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Processing Mechanisms of Argument Structure and Case-marking in Child Development: Neural Correlates and Behavioral Evidence

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Processing Mechanisms of Argument Structure and Case-marking in Child Development: Neural Correlates and Behavioral Evidence

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Preface

Regarding the course and mechanisms of language acquisition, still various puzzling questions remain today. Many insights already exist with concern to the development proceeding from the attunement to specific phonemes and the segmentation of the speech stream in infants to the acquisition of the first words and further on to the acquisition of syntactic rules in toddlers. Yet, different aspects of the acquisitional characteristics and of the time course for certain linguistic structures and functions remain debatable. The underlying principles and, in particular, the underlying developing neural processing system for the different facets of language acquisition gained more and more scientific interest in recent decades.

One particular issue in the context of syntax acquisition is how children determine the relation between participants in a sentence or utterance and which strategies they employ in this regard. In every simple transitive clause, they must find out who is doing what to whom, i.e., who acts in the scene and who receives the action. In German, word order often indicates participants' relation but case marking provides the most informative cue for it. The current study investigates the mechanisms underlying children's acquisition of the cues necessary for sentence interpretation and contributes to the understanding of developing argument expectations. It also examines, for the most part, the characteristics of on-line syntactic processing and their neurophysiological basis in this respect.

To this end, not only a behavioral method but also an eye tracking paradigm and the ERP method will be employed for the first time in children between three and six years of age. These methods allow for the first time to investigate both, the on-line time sequence of sentence interpretation as well as the representational nature of argument structures in preschoolers.

Part I of the current book[1] provides an introduction into the topic of syntax, comprising both linguistic theory and empirical evidence. In Chapter 1, the levels of syntactic description are introduced with specific emphasis on the realization of hierarchical dependencies between the arguments in a sentence. In Chapter 2, a summary of behavioral and neurophysiological evidence concerning syntactic processing in adults is incorporated into neurocognitive models of language comprehension. Chapter 3 discusses behavioral and neurophysiological research on the development of syntactic processing in children, which is embedded in a model of acquisition. Part II consists of a formulation of the research question (Chapter 4), and an explanation of the experimental methods in the present experiments (Chapter 5). It continues

[1] Sections of the introduction, the discussion and especially of Study II regarding the processing of argument violations in children have been published in Schipke, Friederici, and Oberecker (2011). Sections of the introduction, the discussion and especially of Study I and II concerning the processing of object-initial structures are in press (Schipke, Knoll, Friederici, & Oberecker, in press).

with Study I investigating the processing of different argument structures in adults (Chapter 6) and with Study II examining the processing of the same structures in preschoolers at three different ages (Chapter 7). Eventually, in Part III, there is a discussion of the present findings for adults and children and an evaluative comparison of the different methods employed throughout the whole study (Chapter 8). The book closes with future perspectives (Chapter 9) and a conclusion (Chapter 10).

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I Introduction

The key to sentence comprehension lies in understanding the relations between sentential arguments. In simple transitive structures understanding *who is doing what to whom* is essential as it allows the correct interpretation of a sentence's meaning. For instance, in a sentence such as "the man shoots the policeman," it makes a great difference whether the man shoots the policeman or the policeman shoots the man. While the factor word order makes the interpretation of the present example quite easy, it can be more difficult in other languages. In case-marked languages like German, one proposition can be expressed in simple transitive structures in two different ways without changing its meaning: an object-initial or subject-initial construction. Whether the first argument in a transitive sentence functions as a subject or an object depends on its case-marking. Consider the following German examples:

(1a) Der Mann erschießt den Polizisten.
[the man]NOM shoots [the policeman]ACC
'The man shoots the policeman.'

(1b) Den Polizisten erschießt der Mann.
[the policeman]ACC shoots [the man]NOM
'The man shoots the policeman.'

The non-ambiguous case-marking not only alludes to the grammatical function of a constituent but also to its thematic role in this context. The nominative case designates 'der Mann' in (1a) and (1b) as the subject and, crucially, as the actor (Agent) in the scene. The accusative case marks 'den Polizisten' in (1a) and (1b) as the object. Even more important, within the relationship of *who is doing what to whom*, it allows the processing system to deduce that the policeman is the participant being shot and thus the Patient in this proposition. Most notably, word order carries no information in this instance. The meanings of (1a) and (1b) are identical irrespective of the particular word order – pragmatic and contextual factors are not taken into account at this point. Without doubt, word order and animacy differences can also function as cues for identifying argument relations and establishing thematic hierarchical ordering of propositions in German, which will be addressed later.

1 Linguistic Foundation

For the purpose of providing a linguistic basis for the facts sketched above, the following chapters will explain the different levels of description in more detail. They will also serve as an explanation of the nomenclature operated with throughout the remaining book. As illustrated above, linguists refer to the same argument in a sentence or clause with different terms that emphasize different views of it: The level of the syntactic function of the argument or the level of the thematic role of the argument with the latter stressing the rather semantic relations between an argument and the verb. The thematic role or syntactic function can be realized or signaled depending on the language examined, by case-marking on the morphological level, by word order on the syntactic level, and additionally by animacy on the semantic level.

The following chapters will clarify first the syntactic functions of arguments, then the thematic roles of arguments, and furthermore their realizations by case-marking, word order, and animacy.

1.1 Syntactic Functions

The traditional notion of syntactic functions as subject, object, predicate, and adverb is a widely used concept although a precise definition of these functions was never completely achieved. As Dürscheid (2000) points out for example, tests for identifying a subject fail to apply to all subjects and not all criteria stated for subjects are applicable in all cases. Nevertheless, as an operational language and an aid to describe grammatical relations, the traditional terms for syntactic functions are still employed by numerous grammatical approaches as, for example, valence grammar, usage-based approaches, and generative grammar. They will also be used in this book and hence a brief explanation of the concepts will follow; however, it can only be an approximation of these, as clear definitions do not yet exist. Rather, the prototypical features of the syntactic categories will be spelled out. Because it will not occur as a topic of this work, adverbs will not be further explained here.

The syntactic function of a *subject* is independent of its realization by a particular syntactic category. For instance, a subject can occur as a pronoun (e.g., "He sleeps."), or a noun phrase (NP) (e.g., "The man sleeps."), or as an infinitive phrase (e.g., "To wake up was not an option."), or as a clause (e.g., "That he will be asleep was taken for granted."). Nevertheless, from a formal point of view, it is prototypically most often realized as an NP in the nominative case (for a discussion of the relationship between the concepts of subject and nominative, cf. Reis, 1982). In addition, as the subject, it also requires agreement with the predicate in person

and number (Lühr, 2000). In some languages, e.g. Hebrew, it also agrees with the predicate in gender (Deutsch, Bentin, & Katz, 1999). From a pragmatic perspective, the subject usually constitutes the topic of a proposition, the one which is talked about, and in the majority of occurrences, it can be asked for the subject by "who or what" as a test for the syntactic function (Dürscheid, 2000).

The syntactic function of an *object* can also be realized by a pronoun or NP (e.g., "He kisses her/the woman."), or as a clause (e.g., "We know that he kisses her."), or as an infinitive (e.g., "He decided to kiss her."). Traditional grammar distinguishes between direct (e.g., "He gives her a kiss.") and indirect (e.g., "He gives her a kiss.") objects (Eisenberg, 1999). The direct object, which represents the type of object that the following research is examining, associates prototypically with the formal criterion of bearing accusative case-marking and the syntactic criterion of becoming the subject in a transitive passive sentence (e.g., "He kisses the woman." → "The woman is kissed by him."). Pragmatically seen, the direct object constitutes the target point of the action expressed by the predicate (Dürscheid, 2000).

The syntactic function of a *predicate* can only prototypically be realized by the syntactic category of a verb, at least from a traditional viewpoint (Eisenberg, 1999; Lühr, 2000) (e.g., "He kisses her."); in generative grammar, in contrast, the predicate usually equals a verbal phrase that is composed by the verb and the non-verbal phrases that are dependent of the verb (Chomsky, 1981). The predicate semantically designates an action, process, or condition related to the subject and formally agrees with it (Dürscheid, 2000).

From a semantic point of view, the subject is generally associated with taking the role of the Agent (Keenan, 1976). However, as the author emphasizes, this is mainly only true for active transitive sentences. Hence, in the example above "the woman is kissed by him," the subject clearly does not equal the Agent but the Patient in this case of a passive structure. Moreover, this issue applies also to intransitive structures in which the subject does not occur as the Agent (cf. "The earthquake happens.") but rather as the Patient. Nevertheless is the direct object prototypically correlated with the role of the Patient (Dürscheid, 2000). The prototypes of Agents and Patients will be further clarified in the next subchapter as well as the theory of thematic roles in general.

1.2 Thematic Roles and Relations

Thematic roles function to connect semantics with syntax, and more specifically, to map semantics onto arguments bearing syntactic functions. These thematic roles serve as

generalizations over classes of different verbs and their meanings and not only for one verb meaning. For instance, in the example "the man kisses the woman", the role of the *kisser* is assigned to the man and the role of the one being kissed to the woman.

Thematic roles, in turn, permit to generalize these roles to the Agent or the Patient, respectively, over a class of transitive verbs sharing the same thematic and syntactic properties, regardless of the intrinsic particular verb meaning (Haegemann, 1994). Beyond these concepts of thematic roles, which are still many and each describing separate thematic properties of arguments (e.g., the man is being assigned to the role of the Agent in "the man kisses the woman," but to the role of the *Experiencer* in "the man likes the woman" (Grimshaw, 1990)), *generalized thematic roles* or prototypes of thematic roles have been introduced by a number of scholars (Dowty, 1991; Foley & Van Valin, 1984; Kibrik, 1985; Primus, 1999; Van Valin, 1999; Van Valin & La Polla, 1997).

