whether this violation detection is computed on the spot is not entirely clear. Given the speed of the effect, however it is more likely, that the syntactic frame has been projected based on the case information provided earlier in the sentence by the case assigning verb.

When a violation of the expected case-marking of the object is encountered in the sentences used here, it seems likely that simply the case tag, or case index, of the object pronoun is changed. In the incorrect accusative condition, i. e., a dative-marked pronoun is presented, this process of recoindexation elicited a larger negatitivity effect than in the inherent case analogue. This can be taken as an index of deeper, more reliable processing of structural case (see Hypothesis 5.2).

No P600/SPS was observed. Such an effect seems to be confined to processing the case assignor if it is structural case. No structural reanalysis is necessary to mentally correct this type of syntactic violation. Rather, retrieving the correct lexical element or exchanging the case tag of the pronoun seems to be sufficient to remedy the sentence. Changing the case tag seems to result in a larger ERP effect for structural than for lexical case. This view seems to be supported by the absence of a P600 component.

One potential objection to Experiment 7 might be raised. This could be based on the fact the critical elements, the personal pronouns have been repeated over and over again. These high numbers of repetitions might have led the participants to develop a strategy of solving their task (grammatical acceptability judgments) on the basis of a perceptual feature match of ”m” versus ”n” rather than fully comprehending the sentence. This however appears to be unlikely, because there was an interaction of the negativity effect with case. In case of a pure feature match no such interaction should be observed given equally perceivable stimuli (like ”m” and ”n”). Also, a pure perceptual, prelinguistic feature match could be ruled out, because it would have to appear earlier during the time course, at a prelinguistic stage, not in the time-window appropriate for case processing.

To an extent, Experiment 7 can be considered a replication of the negativity results of Experiment 6. A broadly distributed, non-lateralized negativity was found for both incorrect case conditions. For a discussion of the differences see below.

13.5 Summary

This event-related brain potential (ERP) experiment investigated effects of type of verb complement (accusative or dative) on the processing of overtly accusative- or dative-marked pronominal arguments. The verbs, as the case assignor preceded the personal pronoun which served as the object-NP, realizing a case-violation between the case required by the verb (accusative or dative) and the case-marking on the pronoun in half of the sentences. The other half consisted of correct sentences. A 59 channel EEG was recorded while participants (N=16) read 200 sentences in a word-by-word SVP setting at 500ms a word in a fully counter-balanced design without fillers. Grammatical acceptability judgments were used to ensure sentence reading. The ERPs for the case-marked pronouns revealed effects of case violations. In contrast to the correct conditions, both syntactically incorrect conditions elicited more negative going waveforms in the time window between 300 and 500 ms after stimulus onset, that were broadly distributed, larger over posterior sites and non-lateralized. Violations of the accusative, which linguistically can be labeled structural case, resulted in a larger negativity at posterior sites than dative. There was no reliable P600. The data revealed the time window of the processing of case information marked on pronouns. The difference in size of the effect between both violation conditions could indicate that recoindexation of the default case was harder than vice versa.

13.6 General Discussion of Experiments 6 and 7

Both ERP experiments investigated the processing characteristics of structural and inherent case more closely. In particular, the time course of case processing during verb (Experiment 6) and verb object processing (Experiment 7) during sentence comprehension was investigated.

As in all experiments of this study, pure case errors were used. Care was taken that there was no involvement of predictions based on semantic grounds. The verbs used had identical verb-argument structures and sentence phrase structure was identical in all conditions. Furthermore, in the violation conditions no reanalysis of a syntactic sentence structure was necessary. Solely, a change of the case tag associated with the verb object was necessary to repair the sentence. This, apparently, involved different processes in the two ERP experiments. When the violation was encountered on the case assigning verb (Experiment 6), a late positivity, potentially indicating processes of reanalysis, was observed for the structural case condition but not for inherent case. No late positivity effects were found in Experiment 7. This might be accounted for by the fact that the case assigning verb had been processed prior to the critical pronominal object. As the case of the object was already determined by the verb, no processes of reanalysis of the sentence structure were necessary, solely a change of the case tag of the object was required. This might be reflected by earlier negativities as well.

For the negativity effect in Experiment 6, only a correctness effect was found in the statistical analyses. It was broadly distributed over the scalp. There was no interaction with case, thus indicating that the effect was not larger for either of the two case conditions. It can be assumed that the syntactic parser predicted a verb slot in the syntactic sentence structure that featured a case tag congruent with the case information marked on the clause-initial wh-pronoun. The negativity effects found then reflected the violation of this syntactic expectation and subsequent difficulties of lexical integration of the critical element into the sentence structure.

In contrast, in Experiment 7 there were significant interactions in addition to the main effect of syntactic correctness. In this experiment the syntactic parser has projected a case-marked object slot on the basis of the complement information associated with the case-assigning verb. While the correctness effect was present in both the structural as well as the inherent case condition, it was larger for the structural case accusative. In addition, in Experiment 7 there was a significant interaction of syntactic correctness and anterior/posterior ROIs. While present in all four ROIs, the correctness effect was larger over posterior sites, which constituted another difference from Experiment 6. Taken together, the two interaction effects present in Experiment 7 but not in Experiment 6 indicate that additional or other neural generators and thus cognitive processes might be involved in processing the word order variation of the syntactic violations in Experiment 7 as compared to Experiment 6. This dissociation between experiments is taken to reflect different processes of syntactic parsing as induced by the word order variation between experiments and the use of pronoun objects as critical elements instead of case-assigning verbs.

Processing of structural and inherent case was dissociated in both experiments. Structural revealed a qualitative difference in Experiment 6, a late positivity, and a quantitative effect in Experiment 7, a larger negativity.

Clearly, the negativity effects reflect detecting the case violations and dependent difficulties of lexical integration (Friederici, 1995) of the incoming lexical element into the existing sentence structure.

The negativity effects were not predominantly left anterior but rather broadly distributed. Consequently, their topography clearly does not fit the LAN descriptors. There were a number of studies reported in the literature, however, that did not report a LAN or anterior negativity elicited by syntactic violations (see Section 4.5, pp. 41). Given the purely syntactic nature of the experimental manipulation and the morphology of the wave forms the N400 does not seem to be a likely candidate, as well. Hence, despite its broad distribution, the negativity effect found in these two experiments appears to be more related to the LAN than the N400 for reasons of its syntactic nature.

However, there are potential alternative explanations: (a) the negativity effect reflects re-accessing the critical element in the lexicon (Hopf et al., 1998), (b) it was induced by the secondary task, and (c) it represents a new ERP deflection.

As mentioned above, Hopf et al. (1998) found a negativity elicited by case ambiguities that they interpreted as a N400. Beside the fact that are problematic aspects in their study that render its interpretation difficult, the negativity effect found in Experiment 6 is low amplitude and entirely on the descending, positive going ramp of the ERP. It is broadly distributed and it does not follow N400 morphology. In Experiment 7 it is also broadly distributed and does not show a N400 morphology.

The second potential alternative explanation is based on an account of a task-dependent differential effect of the secondary grammatical acceptability judgment task. That is, judging a sentence as incorrect affects the ERP differently than judging it correct. The secondary task was identical in Experiments 6 and 7. Also the ERP effect was broadly distributed in both experiments. However, there was an additional topographical effect present in Experiment 7 that was not present in Experiment 6. If the ERP effects were task-induced, they should have been identical in both experiments given the identical task. They were not, which argues against an account of the ERP effects as induced by the secondary task. Experiment 7 has revealed a larger ERP effect for the accusative violation condition than for the dative conditions, while there was no effect whatsoever in the performance data. If ERP effect was task-related than there should also be an effect in the performance data. This was not the case, hence such an explanation is unlikely. Experiment 5 has demonstrated an RT effect of case violation in a comparable sentence comprehension setting but also without a secondary task. Thus there is an effect of case violation in sentence comprehension without the secondary task and, given the reports in the literature it can be considered unlikely that it would not be picked up by the ERP method. Nonetheless, systematic effects of secondary task on language processing ERPs certainly merit further systematic investigation (see also Section 4.3, pp. 39).

Finally, further systematic investigation is required in order to be able to determine whether or not the negativity effect found in the present study can be considered an ERP deflection in its own right. There have been other reports of syntactically triggered negativity effects in the critical time range that did not fit the LAN descriptors (see Section 4.5 on page 41). The result by Osterhout et al. (1994) is particularly relevant as they found a N400 elicited by a subcategorization violation (see same section).

Time courses of the negativity effects The following section provides a comparison of the times courses of the two negativity effects found in Experiments 6 and 7. The effect occurred approximately 180ms later in Experiment 6 than 7. This can be accounted for by the following facts. The verbs used in Experiment 6 were longer content words. On average, they were of lower frequency of use as the frequently used function words used as critical elements in Experiment 7. These factors determined the time course of lexical access. The time courses of the ERP effects indicated that the availability of case information and its use in syntactic structure building occurred 180ms earlier in Experiment 7.

On the P600/SPS-P300 debate The P600/SPS-P300 debate has been briefly introduced in Section 4.5, pp. 41. If the P600 reflected P3b-type processes of context updating then why should these only occur for the structural case condition. The task was identical for both case conditions, its results showed that the violation has been processed for both case conditions Hence, the participants were aware of the violation in both case conditions which should have resulted in a positive ERP effect for both violation conditions if the P600 were to reflect conscious detection of the violation in terms of a P3b.