These prototypes make a further abstraction of thematic roles to *Proto-Roles* possible. While Dowty (1991) assumes only two Proto-Roles (Proto-Agent and Proto-Patient), Primus (1999) describes three Proto-Roles: Proto-Agent, Proto-Patient, and Proto-Recipient. These Proto-Roles are defined on the basis of *the number of Proto-Role entailments of each argument of a verb* in the case of Dowty (1991), and by *a number of entailments of Proto-Role relations* in the case of Primus (1999). Thus, Proto-Roles are sets of entailments of a class of properties that arguments can bear in relation to each other or to a predicate. The word *Proto-* expresses the fact that not the entire set of entailments needs to match an argument in order to represent a member of a certain Proto-Role. Next, the three Proto-Roles differentiated by Primus (1999) will be briefly explicated since her characterization presents the advantage of defining Proto-Roles on the basis of relations between those; an approach which is also taken by a neurocognitive model of language processing, the *extended Argument Dependency Model* (eADM) (Bornkessel & Schlesewsky, 2006a).

A *Proto-Agent* is a set of entailments of the control relation who causes the event expressed by the predicate. In addition, Primus (1999) assumes that an ideal Proto-Agent acts deliberately, moves, and is animate with *moves* representing that the prototypical control includes a form of physical activity by the Proto-Agent.

A *Proto-Patient* is a set of entailments of basic relations that entirely involve thematic dependency on another argument, e.g., the Proto-Patient is experiencing a stimulus, or is possessed by a possessor, or is causally affected by a causing participant. Hence, Primus (1999) assumes that the Proto-Agent and the Proto-Patient are not different in their basic thematic relations but in their dependencies to each other.

A *Proto-Recipient* takes a middle position between the Proto-Agent and the Proto-Patient as depending on the Proto-Agent, but at the same time has other possible arguments dependent on it.

In consequence, the relations between the three different Proto-Roles are captured in a thematic hierarchy (Primus, 1999) (for similar hierarchies, compare also Bresnan & Kanerva, 1989; Givón, 1984; Grimshaw, 1990; Jackendoff, 1972), which includes that the Proto-Recipient depends thematically on the Proto-Agent and the Proto-Patient depends thematically on the Proto-Agent and the Proto-Recipient. It is also crucial to note that the occurrence of a Proto-Patient presupposes the occurrence of a Proto-Recipient or a Proto-Agent. In this universal hierarchy, the Proto-Agent is ranked highest (cf. example (2)):

Thematic Hierarchy[2]:
Proto-Agent > Proto-Recipient > Proto-Patient

For the reason that the thematic hierarchy is claimed to be a semantic property and universal, it follows that it is completely independent of syntactic structures.

For all thematic roles, the theory of the *Theta Criterion* formulated by Chomsky (1981) as part of the Government-Binding-Theory holds that each thematic role indicated by a respective case should only be assigned once (see also Haegemann, 1994). A one-to-one mapping of thematic roles to syntactic arguments implies, moreover, that every argument can only carry one thematic role, and, vice versa, that every thematic role can only be assigned to one argument. Also as a consequence, every argument needs to be filled with a thematic role and cannot stand without one.

1.3 Morphosyntactic Realizations: Case-marking and Word Order

How is the one-to-one mapping (see above) of thematic roles to arguments realized in the concrete case of German? Although the predicate determines the thematic properties of arguments and the number of arguments to be filled, in many cases the complete set of entailments cannot be obtained from the predicate in online language processing. For example, in German subordinate clauses, the verb takes a final position and thus provides thematic information only at the very end of the sentence. Moreover, given that word order is relatively

[2] Whereby A > B designates A being ranked thematically higher than B.

free in German, thematic roles of arguments have to be unambiguously assigned by other means. Consequently, information about thematic relationships is provided by the arguments themselves independently of and in addition to the predicate. Primus (1999) describes mainly two means of functional linguistic information encoding thematic relationships in arguments: morphological coding (i.e., morphological case-marking in the instance of German) and basic word order. In her theory, morphological coding reflects the number of Proto-Role entailments congruent with a specific argument. Word order, however, follows from thematic relationships or dependencies between arguments. The two functional aspects of linguistic information, case-marking, and word order will be described in more detail in succession.

Case-marking and thematic relations are closely linked in the *Principle of Morphosyntactic Expression of Thematic Information* by Primus (1999). The number of Proto-Agent relations accumulated by a certain argument correlates with the likelihood of bearing the most unmarked case in a particular language. On the other hand, the more Proto-Patient dependencies an argument accumulates, the more likely it will take the second most unmarked case.
Two factors determine a case hierarchy for a given language. The complexity of morphophonological realizations of cases as well as the subcategorization behavior of predicates control the markedness of a given case. The more verbs choose a certain case marker for arguments, the less marked is this particular case. In addition, the less the complexity of the morphophonological realization of the case, in turn, the less marked it is (see also Eisenberg, 1999). The following case hierarchy results:

Case Hierarchy (Primus, 1999):
nominative/absolutive > accusative/ergative > dative > other oblique cases

Given that German is a nominative-accusative language, it follows that the Proto-Agent will be marked by the nominative and the Proto-Patient by the accusative in a simple transitive construction. This case-marking of Proto-Roles in such a transitive relation ensures maximal distinctness between the two given arguments (Comrie, 1989; Hopper & Thompson, 1980). According to Primus (1999), the case that is highest ranked determines verb agreement; thus, in German, it is always the nominative marked argument that agrees with the verb even if this argument does not bear the highest thematic role as it happens in constructions including a dative-experiencer verb. As a consequence, syntactic agreement is independent of the thematic status of arguments and does not serve as a reliable cue for the determination of thematic roles. In contrast, case-marking appears to be a very informative cue in terms of the thematic status

of an argument. While the nominative marking is compatible with the Proto-Agent as well as with thematically dependent arguments, the accusative is only compatible with the Proto-Patient status. These considerations result in the view that thematic information can be extracted by scrutinizing the case-marking of an argument in German. However, nominative and accusative case-marking of nouns is partly ambiguous in German and therefore not an available information in certain instances. Specifically, only masculine nouns are unambiguously case-marked for nominative and accusative while feminine and neuter nouns carry the same, hence ambiguous, case-marking in the nominative and accusative in German, respectively.

Word order, in contrast to case-marking, is a function of thematic relations in Primus' *Principle of Structural Expression of Thematic Dependencies* (Primus, 1999). Argument A is structurally superior to argument B if the latter is thematically dependent on the former. Structural superiority, in turn, surfaces as precedence of A before B in linear word order and/or is additionally defined in terms of c-commandment[3] of the thematically higher-ranking argument over the lower-ranking argument. As a consequence of this principle, certain canonical word orders occur in a given language. Canonical or unmarked word order is characterized as the structure of a sentence that speakers freely choose in a neutral context, as for example in answering the question "What happened?" (Siwierska, 1988).
The nominative-accusative word order constitutes the canonical word order for a simple transitive relation in German, since nominative marked arguments are never outranked by accusative marked arguments[4]. Hence, according to Fanselow (2000) and Wunderlich (1997), every topicalization (i.e., an accusative-initial or object-initial sentence) in German represents a marked, non-canonical, and derived word order.

The third possible realization and mapping of thematic roles, namely *animacy*, will only be briefly summarized, since it will not be a further topic of the work at hand. As mentioned above, when describing the Proto-Agent, it is widely assumed that the Proto-Agent is animate, and, in constrast, that the Proto-Patient is inanimate (Comrie, 1989; Dowty, 1991; Hopper & Thompson, 1980; Langacker, 1991). However, because animacy constitutes an inherent

[3] In particular, it is defined as asymmetric c-command, which is true for an argument A c-commanding B, if and only if (1) A does not dominate B and B does not dominate A, and (2) the first branching node dominating A also dominates B. Asymmetry in the c-commands occurs if A c-commands B and B does not c-command A (Haegemann, 1994).
[4] One exception might be accusative object-experiencer verbs. But for even those, however, the possibility to ascribe Agent attributes to the nominative argument was proven (Bornkessel, 2002; Fanselow, 2000; Scheepers, Hemforth, & Konieczny, 2000).

property of an entity and cannot be manipulated by the speaker as case-marking or word order, it cannot be established as a very reliable or often available feature or cue for identifying thematic roles.

1.4 Interim Summary

This chapter aimed to explain different levels of description in linguistic theory about syntactic arguments and their realization in German in more detail. The traditional notion of the syntactic functions subject, object, and predicate were outlined as well as the theoretical view of their semantic relations as thematic roles were clarified. It was shown that arguments of a sentence are thematically hierarchically ordered to convey the dependencies of participants in an event. Also essential for the purpose of the current thesis, the theta criterion was introduced stating that each thematic role indicated by a respective case can only be assigned once. This one-to-one mapping is mainly realized by the linguistic information of case-marking and word order. From the case hierarchy and structural principles of word order, a prototypical simple transitive German construction results, which includes a nominative-marked agent followed by the verb followed by an accusative-marked patient. As a consequence, topicalized or object-initial structures always represent a marked and non-canonical linguistic instance. Importantly in this context, thematic information can be derived from case-marking of an argument "without necessarily having to make reference to the syntactic structure of a sentence" (Bornkessel, 2002).

The following chapter will provide an overview on studies concerning the processing of case marking, word order, and thematic roles in adults, which led to various neurocognitive models of syntactic processing.

2 The Goal to be Achieved: Syntactic Processing in Adults

In order to establish a common ground of a syntactic processing model that children should eventually reach, the following chapter addresses the behavioral, neuropsychological, and neurophysiological bases of case-marking, thematic roles, word order, and argument structure processing in adults. It first gives special attention to evidence arising from studies concerning non-prototypical word order and those employing violation paradigms regarding case marking as these two subfields are focused by the current research. Given that the method of electroencephalography (EEG)/event related brain potentials (ERPs) was chosen for a large body of the current research, studies relating to the temporal resolution of syntactic processes build the focus rather than those dealing with the spatial resolution of these processes, namely functional magnetic resonance imaging (fMRI). To this end, the chapter commences with a short overview of the most important ERP components well established in context of the neuropsychological science during the past decades.

Second, two models of the underlying cognitive processing mechanisms that have been formulated on the basis of the research in the field of cognitive neuroscience are described; Friederici (2002) postulated the Neurocognitive Model of Auditory Sentence Comprehension and Bornkessel and Schlesewsky (2006a), effectively as an extension of the former model, formulated the extended Argument Dependency Model.

2.1 Behavioral and Neurophysiological Evidence

The method of electroencephalography records changes of voltage at the surface of the scalp over time for the purpose of measuring the exact temporal resolution of ongoing cognitive processes in the brain. Given that language processing requires analysis and integration of numerous and various linguistic aspects within an especially short period of time, this highly time-sensitive online measurement is well suited to investigate linguistic processes in the brain. Resulting from many, mainly adult, ERP studies, different processing aspects of speech could be discriminated by different ERP components. Processing of different levels of linguistic information have been identified concerning low-level acoustic processing (N1-P2 complex), phonetic and phonological processing (mismatch negativity (MMN)), prosodic processing (right anterior negativity (RAN)/closure positive shift (CPS)), and, most importantly for the current research, concerning morphological processing (early left anterior negativity/left anterior negativity (E/LAN)), semantic processing (N400), and syntactic processing (P600). In

the following paragraphs, the latter three ERP components are briefly presented and summarized.

The **LAN** designates a negativity in the ERP at 300-500 ms post-stimulus onset at primarily left anterior electrodes (for an overview, see Friederici, 2002; Gunter, Friederici, & Schriefers, 2000). It occurs in response to morphosyntactic violations, for instance as a reaction to a mismatch between presented and stored morphological forms (Krott, Baayen, & Hagoort, 2006), to subject-verb agreement violations (Osterhout & Mobley, 1995), verb-tense violations (Osterhout & Nicol, 1999), gender violations (Gunter et al., 2000), or case violations (Coulson, King, & Kutas, 1998). Moreover, the LAN was also observed in the processing of verb-argument violations (Rösler, Friederici, Pütz, & Hahne, 1993). Also, from early on in ERP research, the LAN is discussed in conjunction with working memory processing loads (Kluender & Kutas, 1993).

The LAN could be shown in numerous languages as English, Dutch, Italian, Spanish, and German, but appears to depend in its occurrence on the degree to which a certain language makes use of morphological cues for encoding syntactic relations (Friederici & Weissenborn, 2007). As a consequence, it was also described as an index of syntactic-relational processing mechanisms that are employed for thematic role assignment (Friederici, 2002).

The ERP component **N400** occurs in centro-parietal regions as a negativity at around 400 ms (ranges from 300-600 ms) post-stimulus onset. The N400 has been thoroughly investigated and is known to signal lexical-semantic processing at the word level (Holcomb & Neville, 1990) as well as at the sentence level (Kutas & Hillyard, 1980, 1983). The component is related to expectations elicited by the semantic context. The more expected, familiar, or matching a stimulus event is, the less pronounced, or in other words, the more reduced the N400 and thus the semantic integration efforts (Holcomb, 1993). This mechanism, called semantic priming, was employed to study the N400 in various experiments.

A semantic violation paradigm also shows N400 responses in studies on sentence processing, as for instance for sentences including semantically unexpected endings versus semantically expected endings (Friederici, Pfeifer, & Hahne, 1993; Hahne & Friederici, 2002). In addition to these lexical-semantic processes, the N400 has also been reported as a response signaling reanalysis processes on the sentential level as for example in non-preferred disambiguation towards dative-initial interpretations (Bornkessel, McElree, Schlesewsky, & Friederici, 2004). Thus, the N400 does not only reflect lexical-semantic processes but also certain aspects of the processing of grammatical and thereby thematic relations.

The **P600** occurs as a centro-parietal positivity between 600-1000 ms post-stimulus onset in the ERP. It was first observed by Osterhout and Holcomb (1992) in response to a syntactic anomaly. It was described as a syntactic positive shift (SPS) by Hagoort, Brown, and Groothusen (1993). Often, the E/LAN is followed by a P600 in response to syntactic violations in a biphasic pattern (Friederici et al., 1993; Hahne & Friederici, 1999; Osterhout & Mobley, 1995). In light of these findings, it is assumed that, after initial detection of syntactic errors (E/LAN), the P600 reflects controlled processes of syntactic reanalysis and repair. The P600 could be elicited in response to phrase-structure violations (Friederici, Hahne, & Mecklinger, 1996; Hahne, Eckstein, & Friederici, 2004; Hahne & Friederici, 1999), subjacency violations (Neville, Nicol, Brass, Forster, & Garrett, 1991), congruence violations (Friederici et al., 1993), verb tense violations (Gunter, Stowe, & Mulder, 1997), and violations of verb-argument structures and case-marking (Friederici & Frisch, 2000).

The P600 component was not only shown in response to syntactic violations, but also in response to garden-path sentences or syntactically complex structures which demand a high degree of syntactic integration/reanalysis/repair processes (Friederici et al., 1996; Frisch, Schlesewsky, Saddy, & Alpermann, 2002; Hagoort et al., 1993; Kaan, Harris, Gibson, & Holcomb, 2000; Osterhout & Holcomb, 1993; Osterhout, Holcomb, & Swinney, 1994).

On the basis of these various findings, it is assumed that the P600 constitutes a heterogeneous ERP component that reflects different processing mechanisms of syntactic information. Friederici, et al. (2002) were able to demonstrate different distributions for the reanalysis P600 (fronto-central) and the repair P600 (centro-parietal).

In addition, the P600 has also been discussed in relation to the interaction of syntactic and semantic processes (Gunter et al., 2000; Kuperberg, Caplan, Sitnikova, Eddy, & Holcomb, 2006; Kuperberg, Sitnikova, Caplan, & Holcomb, 2003). Moreover, more recent studies reported a P600 in response to semantic violations on the sentence level (Hoeks, Stowe, & Doedens, 2004; Kim & Osterhout, 2005; Kolk, Chwilla, van Herten, & Oor, 2003; Kuperberg, Kreher, Sitnikova, Caplan, & Holcomb, 2007) that question the exclusively syntactic interpretation of the P600. Explanations of these *semantic P600*s all share the involvement of thematic processes which were integrated into the eADM (see below) (Bornkessel-Schlesewsky & Schlesewsky, 2008).

2.1.1 Processing of Non-Canonical Structures in Adults

A large body of literature exists concerning the interpretation and processing of non-prototypical word order and in particular of topicalized objects in German adults. For the

processing of object-initial sentences, adults do not show any problems in comprehension. Moreover, adults were shown to demonstrate no differences in ERPs at the first (NP1) or second nominal phrase (NP2) when processing topicalized objects in unambiguous German main clauses (cf. example 1a/b) compared to canonical word order, suggesting there are no additional processing costs for the non-canonical order (Frisch et al., 2002). A further study replicated this result in general, although a minor effect at NP2 in the form of a more positive-going wave was found at one electrode position for the object-initial structure (Frisch & Schlesewsky, 2005). The authors interpreted this small effect as a preference for a subject-initial word order in German (see below). Nonetheless, it is assumed that object-initial constructions in simple transitive main clauses in German do not lead to reanalysis efforts in adults. This was also shown in a reading study by Schlesewsky et al. (1999).
Other studies examining topicalization in subordinate clauses (Bornkessel, Schlesewsky, & Friederici, 2002a) or ambiguous sentences (see example (2)) (Frisch et al., 2002), however, report various reanalysis costs for object-initial structures in adults.

(2) ‘Die Detektivin hatte der Kommissar gesehen und…’
[the detective]FEM.AMB had [the policeman]MASC.SUB seen and…
‘The policeman had seen the detective and…’

In scrambled German sentences (i.e., in non-canonical sentences including the relevant noun phrases in middle position), a left anterior negativity (LAN), which is usually seen to reflect morphosyntactic processes, was found for non-pronominal object phrases in non-canonical position (Rösler, Pechmann, Streb, Röder, & Hennighausen, 1998; Schlesewsky, Bornkessel, & Frisch, 2003). Also, Matzke, Mai, Nager, Rüsseler, and Münte (2002), reported a LAN at both NP1 and NP2 in response to non-canonical unambiguous sentences using masculine nouns. In Basque OVS structures, also a LAN was found at sentence initial position when compared to SVO sentences (Zawiszewski & Friederici, 2009). For scrambled sentences, the so-called *scrambling negativity* has been observed for accusative-marked initial arguments occurring mostly centrally distributed at 300-500 ms post-stimulus onset (Bornkessel & Schlesewsky, 2006b; Bornkessel, Schlesewsky, & Friederici, 2003; Schlesewsky, Bornkessel, et al., 2003).

Thus, although there seem to be no additional processing costs in very simple object-initial structures, in light of the findings above and also concerning ambiguous or garden-path sentences, several researchers assume a subject-initial preference for German speakers (Beim

Graben, Saddy, Schlesewsky, & Kurths, 2000; Friederici & Mecklinger, 1996; Mecklinger, Schriefers, Steinhauer, & Friederici, 1995). This subject-initial preference could also be evidenced in a reading study concerning embedded clauses (Bader & Meng, 1999), in other behavioral studies regarding main clauses (Hemforth, 1993; Scheepers et al., 2000), and in other Germanic languages as Dutch (Frazier, 1987; Kaan, 1996, 1998). Even for pseudo-word sentences containing case-marked functional elements the same effect was found (Röder et al., 2000).

This subject first preference might not be due to statistically given factors in German (e.g., most German sentences are uttered in a subject-verb-object [SVO] order) but to predictions the language parser makes for structural properties of sentences (Bornkessel, Schlesewsky, & Friederici, 2002b). Hence, a prototypical word order is expected when processing transitive sentences. As a consequence, not the frequency of a structure is responsible for its canonicity but the prototypicality of the order thematic roles are arranged in, i.e., Proto-Agent before Proto-Patient (Ferreira, 2003); see Hyönä and Hujanen (1997) for the opposite perspective.