Part III

General Discussion & Conclusion

Chapter 14

General Discussion

When in Chapter 5 the research questions and goals of this thesis were developed, strings from theoretical linguistics, psycholinguistics and psychophysiology were pulled together in order to investigate characteristics of processing morphological structural and inherent case. Three main questions were posed and specific hypotheses were developed. This general discussion proceeds through these issues.

Processing characteristics as measured by off-line tasks The grammatical acceptability judgment task as well as a sentence completion task were used as off-line tasks in this study.

In all experimental sentences of this study pure case errors were used. There was no possibility of involvement of semantic predictions, because of the way sentences were constructed. Identical verbs featuring identical verb-argument structures were embedded in sentences with identical phrase structures. No reanalysis of the sentence's phrase structure was necessary. This procedure was used to isolate the level of case processing experimentally.

Grammatical acceptability judgments were obtained in Experiment 1 and as a secondary task in Experiments 4 to 7.

Experiment 1 (see Chapter 7) provided clear evidence that native speakers of German process accusative and dative case marking correctly in an off-line grammatical acceptability judgment task. Case was marked on a sentence-initial wh-pronoun. The critical element was the case-assigning verb in an OSV question construction.

The error pattern was descriptively identical in all five replications of the measure. There were main effects for correctness, and case and an interaction of the two factors in Experiments 4, 5 and 6 (Experiment 1 not tested, Experiment 7 not significant). Dative is harder to judge than accusative. In these experiments, incongruently presented dative-assigning verbs accounted for the main effect of correctness and the interaction. Participants had the tendency to accept these sentences as correct. This pattern of results confirmed Hypotheses 5.2 and 5.3.

There were significant judgment latency effects in Experiment 4. The fact these results were not obtained in Experiment 5 shows that the latency effects are contingent on practice, repetition and task load. Participants were presented with more repetitions in Experiment 5 and this made the latency effects disappear. Furthermore, there were no latency effects in Experiments 6 and 7. In these experiments participants had several seconds to prepare for the judgment.

Dative is a special marked case in German (see Chapter 2). Accordingly, one might expect that as a consequence of its markedness more resources are allocated to processing it and thus it is processed more reliably than the default case. This clearly did not occur in the present study and Hypothesis 5.2 was clearly confirmed. The GAJT, multiply replicated, showed that incorrectly presented dative cases are more likely to accepted as correct than any other condition in the experiments.

Processing characteristics as measured by on-line tasks The naming RT Experiments 4 and 5 revealed that the case congruency effect has to be fast enough to affect the naming response of the critical verb.

Also, there were effects of case congruency on on-line sentence comprehension without the secondary grammatical acceptability judgment task in Experiment 5.

The point in time when the ERP effect sets in marks the latest time point for the detection of the case incongruency (see Rugg & Coles, 1995)).

The time-course results from all four on-line experiments are in line with the predictions made by the Friederici model (see Chapter 4. The case congruency effect sets in earliest in the second parsing phase, the phase of lexical integration. The current sentence constituent is integrated into the current partial phrase marker. After word category has been used for the first pass parse in Phase 1, case information is used in the second phase.

The actual processes are dependent on the sentence structure. While Experiments 4 to 6 used OSV wh-constructions. Here the case-assigning verb was the critical element in the sentence, Experiment 7 reversed the order of the sentence constituents in VSO constructions. Here, the case-assigning verb is processed before the critical element is encountered. The word order mattered. While the OSV constructions revealed a P600 for structural case, an indicator of reanalysis or repair, no P600 was obtained for the VSO construction. It appeared that merely changing the case tag of the object was sufficient to remedy the situation.

The very fast time course of the congruency effects in Experiment 7 suggested that the current partial phrase marker contained a projected object slot for the critical element.

A comparison of the time-courses of the case congruency effect obtained in Experiments 4, 5 and 6 showed that the ERP effect set in 80 (Exp. 5) to 170 milliseconds (Exp. 6) earlier than the average response latency of the RT experiments.

Structural and inherent case were dissociated in both ERP experiments. In Experiment 6 using the case-assigning verb as the critical element in an OSV construction, a late positivity effect was observed only for structural case. This effect is taken as indicative of processes of reanalysis or repair. Confirming Hypothesis 5.2, structural case was processed more reliably than inherent case. In Experiment 7, violations of structural case elicited a larger negativity effect than inherent case. This is taken to reflect deeper, more reliable processing of structural case.

In Experiment 4, solely a correctness main effect of target naming latency was obtained. This pattern of results confirmed Hypothesis 5.2, but does not permit confirmation of 5.3. Also, in Experiment 6, which used analogous OSV constructions, the earlier negativity revealed a main effect of correctness. The qualitative difference between structural and inherent case confirming Hypothesis 5.3 was picked up in the ERP measure in the late positivity. This latter effect might also have been present in Experiment 4, but might have occurred too late in order to be detected by the RT measure.

The negativity results that were obtained in both ERP studies did not show left anterior distributions as was predicted. On the other hand, there were a number of studies in the literature that reported syntactically elicited negativities that did not feature a left anterior distribution (see also Chapter 4). The time course information of the effects nonetheless is valid in any case.

Note that the CMNT did not reveal qualitative differences between processing structural and inherent case, while the ERP method did.

Converging empirical evidence for the concepts of structural and inherent case The distinction of structural and inherent case has been found to be reflected in a number of empirical measures used in this study.

The lexical-statistical frequency analysis of the Celex verb-complement structure data reported in Chapter 6 added to the theoretical distinction between structural and inherent case reported in the introduction (see Chapter 2).

The sentence completion studies (Experiments 2 & 3) revealed a feature hierarchy of case, auxiliary verb [1] and verb-argument structure information. Case and auxiliary information are processed more reliably than verb-argument structure information.

Dative as an inherent case for verb objects has to be learned for each individual item during language acquisition. This can be done in more of less accurately. The grammatical acceptability judgment data, overall, can be interpreted as evidence for the distinction of structural and inherent case and as evidence for an eroding case system in German as well. Lexical inherent case (dative) is relatively frequently overridden. In cases of uncertainty the default case accusative is accepted or used.

Interindividual differences A systematic investigation of interindividual differences was beyond the scope of this study. These differences were mainly treated as error variance. Performance outliers were excluded from the analysis. This holds for both ends of the spectrum. While participants showing poor performance were excluded as it is common procedure, also a

[1](*"Ich habe fertig." / "I have done." instead of "I am done." This linguistic error by Italian soccer coach Giovanni Trappatoni is funny for Germans, because it represents a very rare error.)

very well performing participant had to be excluded from the study (Experiment 3). This individual performed flawlessly on the sentence completion task and by far outperformed her peers. She was trained as a professional translator. Undoubtedly, her performance revealed long-term effects of her professional training.

The performance outliers of this study taken together suggest that there is considerable variability between native speakers of German regarding the capability of processing structural and inherent case. Given the results of this study, inherent case is affected substantially more than structural case. Trivially, these differences can be vastly influenced by education.

Open issues and future directions The present study could confirm a number of findings regarding processing characteristics of structural and inherent case. As this was the first systematic investigation of this contrast between two linguistic case concepts, there are, naturally, a number of open issues that await further systematic investigation.

Most prominently, the partly diverging findings of the ERP experiments compared to other ERP studies with at least related goals (Hopf et al., 1998; Friederici & Frisch, submitted; Coulson et al., 1998; Rösler et al., 1998) need to be illuminated. As discussed above, these experiments differed on a number of dimensions, these need to be varied systematically in careful experimentation. Furthermore, studies that aim at localizing neural generators of the processes involved along with the time courses of their activation would be fruitful in order to further disentangle the complex pattern of processes involved in processing structural and inherent case in sentence comprehension.

Various experimental parameters need to be evaluated systematically. In particular, the secondary task used, if any, the proportion of critical sentences and filler and finally reading versus listening need to be investigated.

The ERP effects obtained in this study could be systematically differentiated from effects of semantics (N400), processing thematic roles, processing violations of structural case only (LAN/P600), frequency of use of specific cases in specific sentence types. Also, more natural porcessing conditions could be tested, like, for instance, listening to paragraphs that contain a smaller proportion of errors than the Experiments of the present study. Unfortunately, all these further investigations were beyond the scope of this thesis.

Chapter 15

General Summary and Conclusion

In the present study behavioral off-line and on-line techniques as well as electrophysiological online measures were used to investigate the processing of morphological structural and inherent case in sentence comprehension. The central experimental manipulation consisted of a variation of the object case encoded in the complement structure of two sets of verbs. Accusative (structural) and dative case (inherent) were used.

A lexical-statistical analysis of Celex data on verb-complement structures reported in Chapter 6 added to the theoretical distinction between structural and inherent case reported in the introductory chapter on linguistics (Chapter 2). Experiment 1 (Chapter 7) provided clear evidence that native speakers of German process accusative and dative case marking correctly in an off-line grammatical acceptability judgment task.

In experiments 2 and 3 evidence that structural and inherent case are processed correctly in an off-line sentence processing task with more degrees of freedom than the GAJT was produced. In addition the experimental setting for the subsequent on-line sentence comprehension experiments was validated.