As mentioned previously, animacy information also functions as a cue for thematic hierarchical ordering in German (Frisch & Schlesewsky, 2001, 2005; Kuperberg, 2007; Kuperberg et al., 2003; Schlesewsky & Bornkessel, 2004, 2006). For example, if the first noun phrase is processed as an object (due to accusative case-marking), it is expected that the second noun phrase will be an animate subject (due to the principle of the theta criterion that each thematic role can only be assigned once in a sentence and the prototypicality of the thematic roles). The prototypical actor is presumed to be animate and the prototypical patient to be inanimate. If this noun phrase happens to be inanimate, an N400 results as these constraints are not met (Haupt, Schlesewsky, Roehm, Friederici, & Bornkessel, 2008; Schlesewsky & Bornkessel, 2004). Schlesewsky and Bornkessel (2006) could also show that the mechanisms of reanalysis differ dependent on the argument structure presented. Structures including dative verbs elicited an N400 when prototypical animacy constraints were violated while accusative structures evoked a P600.

The big picture of processing topicalized objects or ambiguous structures in this regard in adults might certainly be even more multilayered when it comes to individual or cross-linguistic differences. Two studies (Bornkessel, Fiebach, & Friederici, 2004; Clifton et al., 2003) focused on individual differences of processing ambiguous structures in high-span and low-span readers. The former but not the latter found differences between those two groups arguing that working memory capacities influence sentence-processing mechanisms and,

moreover, that low-span readers have difficulties to inhibit non-preferred readings. Bornkessel et al. (Bornkessel-Schlesewsky et al., 2011) also observed cross-linguistic differences in processing *semantic reversal anomalies* (see example (3)) that they accounted to differences in form-to-meaning mapping between, e.g., German, Turkish, and Mandarin Chinese. These cross-linguistic processing differences were explained in terms of the eADM (see below).

(3) …dass Schalter Techniker bedienen
…that switches technicians operate
'…that technicians operate switches'

In addition, evidence from impaired language processing in aphasic patients (broca-aphasia) demonstrates that, in an eye tracker experiment, patients displayed only mild impairment in interpreting subject-initial structures while object-initial structures caused more severe difficulties (Hanne, Sekerina, Vasishth, Burchert, & de Bleser, 2009). The results were interpreted as reduced syntactic reanalysis abilities in agrammatism. (Please, also compare Wartenburger, Heekeren, Burchert, De Bleser, & Villringer, 2003; Wartenburger et al., 2004.)

2.1.2 Processing of Syntactic Violations in Adults

Besides investigating adult syntactic processing by presenting non-canonical, complex, or ambiguous (but still correct) structures, violation paradigms are employed in numerous studies regarding the same topic. The rationale behind this is that sub-processes within syntactic online comprehension can be differentiated by violation paradigms. A given syntactic violation will cause a disruption of the ongoing syntactic analysis at its level and point of occurrence and will hence disclose particular steps in language processing. Thus, investigations of case-marking violations especially, allude not only to the processing of case-marking and thematic role functions but also give insights into the anticipation the language system builds up at certain sentence positions.

In particular, electrophysiological studies that used such a violation paradigm have provided crucial information about argument assignment and argument expectations in the adult processing system (Frisch & Schlesewsky, 2005). When arguments in a transitive construction are marked in the identical case (e.g., examples (4a/b)) in German and cannot be hierarchically ordered based on animacy information, Frisch & Schlesewsky (2005) demonstrated that the language system nevertheless tries to resolve this conflict. Adults were tested in an ERP study with double nominative (4a) or double accusative (4b) constructions:

(4a) *Welcher Kommissar lobte der Detektiv im Bahnhof?
[which inspector]NOM commended [the detective]NOM in the railway station

(4b) *Welchen Kommissar lobte den Detektiv im Bahnhof?
[which inspector]ACC commended [the detective]ACC in the railway station

Both conditions yielded to a biphasic N400/P600 ERP pattern. The N400 was interpreted as a result of thematic integration difficulties of the second case-marked noun phrase (NP) and the P600 as a response to the syntactic ill-formedness. Interestingly, in the double accusative condition (4b), the N400 was more pronounced than in the double nominative condition (4a) indicating the former to be appearing more salient to adults. Accordingly, in a study employing a speeded grammaticality task (Schlesewsky, Fanselow, & Frisch, 2003) double nominative constructions were judged as more grammatical than double accusative constructions while requiring more time for the judgment procedure. This supports the view that in adults the accusative violation is more obvious in the course of sentence processing than the nominative violation. However, when the second argument was replaced by a pronoun in otherwise identical sentences, these differences in the grammaticality judgments disappeared. These results are explained in terms of the crucial element's saliency since pronouns are considered more salient than determiner phrases. From their behavioral study, the authors conclude that it is the parser's analysis on the second NP that causes the effects for the double nominative sentences (Schlesewsky, Fanselow, et al., 2003). Thus, the processing of these violations at the second NP is expectation-driven. As mentioned above, it is often assumed that the language system makes predictions for structural properties of a sentence (Bornkessel et al., 2002b) and expects a prototypical, i.e. subject-first, structure when confronted with transitive sentences (Beim Graben et al., 2000; Friederici & Mecklinger, 1996; Mecklinger et al., 1995). In the test sentence (4a), the subject-first hypothesis is met by the first NP being filled by a nominative marked Agent and then further supported by the verb. Consequently, the second NP is readily overlooked in double nominative violations. By means of these processing mechanisms, quick and early semantic interpretations might be possible (Schlesewsky, Fanselow, et al., 2003). The processing of sentence (4b) is different as the initial NP is marked in the accusative case, which is already at this point in conflict with the subject-first hypothesis.

The same violations as in (4) elicited only a P600 when the conflict could be resolved on basis of an animacy hierarchy, i.e., when one argument was animate and one was inanimate, strengthening the view on the N400 signaling difficulties in thematic hierarchically ordering in

these argument violations (Frisch & Schlesewsky, 2001). Compare also the occurrence of an N400 in response to semantic-thematic violations in Kos et al. (2010). Bornkessel (2002) could furthermore show that context information or general world knowledge does not support thematic hierarchically ordering in case of conflicting situations.

The same biphasic N400-P600 pattern was also observed for Japanese speakers (Mueller, Hirotani, & Friederici, 2007) processing sentences including two identical case-marked arguments. Also, semantic mismatches of adjective and nouns and verbs and nouns elicited the same ERP pattern (Zhang, Jiang, Saalbach, & Zhou, 2011). In addition, violations of the number of arguments yield to the same N400-P600 response in German speakers (Friederici & Frisch, 2000) as well as structures which violated the syntactic and thematic restrictions of a verb argument structure (example 5) (Frisch, Hahne, & Friederici, 2004).

(5) *Der Garten wurde am gearbeitet und…
*the garden was on-the worked and…

The combination of number and case violations led to a LAN-N400-P600 pattern, while only number agreement violations usually produce a LAN-P600 effect in German speakers (Roehm, Bornkessel, Haider, & Schlesewsky, 2005). These findings picture the very distinct steps in the domain of syntax for the timely sequence of language processing. However, both the semantic-thematic as well as the syntactic processing step can be manipulated to a certain extent. For instance, Isel and Shen (2011) were able to block an N400 effect by a grammaticality task and a P600 resulted in response to semantically incongruent conditions instead.

In contrast to the biphasic N400/P600 pattern observed in response to case-marking violations in German, a LAN/P600 pattern was found in adults processing case violations on pronouns in English (e.g., The plane took *we to paradise and back.) (Coulson et al., 1998). A biphasic LAN/P600 pattern was also observed as a result of gender agreement errors between nouns, determiners, and adjectives (O'Rourke & Van Petten, 2011). In other English studies, violations of subject-verb agreement (Kutas & Hillyard, 1983) or verb tense violations (Osterhout & Nicol, 1999) did not elicit a LAN that is usually associated with morphosyntactic processes (Fiebach, Schlesewsky, & Friederici, 2002; Friederici, 2002). Hence, Friederici and Weissenborn (2007) argue that the more a certain language relies on morphosyntactic marking the more likely a LAN occurs in experiments in the respective language. Accordingly, even pronoun case violations do not always elicit a LAN, as Frenzel, Schlesewsky, and Bornkessel-

Schlesewsky (2010) proved a N400-late positivity pattern depending on animacy and verb induced agreement.

2.2 Neurocognitive Models

Two models of language processing that are based on the studies cited above and numerous other electrophysiological, functional imaging, and patient studies will be briefly introduced and summarized in the following chapter. In the discussion of the present study, the results will be interpreted on the basis of these two models, the *Neurocognitive Model of Auditory Sentence Comprehension* (Friederici, 1995, 2002; Friederici & Kotz, 2003) and the extended *Argument Dependency Model* (Bornkessel & Schlesewsky, 2006a).

The Neurocognitive Model of Auditory Sentence Comprehension (Friederici, 2002, 2006, in press) assumes three phases for sentence comprehension after an initial phase 0 that includes initial acoustic and phonological analysis of auditory input (0-100ms after sentence onset). Each of the three phases are associated with particular ERP components (see Figure 1).

Phase (1) has the function of syntactic structure building (i.e., phrase-structure building) taking place between 100-300 ms after sentence onset. In Phase (1), the system identifies word forms and assigns words to their syntactic categories for further integration into the given syntactic structure. If a mismatch between the syntactic category of a word and the expectations based on its preceding word occurs, an ELAN results. The ELAN and the processes concomitant with it are presumed to be highly automatic (Friederici et al., 1993; Hahne & Friederici, 1999; Lau, Stroud, Plesch, & Phillips, 2006; Neville et al., 1991).

Phase (2) (300-500 ms after sentence onset) encompasses two independent and parallel pathways. The lexical information of the initial processed word is retrieved in a functional (syntactic) and in an interpretative (semantic) way. Hence, morphosyntactic as well as lexical features are analyzed and integrated, most likely in parallel, into the semantic-thematic structure of the sentence for each word, respectively (e.g., thematic roles are assigned by linking the relations between a verb and its arguments). Lexical-semantic violations elicit an N400 at this stage. However, in this phase a LAN reflects morphosyntactic violations.