Experiments 4 and 5 revealed that structural and inherent case information encoded in the verb-complement structure are processed fast enough in coreference with syntactic sentence structure to influence the naming of the verb target itself.

Experiments 6 and 7 used scalp-recorded event-related brain potentials in order to investigate case processing characteristics in sentence comprehension and especially its time course more closely.

Participle verbs were used as critical elements in wh-object subject verb constructions. More negative going deflections in the time range between 480 to 780 milliseconds after onset of the critical element were obtained as well as a late positivity for incongruently presented verbs featuring structural case.

In Experiment 7 pronouns were used as critical element in verb subject object constructions revealing negativity effects in the time range between 300 - 500 millseconds after onset of the critical element.

All experimental effects that were obtained were replicated within the study.

In the present study, the linguistic concepts of structural and inherent case were operationalized in an effort to isolate their processing in psycholinguistic experiments. Using this approach an aspect of sentence comprehension was investigated. The processing characteristica that were obtained and described above are accomodated be the sentence comprehension model by Friederici (1995).

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Part IV

Appendix

Appendix A

A.1 CELEX complete complementation

CELEX notation for functions of complements (000000000)
Position contents

- 1 Subject, always empty unless it is ”es”
- 2 Subject complement
- 3 Accusative complement
- 4 Second accusative complement
- 5 Dative complement
- 6 Genitive complement
- 7 Prepositional complement
- 8 Second prepositional complement
- 9 Adverbial complement

A.2 Potential factors modulating language ERPs

- Presentation rate of visually presented sentence constituents
- Word-by-word versus phrase-wise presentation in reading
- Paused versus non-paused presentation (ISI duration)
- Syntactic violation versus not (e.g. ambiguities)
- Type of secondary task (attention drawn to critical item)
- Semantic versus non-semantic context
- Discourse level context versus not
- Number of distinct critical items
- Number of critical positions in a sentence
- Number of violations per block
- Artificial sentences versus natural passages
- Punctuation: present versus absent
- Filler sentences: present versus absent
- Isolated sentences versus passages

Appendix B

Experiment Materials

B.1 Material Experiment 1

Accusative (Wh-pronoun for incorrect condition in parentheses)
Wen(wem) hat Peter abgelöst, als er letzte Woche seine neue Stelle antrat?
Wen(wem) hat Frank abgewehrt, als seine Einheit angegriffen wurde?
Wen(wem) hat Hans angegriffen, weil er sich so bedroht fühlte?
Wen(wem) hat Petra aufgestachelt, als sie eine Rede hielt?
Wen(wem) hat Jutta aufgesucht, um sich behandeln zu lassen?
Wen(wem) hat Heinz ausgebildet, während er als Lehrer tätig war?
Wen(wem) hat Mark ausgenutzt, als er kein Geld mehr hatte?
Wen(wem) hat Arne bedauert, nachdem der Professor verstorben war?
Wen(wem) hat Jan bedroht, als er in die Bank stürmte?
Wen(wem) hat Ellen begrüßt, während sie gestern im Vereinshaus war?
Wen(wem) hat Katja bejubelt, während die Parade vorbeizog?
Wen(wem) hat Paul belogen, als er von Reue sprach?
Wen(wem) hat Meike bemerkt, als sie aus dem Fenster blickte?
Wen(wem) hat Volker beschattet, als er neulich Detektiv spielte?
Wen(wem) hat Marie beschimpft, weil dessen Hund die Straße beschmutzte?
Wen(wem) hat Lothar bewundert, weil sie so herrlich singen konnte?
Wen(wem) hat Agnes eingeladen, um ihren Geburtstag zu feiern?
Wen(wem) hat Anja entlarvt, nachdem sie den Gentest anordnete?
Wen(wem) hat Beate ermordet, als sie im Vollrausch war?
Wen(wem) hat Birgit erwähnt, als sie den Jahresbericht vorlegte?
Wen(wem) hat Klaus gefährdet, als er neulich betrunken Auto fuhr?
Wen(wem) hat Claudia umarmt, während sie die Gäste begrüßte?
Wen(wem) hat Karl umgebracht, weil er vor Wut außer sich war?
Wen(wem) hat Jörg verfehlt, als er auf sie schoß?
Wen(wem) hat Doris verflucht, nachdem ihr Auto zerkratzt wurde?
Wen(wem) hat Jens verhört, nachdem die Razzia durchgeführt wurde?
Wen(wem) hat Hubert wahrgenommen, als er aufblickte?

Dative (Wh-pronoun for incorrect condition in parentheses)
Wem(wen) hat Werner aufgeholfen, als draußen Glatteis war?
Wem(wen) hat Horst aufgelauert, als er sich hinter der Hecke verbarg?
Wem(wen) hat Elke beigepflichtet, als sie ihre Argumente vorbrachte?
Wem(wen) hat Gregor beigestanden, als es darauf ankam?
Wem(wen) hat Georg heimgeleuchtet, als er so aufgebracht war?
Wem(wen) hat Frieda mißtraut, nachdem das Geschäft geplatzt war?
Wem(wen) hat Franz nachgeblickt, während er auf der Promenade stand?
Wem(wen) hat Gerda nachgeeifert, als sie sich so sehr anstrengte?
Wem(wen) hat Felix nachgespürt, als er im Archiv war?
Wem(wen) hat Vera nachgetrauert, nachdem sie verlassen wurde?
Wem(wen) hat Erich nachgewunken, als der Zug abfuhr?
Wem(wen) hat Edgar übelgewollt, nachdem er betrogen wurde?
Wem(wen) hat Rita widerstanden, als sie im Club Urlaub machte?
Wem(wen) hat Dieter zugeblinzelt, als er sie in der Straßenbahn wiedererkannte?
Wem(wen) hat Martha zugejubelt, nachdem das Spiel gewonnen war?
Wem(wen) hat Daniel zugelacht, als er den Raum betrat?
Wem(wen) hat Magda zugelächelt, als sie in die Bar kam?
Wem(wen) hat Benno zugenickt, als er begrüßt wurde?
Wem(wen) hat Kirsten zugeprostet, während sie gestern am Stammtisch saß?
Wem(wen) hat Anton zugeredet, weil dessen Probleme übergroß schienen?
Wem(wen) hat Judith zugestimmt, nachdem die Diskussion beendet war?
Wem(wen) hat Achim zugezwinkert, als er neulich im Café saß?

B.2 Material Experiment 2

The material of Experiment 2 consisted of 72 sentence fragments (see section 8.2.2 on page 76).

01 Wen/Wem hat Jutta, 02 Wen/Wem hat Heinz, 03 Wen/Wem hat Mark, 04 Wen/Wem hat Arne, 05 Wen/Wem hat Jan, 06 Wen/Wem hat Paul, 07 Wen/Wem hat Meike, 08 Wen/Wem hat Marie, 09 Wen/Wem hat Lothar, 10 Wen/Wem hat Anja, 11 Wen/Wem hat Beate, 12 Wen/Wem hat Birgit, 13 Wen/Wem hat Klaus, 14 Wen/Wem hat Claudia, 15 Wen/Wem hat Karl, 16 Wen/Wem hat Jörg, 17 Wen/Wem hat Doris, 18 Wen/Wem hat Jens, 19 Wem/Wen hat Werner, 20 Wem/Wen hat Elke, 21 Wem/Wen hat Gregor, 22 Wem/Wen hat Frieda, 23 Wem/Wen hat Felix, 24 Wem/Wen hat Vera, 25 Wem/Wen hat Erich, 26 Wem/Wen hat Edgar, 27 Wem/Wen hat Rita, 28 Wem/Wen hat Dieter, 29 Wem/Wen hat Martha, 30 Wem/Wen hat Daniel, 31 Wem/Wen hat Magda, 32 Wem/Wen hat Benno, 33 Wem/Wen hat Kirsten, 34 Wem/Wen hat Anton, 35 Wem/Wen hat Judith, 36 Wem/Wen hat Achim,

B.3 Material Experiment 3

The material of Experiment 3 was an auditory version of the material of Experiment 2 and is given in Appendix B.2.

B.4 Material Experiment 4

The material of Experiment 4 consisted of an auditory sentence preamble that was identical to Experiments 2 & 3 in terms of words as well as physically identical to Experiment 3 and a critical target verb (see procedure section of Experiment 4).