Phase (3) (500-1000 ms after sentence onset) is responsible for syntactic integration processes including processes of syntactic reanalysis and/or repair. In the case of a mismatch between different kinds of information, a P600 is elicited. Importantly, phrase-structure building processes of Phase (1) are seen independent of semantic processing.

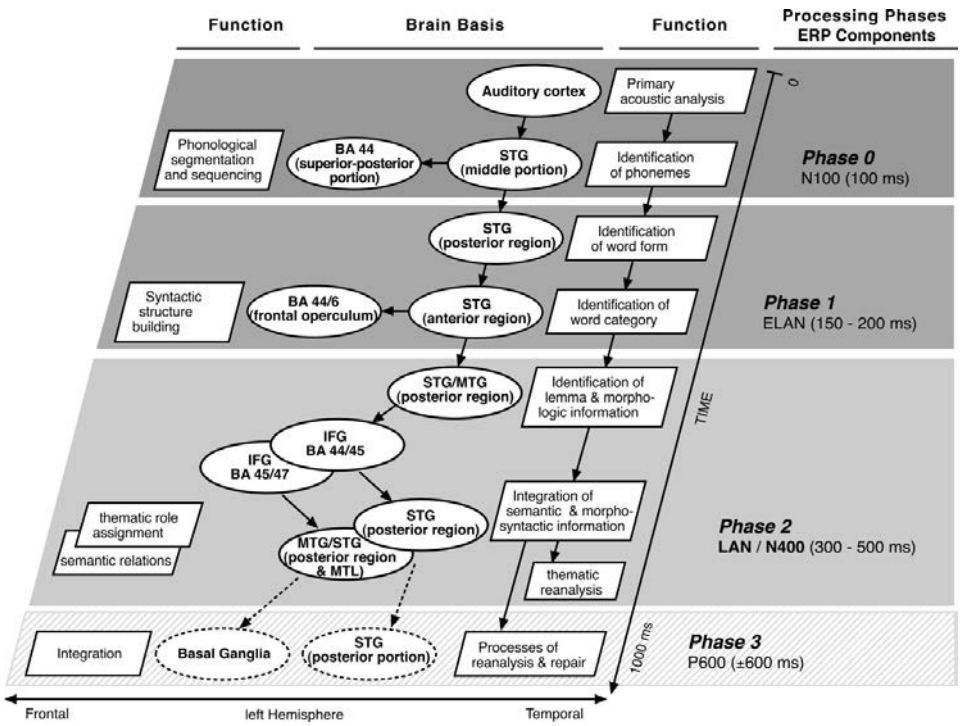


Figure 1. The Neurocognitive Model of Auditory Sentence Comprehension. Every processing phase is related to particular ERP components (Figure from Friederici, 2006).

However, other syntactic information, as in Phase (2) and (3), is taken to dynamically interact with semantic processing. For instance, semantic and structural information retrieved in Phase (2) are mapped onto each other in Phase (3), a process that might require repair of, e.g., non-grammatical sentences or reanalysis of, e.g., non-canonical structures. In contrast to the highly automatic initial phase, processes of Phase (3) established in the current model come to pass in a controlled manner.

The *Dynamic Dual-Pathway Model* extended the *Neurocognitive Model of Language Comprehension* incorporating prosodic (suprasegmental) information as a second pathway to the first segmental pathway described above (Friederici & Alter, 2004). These two pathways interact dynamically depending on the linguistic input and its particular features (for evidence on these two pathways in children, please compare Wartenburger et al., 2007).

The extended Argument Dependency Model (eADM) by Bornkessel and Schlesewsky (2006a) builds on the processing model (Friederici, 2002) described above and thus also attempts to describe semantic and syntactic processes on neurophysiological and neuroanatomical grounds. The model also assumes three processing phases while Phase 2 is subdivided into two phases, Phase 2a and 2b (see Figure 2).

In Phase (1), phrase structure is also processed with the specification of an activation of a formal phrase-structure template (TEMPLATE ACTIVATION). In Phase (2a) relevant features of the noun phrases as well as of the verb are extracted while an argument prominence hierarchy, based on the morphological and positional features, is established for the noun phrases. The computation of these takes place in the subsequent Phase (2b) in which the step COMPUTE PROMINENCE is initiated and hence thematic roles are assigned to the given arguments. The assignment of thematic roles is computed on basis of case-marking, animacy, definiteness and position of arguments and can be executed without the information provided by the verb.

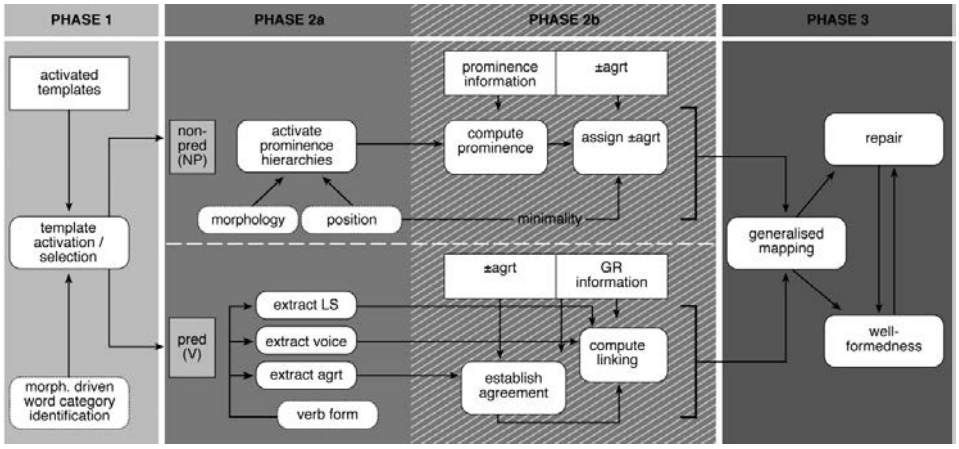


Figure 2. The the extended Argument Dependency Model (Figure from Bornkessel & Schlesewsky, 2006a)

In addition, the formal agreement between the arguments and the verb is established on basis of the prominence information in the step ASSIGN +/- AGRT. In parallel, or more specifically at the position of the verb, and still in Phase (2b), however, the logical structure of the verb is extracted and linked with the argument-based prominence information (COMPUTE LINKING) by assigning the hierarchically ordered argument to a position within this logical or semantic structure. The GENERALIZED MAPPING occurs in the following Phase (3) in which interpretation is modified according to frequency, world knowledge, plausibility, and task demands and necessary repair steps are taken.

For German, Bornkessel and Schlesewsky (2006a) importantly assume in Phase (2a) that the parser either uses morphological or positional features for the establishment of syntactic dependencies. If case information (i.e., morphological information) is ambiguous, the system relies on word order (i.e., positional information). If, however, arguments are unambiguously case-marked, word order information is completely overridden. Bornkessel (2008) distinguishes between primary prominence information as case-marking (e.g., crucial for German) and word order (e.g., crucial for English) and secondary prominence information as animacy and definiteness. This process of form-to-meaning mapping varies cross-linguistically (Bornkessel-Schlesewsky et al., 2011) and consequently elicits different ERP responses in different languages. For all languages, the theta criterion still holds that the form-to-meaning mapping has to take place under the principle that there can only be a one-to-one mapping of thematic roles to arguments (Bornkessel, 2002).

The eADM differs from the *Neurocognitive Model of Language Comprehension* in that it reduces the role of the syntax only to phase (1) while the establishment of thematic hierarchies in phase (2) is guided by other principles and information than syntax in particular (Bornkessel-Schlesewsky & Schlesewsky, 2008).

2.3 Interim Summary

The present chapter's goal was to describe the temporal characteristics of the brain mechanisms underlying the processing of case-marking, thematic roles, word order, and argument structure in adults. The ERP components associated with morphosyntactic processing (LAN), semantic processing (N400), and syntactic processing (P600) have been shortly introduced. Electrophysiological and behavioral research on non-canonical main clauses (i.e., object-initial structures) has revealed no additional processing costs. However, in response to more complex non-canonical structures as subordinate clauses, ambiguous, or garden-path sentences, a LAN or scrambling negativity was often observed, which led to the assumption of a subject-first preference in adults. When processing case and argument violations in German, a biphasic N400-P600 pattern occurs indicating thematic integration difficulties and a response to syntactic ill-formedness. The results of electrophysiological and brain imaging studies on syntactic processing in adults have been integrated in the *Neurocognitive Model of Auditory Sentence Comprehension* (Friederici, 2002) and the *extended Argument Dependency Model* (Bornkessel & Schlesewsky, 2006a). The following chapter will provide a summary of behavioral and electrophysiological research that has given insights into the development of syntactic processing in children until the present.

3 The Development of Syntactic Processing

In the process of language acquisition, children have to attune to the specific phonemes and stress pattern of their native language, segment words from the ongoing speech stream and map them onto their respective meanings, acquire the grammatical combinatorial rules for these words, and learn the pragmatic conventions as how to use these sentences in the specific culture. At around 12 months of age, infants start to produce their first words and about six months later they begin to combine two words into an utterance. Between two and two and a half, toddlers start to utter more complex constructions including three or more words. Afterwards, the elaboration of syntactic structures takes place as, for instance, relative clauses or inversion. Language acquisition, however, is a long process that might not be completely accomplished in German until the age of 12 (Klann-Delius, 1999). Although the course of language acquisition has been described in detail since the beginning of the 20th century (Clark, 2003; Klann-Delius, 1999; Stern & Stern, 1928; Szagun, 2006), many puzzling questions still remain. For instance, one question is posed in the current work as to when and how children assign thematic roles to arguments based on case-marking information in German. The knowledge gathered in this respect on behavioral and neurophysiological grounds will be summarized in the following sections. Furthermore, a theoretical model for the acquisition of syntactic and grammatical structures will be introduced, namely the *competition model* proposed by Bates and MacWhinney (1987, 1989).