Accusative (Wh-pronouns for incorrect condition in parentheses)
Wen (Wem) hat Jutta aufgesucht? (aufsuchen 18),
Wen (Wem) hat Heinz ausgebildet? (ausbilden 27),
Wen (Wem) hat Mark ausgenutzt? (ausnutzen 25),
Wen (Wem) hat Arne bedauert? (bedauern 34),
Wen (Wem) hat Jan bedroht? (bedrohen 47),
Wen (Wem) hat Paul belogen? (belügen 3),
Wen (Wem) hat Meike bemerkt? (bemerken 68),
Wen (Wem) hat Marie beschimpft? (beschimpfen 8),
Wen (Wem) hat Lothar bewundert? (bewundern 23),
Wen (Wem) hat Anja entlarvt? (entlarven 14),
Wen (Wem) hat Beate ermordet? (ermorden 25),
Wen (Wem) hat Birgit erwähnt? (erwähnen 69),
Wen (Wem) hat Klaus gefährdet? (gefährden 47),
Wen (Wem) hat Claudia umarmt? (umarmen 6),
Wen (Wem) hat Karl umgebracht? (umbringen 17),
Wen (Wem) hat Jörg verfehlt? (verfehlen 14),
Wen (Wem) hat Doris verflucht? (verfluchen 8),
Wen (Wem) hat Jens verhört? (verhören 4),

Dative (Wh-pronouns for incorrect condition in parentheses)
Wem (Wen) hat Werner aufgeholfen? (aufhelfen 0),
Wem (Wen) hat Elke beigepflichtet? (beipflichten 1),
Wem (Wen) hat Gregor beigestanden? (beistehen 2),
Wem (Wen) hat Frieda mißtraut? (mißtrauen 4),
Wem (Wen) hat Felix nachgespürt? (nachspüren),
Wem (Wen) hat Vera nachgetrauert? (nachtrauern 0),
Wem (Wen) hat Erich nachgewunken? (nachwinken 0),
Wem (Wen) hat Edgar übelgewollt? (übelwollen 0),
Wem (Wen) hat Rita widerstanden? (widerstehen 8),
Wem (Wen) hat Dieter zugeblinzelt? (zublinzeln 0),
Wem (Wen) hat Martha zugejubelt? (zujubeln 1),
Wem (Wen) hat Daniel zugelacht? (zulachen 0),
Wem (Wen) hat Magda zugelächelt? (zulächeln 1),
Wem (Wen) hat Benno zugenickt? (zunicken 1),
Wem (Wen) hat Kirsten zugeprostet? (zuprosten 0),
Wem (Wen) hat Anton zugeredet? (zureden 1),
Wem (Wen) hat Judith zugestimmt? (zustimmen 44),

Wem (Wen) hat Achim zugezwinkert? (zuzwinkern 0),

Practice sentences (Wh-pronouns for incorrect condition in parentheses)
Wen (Wem) hat Hans angegriffen? (angreifen 18),
Wen (Wem) hat Petra aufgestachelt? (aufstacheln 0),
Wen (Wem) hat Volker beschattet? (beschatten 3),
Wen (Wem) hat Agnes eingeladen? (einladen 57),
Wem (Wen) hat Horst aufgelauert? (auflauern 2),
Wem (Wen) hat Georg heimgeleuchtet? (heimleuchten 1),
Wem (Wen) hat Franz nachgeblickt? (nachblicken 0),
Wem (Wen) hat Gerda nachgeeifert? (nacheifern 1),

B.5 Material Experiment 5

The material of Experiments 5 was identical to the Material of Experiment 4 (see Appendix B.4).

B.6 Material Experiment 6

B.6.1 Verbs

Critical verbs of Experiment 6 in infinitive form, experimental pariticiple forms and subset assignments are given in parentheses (see procedure section of Experiment 6).

Accusative abbilden (abgebildet 1), abdrängen (abgedrängt 2), ablehnen (abgelehnt 1), abmahnen (abgemahnt 2), ächten (geächtet 1), anbeten (angebetet 2), anfeuern (angefeuert 1), angreifen (angegriffen 2), aufmuntern (aufgemuntert 1), aufstacheln (aufgestachelt 1), aufsuchen (aufgesucht 2), ausbilden (ausgebildet 1), ausnutzen (ausgenutzt 2), belügen (belogen 2), einladen (eingeladen 1), heimsuchen (heimgesucht 2), impfen (geimpft 1), kennen (gekannt 2), ködern (geködert 1), liebgewinnen (liebgewonnen 2), losschicken (losgeschickt 1), meiden (gemieden 2), mitnehmen (mitgenommen 1), mustern (gemustert 1), nachahmen (nachgeahmt 2), peinigen (gepeinigt 1), rauswerfen (rausgeworfen 2), rügen (gerügt 1), schinden (geschunden 2), schocken (geschockt 1), sichten (gesichtet 2), spüren (gespürt 1), streicheln (gestreichelt 2), testen (getestet 1), überfahren (überfahren 2), übersehen (übersehen 1), umbringen (umgebracht 2), umstimmen (umgestimmt 1), umwerben (umworben 2), verdreschen (verdroschen 1), verkennen (verkannt 2), vernehmen (vernommen 1), vorladen (vorgeladen 2), vormerken (vorgemerkt 1), vorwarnen (vorgewarnt 2), wachhalten (wachgehalten 1), wachrütteln (wachgerüttelt 2), wahrnehmen (wahrgenommen 1), wegstoßen (weggestoßen 2), zudecken (zugedeckt 2),

Dative ähneln (geähnelt 1), aufhelfen (aufgeholfen 2), auflauern (aufgelauert 1), aushelfen (ausgeholfen 2), beipflichten (beigepflichtet 1), beistehen (beigestanden 2), danken (gedankt 1), dienen (gedient 2), drohen (gedroht 1), einheizen (eingeheizt 2), gehorchen (gehorcht 1), heimleuchten (heimgeleuchtet 1), helfen (geholfen 2), huldigen (gehuldigt 1), lauschen (gelauscht 1), mißtrauen (mißtraut 2), nachblicken (nachgeblickt 1), nacheifern (nachgeeifert 2), nachgeben (nachgegeben 1), nachhelfen (nachgeholfen 2), nachspüren (nachgespürt 1), nachstellen (nachgestellt 2), nachtrauern (nachgetrauert 1), nachweinen (nachgeweint 2), nachwinken (nachgewunken 1), schaden (geschadet 2), schmeicheln (geschmeichelt 1), trotzen (getrotzt 2), vertrauen (vertraut 1), verzeihen (verziehen 2), vorstehen (vorgestanden 1), widersprechen (widersprochen 2), widerstehen (widerstanden 1), winken (gewunken 2), zublinzeln (zugeblinzelt 1), zugucken (zugeguckt 2), zuhören (zugehört 1), zujubeln (zugejubelt 2), zulachen (zugelacht 1), zulächeln (zugelächelt 2), zunicken (zugenickt 1), zuprosten (zugeprostet 2), zuraten (zugeraten 1), zureden (zugeredet 2), zuschauen (zugeschaut 1), zuspielen (zugespielt 2), zusprechen (zugesprochen 1), zustimmen (zugestimmt 2), zutrinken (zugetrunken 2), zuwinken (zugewunken 2),

B.6.2 Sentences

Accusative (Wh-pronouns for incorrect condition in parentheses)
Er erfuhr, wen(wem) Anja abgebildet hat, bevor sie ging.
Sie erzählte, wen(wem) Lukas abgedrängt hat, bevor er ging.
Sie erfuhr, wen(wem) Tobias abgelehnt hat, bevor er zurückkam.
Er bemerkte, wen(wem) Nina abgemahnt hat, nachdem sie zurückkam.
Sie bemerkte, wen(wem) Jonas angebetet hat, bevor er losfuhr.
Er wußte, wen(wem) Anna angefeuert hat, nachdem sie losfuhr.
Er erkannte, wen(wem) Vera angegriffen hat, nachdem sie ankam.
Sie wußte, wen(wem) Thomas aufgemuntert hat, nachdem er ankam.
Er erzählte, wen(wem) Lisa aufgestachelt hat, bevor sie abfuhr.
Sie erkannte, wen(wem) Andreas aufgesucht hat, bevor er abfuhr.
Sie erzählte, wen(wem) Lukas ausgebildet hat, bevor er ging.
Er beschrieb, wen(wem) Anja ausgenutzt hat, nachdem sie ging.
Sie beschrieb, wen(wem) Tobias belogen hat, nachdem er zurückkam.
Sie erfuhr, wen(wem) Tobias überfahren hat, bevor er zurückkam.
Er berichtete, wen(wem) Vera übersehen hat, nachdem sie ankam.
Er bemerkte, wen(wem) Nina eingeladen hat, nachdem sie zurückkam.
Sie bemerkte, wen(wem) Jonas geächtet hat, bevor er losfuhr.
Er erkannte, wen(wem) Vera geimpft hat, nachdem sie ankam.
Sie erkannte, wen(wem) Andreas geködert hat, bevor er abfuhr.
Er erwähnte, wen(wem) Anna gekannt hat, bevor sie losfuhr.
Sie erwähnte, wen(wem) Thomas gemieden hat, bevor er ankam.
Er beschrieb, wen(wem) Anja gemustert hat, nachdem sie ging.
Sie beschrieb, wen(wem) Tobias gepeinigt hat, nachdem er zurückkam.
Er erwähnte, wen(wem) Anna gerügt hat, bevor sie abfuhr.
Sie erwähnte, wen(wem) Thomas geschockt hat, bevor er ankam.
Er beobachtete, wen(wem) Lisa geschunden hat, nachdem sie abfuhr.