3.1 Behavioral and Neurophysiological Evidence

As shown in the first chapter, a prerequisite of the ability to map linguistic forms onto their thematic role functions lies in the knowledge of case-marking and word order regularities of a certain language. While German children have already acquired the prototypical word order rules of German at the age of two and a half (Clahsen, 1986; Klann-Delius, 1999; Szagun, 2006), the acquisition of the forms of case-marking and its functions requires a much longer time.

Regarding the acquisition of the form of the accusative case-marking, Stern and Stern (1928) observed the production of it on determiners starting at the age of two and a half in their diary study, while Clahsen (1984) reports the same from a twin study, but only after the third birthday. In contrast, Szagun's (2004) analysis of a corpus study found evidence for accusative case-marking produced already by two-year-olds. However, the error rate in the usage of the accusative form was still much higher than the one for the nominative at the age of three-years

eight-months. According to Clahsen (1984), Tracy (1986) describes four phases of the acquisition of case morphology. During Phase (1) no case markers are produced, in Phase (2) the nominative form appears, while in Phase (3) a 'binary system' of nominative and accusative case forms emerges including overgeneralizations of the accusative to dative, which, in turn, occurs in Phase (4).

The acquisition of the declination system is influenced by a set of factors. While syntactic categories might advance the process (Clahsen, 1984; Tracy, 1986), perceptual saliency, distributional and conceptual factors also might play a role (Szagun, 2004). Conceptually, the more unambiguous a form-meaning mapping of a particular relation is, the faster the acquisition improves (see also below, Bates & MacWhinney, 1987, 1989). Perceptually, the definite article 'den' in the accusative is very salient and might thus appear first in German (Tracy, 1986).

The final disentangling of word-order and case-marking occurs as one of the last steps in children's development of the case system according to Tracy (1986); she concludes, "…children learning German may still rely on word-order strategies in perception and ignore inflections, even at times when their own productions show correct assignment of cases, at least for nominative and accusative in variable positions" (Tracy, 1986, p. 71). Behavioral evidence for the question of what age children have disentangled word order and case-marking and furthermore are able to use the latter for correct form-meaning mapping onto thematic roles in reception will be presented next.

In an acting out task, Dittmar et al. (2008a) tested German children at the age of two, five, and seven. For two-year-olds, both word order and case-marking cues were necessary to correctly mimic the action encoded in a test sentence. Five-year-olds were able to use the word order cue alone, but not case-marking alone. Interestingly, only seven-year-olds were eventually able to assign correct thematic roles to constituents in a transitive sentence based on the case-marking cue alone.

The development of the sensitivity to the word order and case-marking cue between 21 months and five years of age was described at closer age intervals in several other studies. In a preferential looking task, 21-month-olds were able to correctly interpret German transitive sentences including the coalition of word order and case-marking cues, but only after syntactic training (Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008b). This study replicated findings found in English children before (Gertner, Fisher, & Eisengart, 2006). Furthermore, Chan, Lieven & Tomasello (2009) showed an increase in reliance on the word-order cue from two and a half to three and a half to four and a half, with the latter age group displaying the highest

use of word order and the youngest age group understanding only prototypical transitive sentences with a coalition of the animacy and word order cue. Starting at the age of five, there seems to be more attendance to the case-marking cue (Lindner, 2003; Mills, 1977; Schaner-Wolles, 1989) as Mills (1977) found a blocking of the word-order strategy for unambiguous accusative markers in the initial position at this age. The overall results by Lindner (2003) outline the development in the way that children start with lexical semantics (i.e., animacy), then proceed to grammatical cues, as the nominative case, or agreement with the usage of the latter occurring at five years. A similar result was reported for German children aged five and a half who interpreted object-initial structures up to 78% correctly (Watermeyer, 2010).

These findings contradict the study by Dittmar et al. (2008a) as it was not until children were 7 years of age that they were able to correctly use the case-marking cue. Future studies must clarify the picture and reveal under which conditions children are sensitive to which cues for sentence interpretation during development. Furthermore, another discrepancy was shown between different behavioral methods that have been employed. While production and act-out studies showed only knowledge of a canonical transitive construction beginning at the age of three, preferential looking studies suggest the same already for two-year-olds or even 21-month-olds. Apparently, these two tasks measure children's syntactic knowledge in very different ways.

Another factor that enhances the understanding of transitive construction could be proved in a study including prosody as a cue for interpretation. Children aged five indentified thematic roles better if the non-canonical object-initial structure was accompanied with a typical intonation pattern (Grünloh, Lieven, & Tomasello, 2011).

Cross-linguistic research has provided evidence that children are sensitive to the cues relevant for thematic role interpretation at different ages depending on their respective native language. Regarding English, one-third of all three-year-olds produce transitive constructions (Tomasello, 2005). Concerning reception, English two-year-old children are shown to be able to already make use of the very reliable word order cue for the language in a forced-choice paradigm (Dittmar, Abbot-Smith, Lieven, & Tomasello, in press; Noble, Rowland, & Pine, 2011). However, employing an acting out paradigm, it was demonstrated that children under the age of 3 were not able to understand agents and patients in sentences with novel verbs based on the word-order cue alone (Akhtar & Tomasello, 1997). Given that the latter study used a different paradigm, it is once more emphasized that different behavioral methods deliver very different results.

In further cross-linguistic evidence with the acting out task, it was evident that children rely on the case-marking cue in Turkish at the age of two (due to the very high cue validity in that language, see below), Hungarian children at the age of three-years one-month and Serbo-Croatian children at the age of four-years two-months (Bates et al., 1984; Slobin & Bever, 1982). In contrast, Italian children rely most often on the animacy cue (Bates et al., 1984).

A key consideration is the neural underpinnings of the processing of case-marking functions, thematic roles and argument expectations in children. Electrophysiological methods might be able to elucidate the question of which cues are recognized and employed by children at what age and which developmental steps are followed.

Since the crucial ERP components observed in the adult studies on syntactic-thematic processing in German are the LAN, the N400, and P600 the literature on the development of these components will be briefly reviewed. The following ERP effects have been identified so far in early childhood.

In reaction to semantically anomalous sentences, two studies (Hahne et al., 2004; Holcomb, Coffey, & Neville, 1992) have reported the occurrence of an N400 in five- and six-year-olds, respectively. Another study reported several negativities that were apparent over anterior regions of the scalp in children aged three- and four-years for semantically incongruous words at the sentence level (e.g., My uncle will blow the movie.) (Silva-Pereyra, Rivera-Gaxiola, & Kuhl, 2005). While four-year-olds displayed two negativities, at 400 ms and between 500-800 ms, three-year-olds exhibited three negativities (at 300-500 ms, 500-800 ms, and 800-1000 ms). The authors (Silva-Pereyra, Rivera-Gaxiola, et al., 2005) interpreted the first negativity as similar to the adult-like N400 and the late negativities as signaling a process that they labeled as ‘sentence closure’. In a second study employing the same paradigm (Silva-Pereyra, Klarman, Lin, & Kuhl, 2005), 30-month-old infants also showed a negativity peaking around 500 ms that was taken as an N400. Friedrich and Friederici (2005) were able to report similar results in 19- and 24-month-olds for sentences in which the semantics of an object did not match the antecedent verb (e.g., The cat drinks the ball.): 19-month-olds were found to display two negativities (from 400-500 ms and 600-1200 ms) and 24-month-olds one long-lasting negativity from 300-1200 ms. Thus, negativities as a precursor to the adult-like N400 for semantic incongruence at the sentence-level start very early in infancy and are reflected as negativities that differ in latency throughout child development. The syntax-related N400 has not been investigated in children until today.

Regarding syntactic violations, Silva-Pereyra et al. (2005) reported a broadly distributed positivity in three- and four-year-olds in response to morphosyntactic violations (e.g., My

uncle will watching the movie.). A LAN that would have been expected according to adults' ERPs did not appear in these two groups or in 30-month-olds (Silva-Pereyra, Klarman, et al., 2005). However, for the processing of phrase-structure violations, an ELAN and a P600 were present in 32-month-olds (Oberecker, Friedrich, & Friederici, 2005). The ELAN, which is taken to reflect automatic phrase-structure building processes (Friederici, 2002), could not be found in 24-month-olds using the same stimuli, although a P600, which is taken to reflect more controlled processes, was shown in this age group (Oberecker & Friederici, 2006). In contrast, for violated passive sentences the ELAN occurs only very late in development. Hahne, Eckstein, and Friederici (2004) reported no negativity in six-year-olds and a broadly distributed negativity in seven-year-olds when processing these violations (see example 6).

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

Only 13-year-olds demonstrated an ELAN-like effect in this study. Similar results of the development of left anterior negativities were also shown for the LAN (Lück, Hahne, & Clahsen, 2001). In response to sentences including violations of the German plural inflection, seven-year-olds displayed a broadly distributed negativity, which reduced gradually to frontal electrodes and resembled a LAN eventually in children at the age of 11 and a half. In summary, concerning ERP components associated with syntactic and morphosyntactic processing, the P600 might be detected earlier in children than the ELAN which, in turn, might be detected earlier than the LAN.

To date, there are very few ERP studies specifically on the processing of object-initial structures in children. Testing three-year-olds, Mahlstedt (2008) found a positivity (300-500 ms) time locked to NP1 for object-initial compared to subject-initial structures and a biphasic early positivity (220-600 ms) and late negativity (750-1200 ms) time locked to NP2. These findings were interpreted as an indication for a subject-initial preference in three-year-olds. However, in this experiment, the processing of case marking was not directly tested, but was crossed and partly confounded with animacy cues. Children at the age of eight who were also tested with object-initial structures in an ERP experiment (Leuckefeld, 2005) processed the unambiguously case-marked non-canonical sentences in a similar way to adults, showing no additional processing costs. Regarding the processing of different argument structures, ambiguous object-initial sentences elicited an adult-like biphasic N400/P600 pattern in eight-year-olds (Leuckefeld, 2005).