Sie beobachtete, wen(wem) Lukas gesichtet hat, nachdem er ging.
Er beobachtete, wen(wem) Lisa gespürt hat, bevor sie losfuhr.
Er zeigte, wen(wem) Nina gestreichelt hat, bevor sie zurückkam.
Sie beobachtete, wen(wem) Lukas getestet hat, bevor er ging.
Sie zeigte, wen(wem) Jonas heimgesucht hat, bevor er losfuhr.
Er berichtete, wen(wem) Vera liebgewonnen hat, nachdem sie ankam.
Er zeigte, wen(wem) Nina losgeschickt hat, bevor sie zurückkam.
Sie zeigte, wen(wem) Jonas mitgenommen hat, nachdem er losfuhr.
Sie berichtete, wen(wem) Andreas nachgeahmt hat, nachdem er abfuhr.
Er erfuhr, wen(wem) Anja rausgeworfen hat, bevor sie ging.
Er wußte, wen(wem) Anna umgebracht hat, nachdem sie losfuhr.
Sie berichtete, wen(wem) Andreas umgestimmt hat, nachdem er abfuhr.
Sie wußte, wen(wem) Thomas umworben hat, nachdem er ankam.
Er erfuhr, wen(wem) Anja verdroschen hat, bevor sie ging.
Er erzählte, wen(wem) Lisa verkannt hat, bevor sie abfuhr.
Sie erfuhr, wen(wem) Tobias vernommen hat, nachdem er zurückkam.
Sie erzählte, wen(wem) Lukas vorgeladen hat, bevor er ging.
Er wußte, wen(wem) Anna vorgemerkt hat, nachdem sie losfuhr.
Er bemerkte, wen(wem) Nina vorgewarnt hat, nachdem sie zurückkam.
Sie wußte, wen(wem) Thomas wachgehalten hat, nachdem er ankam.
Sie bemerkte, wen(wem) Jonas wachgerüttelt hat, nachdem er losfuhr.
Er erzählte, wen(wem) Lisa wahrgenommen hat, bevor sie abfuhr.
Er erkannte, wen(wem) Vera weggestoßen hat, bevor sie ankam.
Sie erkannte, wen(wem) Andreas zugedeckt hat, bevor er abfuhr.

Dative (Wh-pronouns for incorrect condition in parentheses)

Sie beobachtete, wem(wen) Lukas aufgeholfen hat, bevor er ging.
Er beschrieb, wem(wen) Anja aufgelauert hat, nachdem sie ging.
Er zeigte, wem(wen) Nina ausgeholfen hat, bevor sie zurückkam.
Sie beschrieb, wem(wen) Tobias beigepflichtet hat, nachdem er zurückkam.
Sie zeigte, wem(wen) Jonas beigestanden hat, nachdem er ankam.
Er berichtete, wem(wen) Vera eingeheizt hat, nachdem sie ankam.
Er erwähnte, wem(wen) Anna geähnelt hat, bevor sie losfuhr.
Sie erwähnte, wem(wen) Thomas gedankt hat, nachdem er ankam.
Sie berichtete, wem(wen) Andreas gedient hat, nachdem er abfuhr.
Er beobachtete, wem(wen) Lisa gedroht hat, nachdem sie abfuhr.
Er erfuhr, wem(wen) Anja geholfen hat, bevor sie ging.
Sie beobachtete, wem(wen) Lukas gehorcht hat, nachdem er ging.
Er zeigte, wem(wen) Nina gehuldigt hat, bevor sie zurückkam.
Sie zeigte, wem(wen) Jonas gelauscht hat, bevor er losfuhr.
Sie erfuhr, wem(wen) Tobias geschadet hat, bevor er zurückkam.
Er berichtete, wem(wen) Vera geschmeichelt hat, nachdem sie ankam.
Er wußte, wem(wen) Anna getrotzt hat, nachdem sie losfuhr.
Sie wußte, wem(wen) Thomas gewunken hat, bevor er losfuhr.

Sie berichtete, wem(wen) Andreas heimgeleuchtet hat, nachdem er abfuhr.
Er erzählte, wem(wen) Lisa mißtraut hat, nachdem sie abfuhr.
Er erfuhr, wem(wen) Anja nachgeblickt hat, bevor sie ging.
Sie erzählte, wem(wen) Lukas nachgeeifert hat, bevor er ging.
Sie erfuhr, wem(wen) Tobias nachgegeben hat, bevor er zurückkam.
Er bemerkte, wem(wen) Nina nachgeholfen hat, nachdem sie zurückkam.
Er wußte, wem(wen) Anna nachgespürt hat, nachdem sie losfuhr.
Sie bemerkte, wem(wen) Jonas nachgestellt hat, nachdem er losfuhr.
Sie wußte, wem(wen) Thomas nachgetrauert hat, bevor er ankam.
Er erkannte, wem(wen) Vera nachgeweint hat, nachdem sie ankam.
Er erzählte, wem(wen) Lisa nachgewunken hat, bevor sie abfuhr.
Sie erzählte, wem(wen) Lukas vertraut hat, bevor er ging.
Sie erkannte, wem(wen) Andreas verziehen hat, bevor er abfuhr.
Er bemerkte, wem(wen) Nina vorgestanden hat, nachdem sie zurückkam.
Er beschrieb, wem(wen) Anja widersprochen hat, bevor sie ging.
Sie bemerkte, wem(wen) Jonas widerstanden hat, nachdem er losfuhr.
Er erkannte, wem(wen) Vera zugeblinzelt hat, bevor sie ankam.
Sie beschrieb, wem(wen) Tobias zugeguckt hat, nachdem er zurückkam.
Sie erkannte, wem(wen) Andreas zugehört hat, bevor er abfuhr.
Er erwähnte, wem(wen) Anna zugejubelt hat, bevor sie losfuhr.
Sie erwähnte, wem(wen) Thomas zugelächelt hat, bevor er ankam.
Er beschrieb, wem(wen) Anja zugelacht hat, nachdem sie ging.
Sie beschrieb, wem(wen) Tobias zugenickt hat, nachdem er zurückkam.
Er beobachtete, wem(wen) Lisa zugeprostet hat, nachdem sie zurückkam.
Er erwähnte, wem(wen) Anna zugeraten hat, bevor sie losfuhr.
Sie beobachtete, wem(wen) Lukas zugeredet hat, nachdem er ging.
Sie erwähnte, wem(wen) Thomas zugeschaut hat, bevor er ankam.
Er zeigte, wem(wen) Nina zugespielt hat, bevor sie abfuhr.
Er beobachtete, wem(wen) Lisa zugesprochen hat, nachdem sie abfuhr.
Sie zeigte, wem(wen) Jonas zugestimmt hat, bevor er losfuhr.
Er berichtete, wem(wen) Vera zugetrunken hat, nachdem sie ankam.
Sie berichtete, wem(wen) Andreas zugewunken hat, nachdem er abfuhr.

B.7 Material Experiment 7

B.7.1 Verbs

The critical verbs used in Experiment 7 were identical to the verbs used in Experiment 6 (see Appendix B.6.1).

B.7.2 Sentences

Accusative (Personal pronouns for incorrect condition in parentheses)
Hans bemerkte, ächten würde Jonas ihn(ihm) nur, bevor dieser losfuhr.
Klaus erfuhr, abbilden würde Anja ihn(ihm) nur, bevor diese ging.
Hans erzählte, abdrängen würde Lukas ihn(ihm) erst, bevor dieser ging.
Hans erfuhr, ablehnen würde Tobias ihn(ihm) erst, wenn dieser zurückkam.
Klaus bemerkte, abmahnen würde Jonas ihn(ihm) erst, wenn dieser zurückkam.
Hans bemerkte, anbeten würde Nina ihn(ihm) nur, bevor diese losfuhr.
Klaus wußte, anfeuern würde Anna ihn(ihm) erst, wenn diese losfuhr.
Klaus erkannte, angreifen würde Vera ihn(ihm) nur, wenn diese ankam.
Hans wußte, aufmuntern würde Thomas ihn(ihm) nur, wenn dieser ankam.
Klaus erzählte, aufstacheln würde Lisa ihn(ihm) erst, bevor diese abfuhr.
Hans erkannte, aufsuchen würde Andreas ihn(ihm) erst, bevor dieser abfuhr.
Hans erzählte, ausbilden würde Lukas ihn(ihm) nur, bevor dieser ging.
Klaus beschrieb, ausnutzen würde Anja ihn(ihm) erst, wenn diese ging.
Hans beschrieb, belügen würde Tobias ihn(ihm) nur, wenn dieser zurückkam.
Hans erfuhr, überfahren würde Tobias ihn(ihm) erst, wenn dieser zurückkam.
Klaus berichtete, übersehen würde Vera ihn(ihm) erst, wenn diese ankam.
Klaus bemerkte, einladen würde Nina ihn(ihm) erst, wenn diese zurückkam.
Hans vermutete, heimsuchen würde Jonas ihn(ihm) erst, bevor dieser losfuhr.
Klaus erkannte, impfen würde Vera ihn(ihm) nur, wenn diese ankam.
Hans erkannte, ködern würde Andreas ihn(ihm) erst, bevor dieser abfuhr.
Klaus erwähnte, kennen würde Anna ihn(ihm) erst, bevor diese losfuhr.
Klaus berichtete, liebgewinnen würde Vera ihn(ihm) erst, wenn diese ankam.
Klaus vermutete, losschicken würde Nina ihn(ihm) nur, wenn diese zurückkam.
Hans erwähnte, meiden würde Thomas ihn(ihm) nur, wenn dieser ankam.
Hans vermutete, mitnehmen würde Jonas ihn(ihm) erst, wenn dieser losfuhr.
Klaus beschrieb, mustern würde Anja ihn(ihm) erst, bevor diese ging.
Hans berichtete, nachahmen würde Andreas ihn(ihm) nur, wenn dieser abfuhr.
Hans beschrieb, peinigen würde Tobias ihn(ihm) nur, wenn dieser zurückkam.
Klaus erfuhr, rauswerfen würde Anja ihn(ihm) nur, bevor diese ging.
Klaus erwähnte, rügen würde Anna ihn(ihm) nur, bevor diese abfuhr.
Klaus betonte, schinden würde Lisa ihn(ihm) erst, bevor diese abfuhr.
Hans erwähnte, schocken würde Thomas ihn(ihm) erst, wenn dieser ankam.
Hans betonte, sichten würde Lukas ihn(ihm) nur, bevor dieser ging.
Klaus betonte, spüren würde Lisa ihn(ihm) erst, bevor diese losfuhr.
Klaus vermutete, streicheln würde Nina ihn(ihm) nur, wenn diese zurückkam.
Hans betonte, testen würde Lukas ihn(ihm) nur, bevor dieser ging.
Klaus wußte, umbringen würde Thomas ihn(ihm) erst, bevor dieser losfuhr.
Hans berichtete, umstimmen würde Andreas ihn(ihm) nur, bevor dieser abfuhr.
Hans wußte, umwerben würde Anna ihn(ihm) nur, wenn diese ankam.
Klaus erfuhr, verdreschen würde Anja ihn(ihm) nur, bevor diese ging.
Klaus erzählte, verkennen würde Lisa ihn(ihm) nur, bevor diese abfuhr.
Hans erfuhr, vernehmen würde Tobias ihn(ihm) erst, wenn dieser zurückkam.
Hans erzählte, vorladen würde Lukas ihn(ihm) erst, bevor dieser ging.
Klaus wußte, vormerken würde Anna ihn(ihm) erst, bevor diese losfuhr.