3.2 A Theoretical Account on the Development of Syntax Acquisition

In the present chapter, a theoretical model of syntax acquisition will be introduced. More specific, it will focus on a theoretical account of the course of development outlined above for word order, case-marking functions, and assignment of thematic roles in children. The *Competition Model* by Bates & MacWhinney (1987, 1989) will also deliver a concept that attempts to explain the relatively late acquisition of the accusative function for thematic role assignment in German children.

The Competition Model focuses on sentence comprehension and provides also a model for the development of children's interpretational syntactic strategies (Bates & MacWhinney, 1987, 1989; Bates et al., 1984; MacWhinney, Bates, & Kliegl, 1984). According to the model's basic assumption, linguistic cues are operated on in a probabilistic manner by the system to process sentential relationships. The probability is defined by the function of 'cue validity,' which is, in turn, determined by the combination of 'cue availability' and 'cue reliability'. For instance, cues such as case-marking, word order, or verb agreement can be employed to assign thematic roles in sentential relationships. The more often a particular cue is available, (e.g., overt case-marking), the higher the value of the 'cue availability'. In parallel, the less ambiguous a particular cue (e.g., the feminine determiner 'die' can be nominative or accusative case in the singular), the higher the 'cue reliability'.

The model (Bates & MacWhinney, 1987, 1989) posits that, in German, the most reliable cue is case-marking, but its cue availability is low since only masculine nouns are unambiguously marked. The word order cue, however, is highly available, as arguments always have to be sequentially ordered, but is not always reliable. Because German has a very flexible word order, the agent does not always stand in the initial position. Each linguistic cue can thus be assigned a specific value of validity. Due to its low availability, the case-marking cue has low cue validity in German. Lindner (2003) has calculated the cue validities for the possible cues of thematic role assignment in German with the following results: Word order cue: 0.891, animacy contrast cue: 0.770, case-marking cue: 0.653, subject-verb-agreement cue: 0.652.

Adults will rely on the cue carrying the highest degree for sentence interpretation. Since not every cue is always available in a certain context, adults will, however, also attune very flexible to less valid cues. As the name of the model implies, thematic role assignment will result from a dynamic competition between the different cues that are simultaneously activated. The competition, thus, produces a winning interpretation based on the so-called 'relative cue strength' of the cues in a particular context (Bates & MacWhinney, 1989).

Children might first acquire cues with the highest validity and thus word order cues in German. The acquisition of the case-marking cue will only occur later mainly for the reason of its low

availability value in the input. In the course of language acquisition, however, the child has to learn that case-marking presents a much more reliable cue than word order, although it is sometimes ambiguous. Hence, the initial advantage of the high availability of the word order cue has to subordinate to the higher reliability of morphological case-marking (MacWhinney, Leinbach, Taraban, & McDonald, 1989).

Cue values of availability, reliability, and consequently validity vary widely across languages. These different values, following the competition model, cross-linguistically account for the different ages at which particular cues are used by children and at which the interpretation of thematic role relationships is mastered. In Turkish, for instance, the case cue carries very high cue validity as it is both of high availability and high reliability. These considerations match perfectly the behavioral findings for Turkish children reported above that they already rely on the case-marking cue at the age of two (Bates et al., 1984).

Moreover, if all cues are available in coalition for a child and form, for instance, a prototypical German sentence, this might be the easiest situation for children (coalitions-as-prototypes model; (Bates & MacWhinney, 1987)).

3.3 Interim Summary

The present chapter's aim was to give an overview of the syntactic development in language acquisition with special regard to the acquisition of linguistic information as word order rules and case marking for thematic role assignment. Children start to produce the accusative case-marking necessary for marking patient roles in transitive structures between two and three years of age. Behavioral evidence, although reporting heterogeneous results, points towards the finding that children start to be able to use this case-marking for thematic role interpretation between five and seven years of age. Neural correlates of these studies have so far been sparsely reported. However, it is known that the P600 could be found in children much earlier (at 24 months) than the ELAN (at 32 months) than the LAN (only found at the age of seven).

A theoretical account of syntactic acquisition, the *Competition Model* (Bates & MacWhinney, 1987, 1989), predicts based on cue values assigned to interpretational cues for thematic roles as, for example, case-marking that German children might first rely on the word order cue and will only later acquire the case-marking cue. These predictions fit the data gained in behavioral research.

II Empirical Investigations

4 Research Questions

As proposed by the competition model (Bates & MacWhinney, 1987, 1989), the usage of different cues for thematic role assignment in language comprehension play a crucial role at different stages of language acquisition. As outlined in Chapter 1, it is essential for sentence comprehension to understand 'who is doing what to whom' and hence to assign participant roles to the particular arguments in a clause. Various morphological realizations exist in the German language based on which of the thematic roles of Agents and Patient can be assigned. While the prototypical word order in simple transitive German sentences positions the Agents first followed by the verb followed by the Patient, it can still vary. The reason for this is that case-marking signals at least for masculine nouns unambiguously the nominative or accusative which are prototypically associated with the Agent or Patient role, respectively. In this regard, the acquisition of the functions of case marking for thematic role assignment seems to be particularly relevant for syntax acquisition. As outlined in Chapter 3, results of behavioral methods differ as to when German children make use of which morphological cues during language development. For this reason, further studies are required that investigate the mechanisms underlying children's acquisition of the cues necessary for sentence interpretation. Given that this evidence is also at variance due to methodological differences, two distinct behavioral methods will be employed. The *behavioral study* of sentence-picture matching examines offline the ability of children to match subject-initial and object-initial sentences that are unambiguously case-marked to matching pictures. Hence, their ability to interpret the non-prototypical word order of object-initial clauses based on the case-marking cue will be investigated. The same ability with the exact same sentences and pictures will be studied by the *eye tracker study*. Preferential looking studies have reported earlier abilities in children regarding sentence interpretation than behavioral methods as acting out (3.1). Thus, the eye tracker study aims to deliver converging evidence for this methodological question and furthermore aims to gain further insights into the sensitivity to the different morphological cues by analyzing the timely sequence of gaze behavior in children. In contrast to behavioral studies, the ERP method allows scrutinizing online stimulus processing. Syntactic processing is reflected by the ERP components LAN, P600 and partly N400 (2.1). *ERP study I* examines the neurophysiological basis of non-prototypical sentences in German by comparing the processing of subject-initial versus object-initial clauses in children.

Furthermore, as introduced in Chapter 1, the theta criterion holds that every thematic role can only be assigned once in a single sentence. The development for this rule in children will be tested in *ERP study II*. It aims to investigate the neurophysiological basis and timely sequence of processing case-marking violations in children as well as their repair mechanisms for thematic hierarchically ordering as visible in the ERPs. As discussed in Chapter 2.1.2, especially violation paradigms are suitable for revealing sub-processes within syntactic online comprehension. To this end, the processing of double-nominative and double-accusative constructions will be assessed in comparison to their correct counterparts.

Given that for all research questions the development of the syntactic abilities in children will be investigated, all studies have been conducted with three age groups: three-year-olds, 4;6-year-olds, and six-year-olds. Because children start to produce the accusative case marking at the age of three or shortly before (3.1), the ability to assign a function to this case becomes particularly relevant starting at that age. Further development from this age on will be depicted by 4;6-year-olds and six-year-olds while it is known that beginning at around the age of five, children start to use the case-marking cue more consistently.

All studies have been additionally conducted with adults whose results will serve as a reliable comparison to the children's data.

The specific hypotheses for these experiments for adults and children will be formulated in Chapter 6 and Chapter 7 in the context of the respective experiments.

5 General Methods

The behavioral, ERP, and eye-tracker experiments as well as their analyses were all conducted, as far as possible, in a standardized manner with the same procedures. The current chapter serves as an overview of all the experiments carried out and the general methods employed. In the respective method sections of the different age groups, particular information is given when necessary.

5.1 Experimental Design and Material

For all experiments, 24 test sentences were created, 12 with subject-initial word order and 12 with object-initial word order. All nouns used were of masculine gender, belonging to the strong declination type, and were animate. It is only in masculine nouns that nominative and accusative can be unambiguously case-marked in German and only the determiner preceding the noun indicates the case in strong nouns. In this way, all nominal constituents in a sentence were unambiguously marked for accusative or nominative at the determiner (see Table 1). Nouns and their combining transitive verbs were chosen after a pretest with 30 children (10 three-year-olds, 10 five-year-olds, 10 six-year-olds) to ensure that all preschoolers knew the relevant words and named every actor and the action on the pictures consistently. For details of this pretest and an overview of the resulting final material, please see Appendix A and B, respectively. For the test sentences, six nouns and six verbs resulted:

Nouns: Igel (hedgehog), Hund (dog), Tiger (tiger), Vogel (bird), Käfer (beetle), Frosch (frog)

Verbs: ziehen (to pull), küssen (to kiss), waschen (to wash), malen (to paint), tragen (to carry), kämmen (to comb)

Table 1. Stimulus examples for the subject-initial and the object-initial condition, used in the behavioral, ERP, and eye-tracking experiments:

1) Subject-initial
Der Tiger küsst den Frosch.
[the tiger]NOM kisses [the frog]ACC
'The tiger kisses the frog.'
2) Object-initial
Den Frosch küsst der Tiger.
[the frog]ACC kisses [the tiger]NOM
'The tiger kisses the frog.'

Every animal occurred equally often as Agent, Patient, and in interaction with other animals as well as in an NP1 or NP2 position. From a semantic point of view, all Agents consisted of ideal Agent-Roles in terms of Primus (1999) as they met the criteria of acting deliberately, involving a physical action and being animate.

The corresponding pictures were created using Adobe illustrator and showed the respective two animals engaging in the respective action. Animals were controlled for size and position within the picture frame; the illustration of the action performed by one of two animals was counterbalanced in order to show the agent to the right or to the left of the patient in an equal number of cases.