Klaus bemerkte, vorwarnen würde Nina ihn(ihm) erst, wenn diese zurückkam.
Hans wußte, wachhalten würde Thomas ihn(ihm) nur, wenn dieser ankam.
Hans bemerkte, wachrütteln würde Jonas ihn(ihm) nur, wenn dieser losfuhr.
Klaus erzählte, wahrnehmen würde Lisa ihn(ihm) nur, bevor diese abfuhr.
Klaus erkannte, wegstoßen würde Vera ihn(ihm) nur, wenn diese ankam.
Hans erkannte, zudecken würde Anja ihn(ihm) erst, bevor diese abfuhr.

Dative (Personal pronoun for incorrect condition in parentheses)
Klaus erwähnte, ähneln würde Anna ihm(ihn) erst, bevor diese losfuhr.
Hans betonte, aufhelfen würde Lukas ihm(ihn) nur, bevor dieser ging.
Klaus beschrieb, auflauern würde Andreas ihm(ihn) erst, wenn dieser ging.
Klaus vermutete, aushelfen würde Nina ihm(ihn) nur, wenn diese zurückkam.
Hans beschrieb, beipflichten würde Tobias ihm(ihn) nur, wenn dieser zurückkam.
Hans vermutete, beistehen würde Jonas ihm(ihn) erst, wenn dieser ankam.
Hans erwähnte, danken würde Thomas ihm(ihn) erst, wenn dieser ankam.
Hans berichtete, dienen würde Andreas ihm(ihn) nur, bevor dieser abfuhr.
Klaus betonte, drohen würde Lisa ihm(ihn) nur, bevor diese abfuhr.
Klaus berichtete, einheizen würde Vera ihm(ihn) erst, wenn diese ankam.
Hans betonte, gehorchen würde Lukas ihm(ihn) nur, bevor dieser ging.
Hans berichtete, heimleuchten würde Andreas ihm(ihn) nur, wenn dieser abfuhr.
Klaus erfuhr, helfen würde Anja ihm(ihn) nur, bevor diese ging.
Klaus vermutete, huldigen würde Nina ihm(ihn) nur, bevor diese zurückkam.
Hans vermutete, lauschen würde Jonas ihm(ihn) erst, bevor dieser losfuhr.
Klaus erzählte, mißtrauen würde Lisa ihm(ihn) nur, wenn diese abfuhr.
Klaus erfuhr, nachblicken würde Anja ihm(ihn) erst, bevor diese ging.
Hans erzählte, nacheifern würde Lukas ihm(ihn) erst, bevor dieser ging.
Hans erfuhr, nachgeben würde Tobias ihm(ihn) nur, bevor dieser zurückkam.
Klaus bemerkte, nachhelfen würde Jonas ihm(ihn) erst, wenn dieser zurückkam.
Klaus wußte, nachspüren würde Anna ihm(ihn) erst, wenn diese losfuhr.
Hans bemerkte, nachstellen würde Nina ihm(ihn) nur, bevor diese losfuhr.
Hans wußte, nachtrauern würde Thomas ihm(ihn) nur, wenn dieser losfuhr.
Klaus erkannte, nachweinen würde Vera ihm(ihn) nur, wenn diese abfuhr.
Klaus erzählte, nachwinken würde Lisa ihm(ihn) nur, wenn diese abfuhr.
Hans erfuhr, schaden würde Tobias ihm(ihn) erst, wenn dieser zurückkam.
Klaus berichtete, schmeicheln würde Vera ihm(ihn) erst, wenn diese ankam.
Klaus wußte, trotzen würde Anna ihm(ihn) erst, bevor diese losfuhr.
Hans erzählte, vertrauen würde Lukas ihm(ihn) erst, bevor dieser ging.
Hans erkannte, verzeihen würde Andreas ihm(ihn) erst, bevor dieser ankam.
Klaus bemerkte, vorstehen würde Jonas ihm(ihn) erst, wenn dieser zurückkam.
Klaus beschrieb, widersprechen würde Anja ihm(ihn) erst, bevor diese ging.
Hans bemerkte, widerstehen würde Nina ihm(ihn) nur, bevor diese ankam.
Hans wußte, winken würde Thomas ihm(ihn) nur, bevor dieser losfuhr.
Klaus erkannte, zublinzeln würde Vera ihm(ihn) nur, wenn diese ankam.
Hans beschrieb, zugucken würde Tobias ihm(ihn) nur, wenn dieser zurückkam.

Hans erkannte, zuhören würde Andreas ihm(ihn) nur, bevor dieser abfuhr.
Klaus erwähnte, zujubeln würde Anna ihm(ihn) nur, bevor diese losfuhr.
Hans erwähnte, zulächeln würde Thomas ihm(ihn) erst, wenn dieser ankam.
Klaus beschrieb, zulachen würde Anja ihm(ihn) erst, bevor diese ging.
Hans beschrieb, zunicken würde Tobias ihm(ihn) erst, wenn dieser zurückkam.
Klaus betonte, zuprosten würde Lisa ihm(ihn) erst, wenn diese zurückkam.
Klaus erwähnte, zuraten würde Anna ihm(ihn) nur, bevor diese losfuhr.
Hans betonte, zureden würde Lukas ihm(ihn) nur, wenn dieser ging.
Hans erwähnte, zuschauen würde Thomas ihm(ihn) erst, wenn dieser ankam.
Klaus vermutete, zuspielen würde Nina ihm(ihn) nur, bevor diese abfuhr.
Klaus betonte, zusprechen würde Lisa ihm(ihn) erst, bevor diese abfuhr.
Hans vermutete, zustimmen würde Jonas ihm(ihn) erst, bevor dieser losfuhr.
Klaus berichtete, zutrinken würde Vera ihm(ihn) erst, wenn diese ankam.
Hans berichtete, zuwinken würde Andreas ihm(ihn) nur, wenn dieser abfuhr.

Appendix C

Experiment Instructions

C.1 Instruction Experiment 1

"Liebe Teilnehmerin, lieber Teilnehmer,

bitte lesen Sie jeden der folgenden Sätze ganz genau. Entscheiden Sie für jeden einzelnen Satz, ob dieser grammatikalisch korrekt ist oder nicht. Markieren Sie bitte "ja" auf Ihrem Bogen, wenn der Satz grammatikalisch korrekt ist. Markieren Sie bitte "nein", wenn der Satz grammatikalisch falsch ist. Falls Sie sich nicht sicher sind, ob der Satz grammatikalisch richtig oder falsch ist, dann markieren Sie bitte "weiß nicht". Bitte nutzen Sie diese Antwortalternative nur dann, wenn Sie überhaupt nicht entscheiden können, ob der vorliegende Satz richtig oder falsch ist.

Vielen Dank für Ihre Mitarbeit.

Wenn Sie Fragen haben, stellen Sie diese bitte jetzt."

C.2 Instruction Experiment 2

"Liebe Teilnehmerin, lieber Teilnehmer,

auf den nächsten Seiten finden Sie eine Reihe von unvollständigen Fragen oder Sätzen. Bitte lesen Sie jeden Satzanfang und finden Sie dazu eine Fortsetzung, die den Satz sinnvoll und grammatikalisch richtig zu Ende bringt.

Hier sind einige Beispiele:

Wen hat Horst "beschwatzt" ? oder:

Wem hat Petra "aufgelauert" ?

Vervollständigen Sie bitte Sätze dieser Art mit nur einem Wort. Vermeiden Sie es nach Möglichkeit, Wörter, die Sie schon einmal für Sätze dieser Art verwendet haben, erneut zu verwenden.

Denken Sie daran: Es gibt keine inhaltlich richtigen Antworten. Seien Sie bitte spontan und schreiben Sie die Vervollständigung, die Ihnen zuerst einfällt, auf die dafür vorgesehene Linie. Achten Sie darauf, daß Ihre Vervollständigung grammatikalisch korrekt ist.

Herzlichen Dank für Ihre Teilnahme."

C.3 Instruction Experiment 3

"Liebe Teilnehmerin, lieber Teilnehmer,

in unserem heutigen Experiment werden Ihnen eine Reihe von unvollständigen Fragesätzen über Kopfhörer vorgespielt. Bitte hören Sie sich jeden Satzanfang genau an und finden Sie dazu eine Fortsetzung, die den Satz sinnvoll und grammatikalisch richtig zu Ende bringt.

Hier sind zwei Beispiele:

Wen hat Horst "beschwatzt" ? oder:

Wem hat Petra "aufgelauert" ?

Vervollständigen Sie bitte die Sätze mit nur einem Wort. Vermeiden Sie es nach Möglichkeit, Wörter, die Sie schon einmal für Sätze dieser Art verwendet haben, erneut zu verwenden.

Geben Sie Ihre Antwort über die Tastatur ein. Sie können sich korrigieren. Beenden Sie ihre Eingabe durch Betätigen der Enter-Taste. Zur Bestätigung ertönt ein kurzer Ton. Den nächsten Satz starten Sie durch Drücken der Leertaste. Es ertönt zunächst ein kurzer Hinweiston. Hören Sie sich den Satzanfang genau an. Für ihre Antwort haben Sie 30 Sekunden Zeit. Mit Ende dieses Intervalls ertönt wiederum ein kurzer Ton.

Denken Sie daran: Es gibt keine inhaltlich richtigen Antworten. Seien Sie bitte spontan und geben Sie die Vervollständigung, die Ihnen zuerst einfällt, ein. Achten Sie darauf, daß Ihre Vervollständigung grammatikalisch korrekt ist.

Herzlichen Dank für Ihre Teilnahme."

C.4 Instructions Experiment 4

C.4.1 Instruction voice key calibration

"Herzlich willkommen. Heute wirst Du an einem Experiment zur Erforschung des Sprachverstehens teilnehmen.

Während des Experiments werde ich mit Hilfe des Mikrophons, das sich an Deiner Kopfhörerkombination befindet, Deine Antworten aufzeichnen. Zu diesem Zweck müssen wir zunächst die Empfindlichkeit des Mikrophons einstellen. Bitte lies die folgende Wortliste laut und deutlich vor:

Gaukler
Klemme
Bach
Panik
Daumen
Text
Schrank
Feige

Um Meßfehler zu vermeiden, ist es wichtig, daß Atemgeräusche, Räuspern, Husten und dergleichen die Messung nicht beeinflussen. Laß uns ausprobieren, wie sich das Gerät verhält, wenn Du laut atmest oder Dich räusperst.

[Atem]
[Räuspern]

Lies jetzt bitte noch folgende Wörter laut und deutlich:

Schramme
Feile
Wanne
Seife
Junge
Vielen Dank!”

C.4.2 Instruction main experiment

”Während des Experimentes werden Dir grammatikalisch richtige und grammatikalisch falsche Fragesätze präsentiert. Zum Beispiel:

”Wen hat Axel gesehen?”

*”Wem hat Axel gesehen?”

In diesem Beispiel ist der erste Satz grammatikalisch korrekt und der zweite ist es nicht.

Ein Hinweiston kündigt Dir den jeweils nächsten Satz an. Über den Kopfhörer wird Dir dann ein Satzanfang vorgespielt. Danach wirst Du auf dem Bildschirm jeweils kurz ein Wort sehen, das den Satz vervollständigt. Höre Dir jeden Satz genau an. Dabei hast Du mehrere Aufgaben.

1.) Deine erste Aufgabe ist es, Dir diesen Satzanfang anzuhören, das Wort zu lesen und den kompletten Satz zu verstehen.

2.) Nachdem Du einen Satzanfang gehört hast, erscheint ein einzelnes Wort auf dem Bildschirm vor Dir, und zwar genau an der Stelle, die durch ein kleines Kreuz markiert ist. Das Wort wird nur für eine sehr kurze Zeit auf dem Bildschirm zu sehen sein. Wenn Du Dich (neben dem Satz) auf den Bildschirm konzentrierst, ist das Wort jedoch gut lesbar. Deine zweite Aufgabe ist es, das Wort zu lesen und es korrekt und gleichzeitig prompt auszusprechen.

Es ist sehr wichtig, daß Du dieses Wort so prompt wie möglich und dabei korrekt aussprichst. Sage kein anderes Wort, auch nicht nur einen Teil des Wortes auf dem Bildschirm. Mache keine Pause während Du das Wort aussprichst. Beginne Deine Äußerung nicht mit einem ”Hmm”, ”Ähh” oder Ähnlichem. Atme nicht in das Mikrophon. Falls Du Dich räuspern mußt, warte auf eine Pause zwischen Sätzen. Spreche bitte laut und deutlich. Alle diese kleinen Regeln sind notwendig, um Deine Antworten so präzise wie möglich aufzeichnen zu können.

Nachdem ein Satz vorüber ist, erscheint ein Fragezeichen auf dem Bildschirm. Dies ist eine Aufforderung für Dich, zu entscheiden, ob der vorherige Satz grammatikalisch korrekt war oder nicht. Drücke bitte die rechte/linke Taste für ”Ja, der Satz war grammatikalisch korrekt” und die linke/rechte Taste für ”Nein, der Satz war grammatikalisch nicht korrekt”.

Es ist also notwendig, daß Du Dir den Satz genau anhörst, damit Du die Frage korrekt beantworten kannst. Drücke die Taste auf der Antworttastatur, die der richtigen Antwort entspricht. Falls Du einen Fehler machen solltest, hänge ihm nicht nach. Bereite Dich einfach auf den nächsten Satz vor.

Es ist sehr wichtig, daß Du Dich so gut wie möglich konzentrierst. Du hast also zwei Aufgaben: 1. höre Dir den Satz, den Du über den Kopfhörer präsentiert bekommst, genau an, damit Du die Frage beantworten kannst und 2. wiederhole das Wort, das auf dem Bildschirm erscheint, korrekt und so prompt Du kannst.

Hast Du noch Fragen?”

C.5 Instruction Experiment 5

C.5.1 Instruction voice key calibration

See Appendix C.4.1.

C.5.2 Instruction training

"Nach dem Start dieses Trainingsteils des Experiments werden die Dir schon bekannten Wörter auf dem Bildschirm vor Dir gezeigt.

Zunächst erscheint ein kleines Kreuz in der Mitte des Bildschirms, und Du hörst einen Warnton. Dann erscheint ein einzelnes Wort auf dem Bildschirm, und zwar genau an der Stelle, die vorher durch das Kreuz markiert wurde. Das Wort wird nur für eine sehr kurze Zeit auf dem Bildschirm zu sehen sein. Wenn Du Dich auf den Bildschirm konzentrierst, ist das Wort jedoch gut lesbar. Deine Aufgabe ist es, das Wort zu lesen und es korrekt und gleichzeitig prompt auszusprechen.

Es ist sehr wichtig, daß Du dieses Wort so prompt wie möglich und dabei korrekt ausprichst. Sage kein anderes Wort, auch nicht einen Teil des Wortes auf dem Bildschirm. Mache keine Pause während Du das Wort aussprichst. Beginne Deine Äußerung nicht mit einem "Hmm", "Ähh" oder Ähnlichem. Atme nicht in das Mikrophon. Falls Du Dich räuspern mußt, warte auf eine Pause zwischen Sätzen. Spreche bitte laut und deutlich. Alle diese kleinen Regeln sind notwendig, um Deine Antworten so präzise wie möglich aufzeichnen zu können.

Hast Du noch Fragen?"

C.5.3 Instruction main experiment

Instruction part I Example of an instruction of the experiment variant judgment task during the first part followed by the part without judgment.

"Während dieses Teils des Experimentes werden Dir grammatikalisch richtige und grammatikalisch falsche Fragesätze präsentiert. Zum Beispiel:

"Wen hat Axel gesehen?"

*"Wem hat Axel gesehen?"

In diesem Beispiel ist der erste Satz grammatikalisch korrekt und der zweite ist es nicht.

Ein Hinweiston kündigt Dir den jeweils nächsten Satzanfang an. Über den Kopfhörer wird Dir dann ein Satzanfang vorgespielt. Höre Dir den Satz genau an. Danach wirst Du auf dem Bildschirm jeweils kurz ein Wort sehen, das den Satz vervollständigt. In diesem Teil des Experiments hast Du zunächst drei Aufgaben:

1.) Deine erste Aufgabe ist es, Dir den Satzanfang über Kopfhörer genau anzuhören. Nachdem Du den Satzanfang gehört hast, erscheint - so wie im Trainingsdurchlauf zuvor - ein einzelnes Wort auf dem Bildschirm vor Dir, und zwar genau an der Stelle, die vorher durch ein kleines Kreuz markiert wurde. Das Wort wird wieder nur für eine sehr kurze Zeit auf dem Bildschirm zu sehen sein und Deine Aufgabe ist es, das Wort zu lesen und den gesamten Satz zu verstehen.

2.) Wenn das Wort auf dem Bildschirm erscheint, ist es Deine zweite Aufgabe, dieses Wort korrekt und gleichzeitig prompt auszusprechen.

Es ist wiederum sehr wichtig, daß Du dieses Wort so prompt wie möglich und dabei korrekt aussprichst. Sage kein anderes Wort, auch nicht nur einen Teil des Wortes auf dem Bildschirm. Mache keine Pause während Du das Wort aussprichst. Beginne Deine Äußerung nicht mit einem "Hmm", "Ähh" oder Ähnlichem. Atme nicht in das Mikrophon. Falls Du Dich räuspern mußt, warte auf eine Pause zwischen Sätzen. Spreche bitte laut und deutlich. Alle diese kleinen Regeln sind notwendig, um Deine Antworten so präzise wie möglich aufzeichnen zu können.

3.) Nachdem ein Satz vorüber ist, erscheint ein Fragezeichen auf dem Bildschirm. Dies ist eine Aufforderung für Dich, zu entscheiden, ob der vorherige Satz grammatikalisch korrekt war oder nicht. Drücke bitte die rechte/linke Taste für "Ja, der Satz war grammatikalisch korrekt" und die linke/rechte Taste für "Nein, der Satz war grammatikalisch nicht korrekt". Es ist also notwendig, daß Du Dir den kompletten Satz genau anhörst, damit Du die Frage korrekt beantworten kannst. Drücke die Taste auf der Antworttastatur, die der richtigen Antwort entspricht. Denke bitte daran, daß Du die Taste, für die Du Dich entschieden hast, immer erst nach dem Erscheinen des Fragezeichens drückst.

Falls Du einen Fehler machen solltest, hänge ihm nicht nach. Bereite Dich einfach auf den nächsten Satz vor.

Es ist sehr wichtig, daß Du Dich so gut wie möglich konzentrierst. Du hast also drei Aufgaben: 1. höre Dir den Satz, den Du über den Kopfhörer präsentiert bekommst, genau an, damit Du die Frage beantworten kannst, 2. wiederhole das Wort, das auf dem Bildschirm erscheint, korrekt und so prompt Du kannst und 3. entscheide, ob der Satz grammatikalisch korrekt war oder nicht und drücke die entsprechende Taste.

Hast Du noch Fragen?"

Instruction part II "In diesem Teil des Experiments hast Du nur noch diese Aufgaben:

1.) Höre Dir den Satzanfang über Kopfhörer genau an. Nachdem Du den Satzanfang gehört hast, erscheint wieder - so wie im vorherigen Teil - ein einzelnes Wort auf dem Bildschirm vor Dir. Lies bitte das Wort und versuche, den gesamten Satz zu verstehen.

2.) Wenn das Wort auf dem Bildschirm erscheint, ist es Deine zweite Aufgabe, dieses Wort korrekt und gleichzeitig prompt auszusprechen.

Wie immer ist es sehr wichtig, daß Du dieses Wort so prompt wie möglich und dabei korrekt aussprichst, kein anderes Wort, auch nicht nur einen Teil des Wortes auf dem Bildschirm aussprichst und keine Pause machst, während Du das Wort aussprichst. Beginne Deine Äußerung nicht mit einem "Hmm", "Ähh" oder Ähnlichem, atme nicht in das Mikrophon und versuche, falls Du Dich räuspern mußt, auf eine Pause zwischen Sätzen zu warten. Spreche weiterhin laut und deutlich.

Falls Du einen Fehler machen solltest, hänge ihm nicht nach. Bereite Dich einfach auf den nächsten Satz vor.

Es ist sehr wichtig, daß Du Dich so gut wie möglich konzentrierst. Du hast jetzt also nur noch zwei Aufgaben: 1. höre Dir den Satz, den Du über den Kopfhörer präsentiert bekommst, genau an und 2. wiederhole das Wort, das auf dem Bildschirm erscheint, korrekt und so prompt Du kannst.

Hast Du noch Fragen?"

C.6 Instruction Experiment 6

C.6.1 Reading list

”Bitte lies die folgenden Verben vor.

zusprechen belügen danken auflauern vorsprechen helfen zuschauen verhören schocken antworten nachhelfen heimsuchen kennen vorladen erwähnen umwerben abdrängen rauswerfen beistehen verkennen mitnehmen umarmen überfahren vorspielen bedauern verzeihen zujubeln nachstellen einladen verfluchen wachrütteln vorwarnen gefährden mustern vormerken aushelfen vertrauen ermorden zublinzeln streicheln vorstehen aufstacheln trotzen aufsuchen zuspielen ausnutzen sichten zureden dienen zuwinken nachspüren zulachen spüren losschicken umbringen wachhalten gehorchen zulächeln mißtrauen zusagen abbilden zutrinken umstimmen testen winken drohen peinigen zusetzen wahrnehmen angreifen ähneln zunicken entlarven zudecken meiden einheizen aufmuntern zuhören zustimmen schreiben ausbilden beipflichten nachblicken ködern wegstoßen schmeicheln rügen nachgeben abmahnen vortanzen zuraten nachwinken ablehnen nachtrauern beichten zuprosten übersehen verdreschen heimleuchten nacheifern bewundern ächten widersprechen nachahmen impfen anbeten nachweinen anfeuern glauben aufhelfen verfehlen schinden vernehmen lauschen huldigen zugucken vorsagen widerstehen schaden liebgewinnen”

C.6.2 Main instruction

[General EEG instructions were given orally.]

”Instruktion

Bei unserem heutigen Experiment wirst Du Sätze lesen, die Dir Wort für Wort auf dem Bildschirm präsentiert werden.

Er wußte, wen Jonas bewundert hat, bevor er abfuhr.

* Sie berichtete, wem Anja begnadigt hat, nachdem sie ankam.

Diese Sätze können grammatikalisch korrekt oder inkorrekt (*) sein .

Deine Aufgabe ist es, jeden Satz aufmerksam zu lesen. Bitte halte dabei Deine Augen auf die Mitte des Bildschirms fixiert, an die Stelle, an der das Fixationskreuz erscheint. Am Ende eines Satzes entscheide bitte, ob dieser grammatikalisch korrekt oder inkorrekt war. Drücke bitte die rechte Taste wenn der Satz korrekt und die linke Taste wenn der Satz inkorrekt war.

Hast Du Fragen?

Vielen Dank für Deine Mitarbeit.”

C.7 Instruction Experiment 7

C.7.1 Reading list

The reading list was identical to Experiment 6 C.6.1

C.7.2 Main instruction

[General EEG instructions were given orally.]

”Instruktion

Bei unserem heutigen Experiment wirst Du Sätze lesen, die Dir Wort für Wort auf dem Bildschirm präsentiert werden.

Klaus wußte, bewundern würde Jonas ihn erst, bevor dieser abfuhr.

* Hans berichtete, begnadigen würde Anja ihm nur, wenn diese ankam.

Diese Sätze können grammatikalisch korrekt oder inkorrekt (*) sein .

Deine Aufgabe ist es, jeden Satz aufmerksam zu lesen. Bitte halte dabei Deine Augen auf die Mitte des Bildschirms fixiert, an die Stelle, an der das Fixationskreuz erscheint. Am Ende eines Satzes entscheide bitte, ob dieser grammatikalisch korrekt oder inkorrekt war. Drücke bitte die rechte Taste wenn der Satz korrekt und die linke Taste wenn der Satz inkorrekt war.

Hast Du Fragen?

Vielen Dank für Deine Mitarbeit.”

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Dissertationsbezogene bibliographische Daten

Jacobsen, Thomas

Characteristics of processing morphological structural and inherent case in language comprehension

Universität Leipzig, Dissertation

191 Seiten, 256 Literaturangaben, 14 Abbildungen, 18 Tabellen

Referat

In der vorliegenden Arbeit wurden Charakteristika der Verarbeitung von morphologisch markiertem strukturellem und inhärentem Kasus während des Satzverstehens untersucht. In insgesamt sieben Experimenten wurden neben Reaktionszeiten und Fehlerraten ereignis-korrelierte Potentiale (EKP) als abhängige Variablen verwendet.

Als 'off-line'-Aufgaben wurden grammatikalische Akzeptabilitätsbeurteilungen und Satzvervollständigungen verwendet. Eine Variante der cross-modalen Benennungsaufgabe und Lesen bei gleichzeitiger EEG-Aufzeichnung kamen als 'on-line'-Aufgaben zum Einsatz.

Die Ergebnisse belegen, daß inhärenter und struktureller und struktureller Kasus im Deutschen in der Regel korrekt verarbeitet werden. Struktureller Kasus wird leichter und verläßlicher verabreitet. Inkongruent präsentierter inhärenter Kasus wird eher absorbiert als vice versa.

Während der Satzverarbeitung werden mit dem zu benennenden Zielwort assoziierter struktureller und inhärenter Kasus in einem Zeitfenster verarbeitet, welches klein genug ist, die Benennung des Zielwortes selbst zu beeinflussen. Genaueren Aufschluß über den Zeitverlauf und qualitative sowie quantitative Dissoziationen der Verarbeitungscharakteristika beider Kasus ergaben die EKPs.

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