For the behavioral experiment, each picture card then contained two pictures in counterbalanced order aligned on the horizontal axis, the corresponding picture to the respective test sentence and the picture with reversed Agent and Patient (For examples of the picture material, please see Appendix B).

For the eye-tracking experiment, the identical sentence and picture material as in the behavioral experiment was used (see Appendix B). Pictures were presented on a screen and auditory sentences assembled to a movie generated with a film software (Edius by Canopus). Regarding the recording and splicing procedure of the auditory stimuli see below as a subset of the material created for the ERP experiment was utilized.

For the ERP experiment, the same sentences as in the behavioral experiment were used. In addition, stimuli were expanded with six additional transitive verbs: schieben (to push), kratzen (to scratch), schlagen (to hit), fangen (to catch), beißen (to bite), and treten (to kick). This resulted in a total of 48 test sentences and thus a larger number of trials for the ERP experiment (24 in the subject-initial condition, 24 in the object-initial condition). A violation paradigm was also presented within the ERP experiment containing double nominative or double accusative sentences. The structures employed violated the theta criterion in order to investigate argument expectations and repair mechanisms for thematic hierarchies on a neurophysiological basis. The violations contained identical verbs and nouns as the correct sentences that were simply violated in these former two conditions. 24 double nominative and 24 double accusative constructions resulted (see Table 2). All test sentences are included in Appendix B.

Table 2. Stimulus examples for the double nominative and the double accusative condition, used in the ERP experiment:

3) Double nominative
*Der Tiger küsst der Frosch.
[the tiger]NOM kisses [the frog]NOM
4) Double accusative
*Den Tiger küsst den Frosch.
[the tiger]ACC kisses [the frog]ACC

For the purpose of auditory stimuli presentation, the correct sentences (subject-initial and object-initial material) were recorded. A trained female speaker produced the given sentences in a soundproof chamber speaking the material in a mildly child-directed manner. After recording, sentences were digitized (44.1 kHz/16bit sampling rate, mono) and normalized in amplitude to 70%. The last noun phrase was cross-spliced afterwards to create the violated sentences and to retain natural prosody at the sentences' final position. For assuring comparability, the correct sentences were likewise cross-spliced. The eye-tracker experiment employed a subset of these correct stimuli (For acoustic analyses of the auditory material, please see Appendix C).

5.2 Participants

5.2.1 Adults

All adult participants were monolingual German native speakers and right-handed, as assessed by a German version of the Edinburgh Handedness Inventory (Oldfield, 1971). The research was approved by the ethics committee of the University Leipzig. No hearing deficits or neurological problems were known for these subjects. There were three groups of adults: One group received the ERP experiment, one group the eye-tracking experiment, and one the behavioral testing. The eye-tracking participants were recruited in Berlin from the database of the BabyLab Berlin. For the behavioral and EEG-testing, adults were recruited from the database of the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany.

5.2.2 Children

Toddlers and preschool children were recruited from kindergartens and from the database of the BabyLab Berlin. The research was approved by the ethics committee of the University Leipzig. All participants were healthy, monolingual German children without any hearing or neurological problems. They were all born at full-term after no unusual circumstances during pregnancy of their mothers. Prior to participation, informed parental consent was attained for every child. All age groups were tested within an age range of plus/minus two months. There were two groups of children: One group was tested in the ERP experiment, and one group received the eye-tracker experiment. Both groups were assessed with the behavioral test and the language development test (TROG-D).

5.3 Behavioral Method: Sentence-picture Matching

For the behavioral experiment, children sat together at a table with the experimenter and were first familiarized with the animal pictures and were asked to name each animal separately. Next, the task was introduced: "Now, I am going to show you a picture card with two pictures on it. I am going to tell you which picture you can find for me". Then the first picture card was presented on the table. Shortly after, the experimenter told the toddler: "Show me …" followed by the test sentence. During this procedure, the experimenter always looked to the child and never to the picture cards. The experimenter repeated each test sentence a maximum of two times. After the child identified one picture as the corresponding one by pointing, the answer was noted. The protocol of the child's reactions did not include second answers to the same test sentence. There were three possible responses: (1) The child pointed to the left picture, (2) to the right picture, or (3) to no picture at all. Adults were tested with the exact same procedure. The whole behavioral test of 24 trials took approximately 10 minutes.

The order of test sentences was pseudo-randomized in the way that neither the same condition (object-initial/subject-initial) nor the correct position of the pictures (left/right) were repeated more than three times in a row. In addition, the same action in which the actors engaged (i.e., the verb used) reoccurred no more than two times directly after each other. Four sets of pseudo-randomization resulted and were distributed randomly amongst all participants.

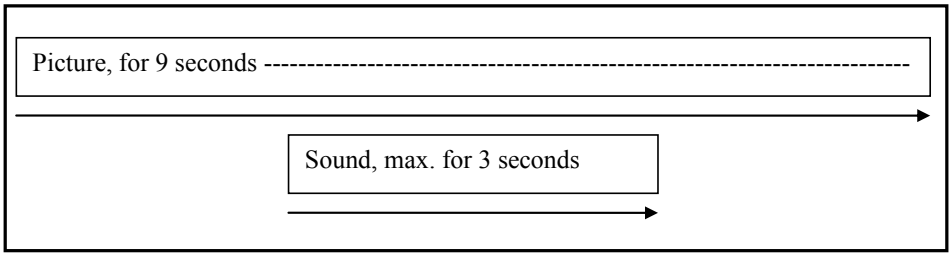
5.4 Eye Tracking

All children sat in a car safety seat (Chicco, Neptun) placed in front of the eye tracker in a viewing distance of approximately 60cm. Concerning the youngest age group, parents stood behind their child while wearing sunglasses to prevent interferences of their eyes and were

instructed not to interact with their child. The experimenter controlled the experiment via a second computer sitting in a different part of the room not visible to the child or parent. Children were instructed, "just to watch TV" in order to measure automatic and task-independent behavior. A Tobii T120 near infrared remote eye tracker recorded the participant's gaze. This device is integrated into a 17 inch TFT monitor with no apparent tracking devices. It accounts for freedom of head movements of 44 x 22 x 30 cm. Before recording the gaze, a 9-point infant calibration was carried out that showed a blue and white ball which expanded and contracted at regular intervals (extended diameter: 3.3 visual degrees). A sound accompanied the appearance of the ball in order to attract even greater attention. After successful calibration, the experiment started and the gaze was recorded at a sampling rate of 60 Hz.

In each trial (see Table 3), both pictures (corresponding and non-corresponding) showed for nine seconds, the whole length of the trial. After three seconds, the sound (sentence duration between 2030-2610 ms) played which allowed for at least three more seconds of eye tracking after participants had listened to the test sentence. The inter-stimulus interval, during which the screen was black, lasted for two seconds. The total duration of the experiment including 24 trials amounted to 4.5 minutes.

Table 3. Example of the course of one trial in the eye-tracker experiment



The pictures in each trial were aligned on the horizontal axis and vertically located at the center of the screen (for an example, see Appendix B); the resolution of the screen was 1024x768.

The procedure of pseudo-randomization equaled the one of the behavioral test.

5.5 From EEG to ERP

To record electrical brain activity, the method of electroencephalography (EEG) is utilized. Electrodes attached to the scalp measure the voltage changes resulting from the differences between recording electrode and reference electrode potentials. The current is a consequence

of large synchronously active populations of neurons (mainly pyramidal cells) in the neocortex, which produce the extracellular flow of electrical activity due to dipoles between their respective somas and dendrites.

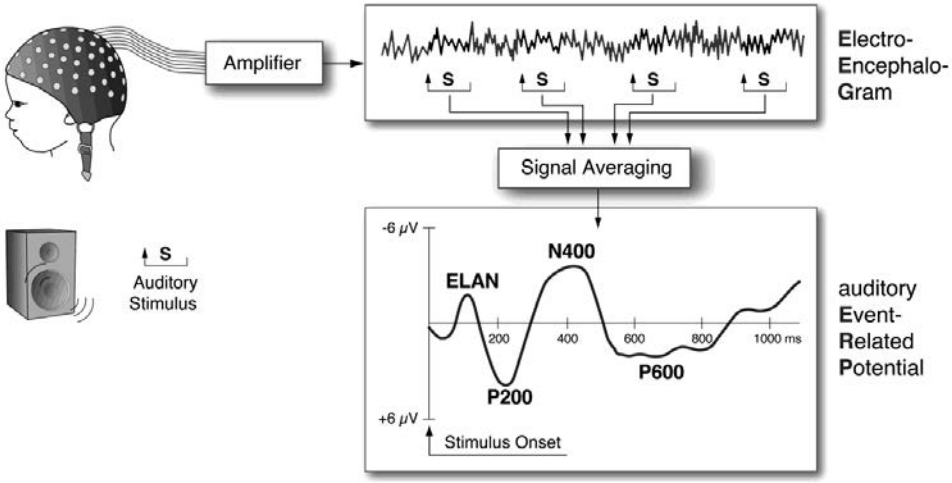


Figure 3. From EEG to ERP: The averaging procedure of an EEG that results in an exemplary ERP waveform. Importantly, by convention, negativity is plotted upwards.

If these voltage changes are time-locked to a given stimulus (see Figure 3), an event-related brain potential (ERP) can be extracted. In comparison to the voltage changes of an EEG (50-100µV), those of an ERP are relatively small: maximally 10 µV (Regan, 1989). Hence, a large number of stimuli of each respective type are needed in order to obtain the ERP signal out of the noise of the EEG. By means of averaging the EEG across all events of one stimulus type, noise is reduced and voltage changes not related to the processing of the stimulus are eliminated. Eventually, grand-averages over all participants are computed to further gain a better signal-to-noise ratio and to decrease inter-individual differences. Generally, ERP components are characterized by their polarity (negative or positive relative to another experimental condition), their latency (temporal characteristics relative to stimulus onset), their topography (spatial distribution over the scalp), and their functional significance (specific elicitation under certain experimental manipulations) (Rugg & Coles, 1996).

The EEGs in the present studies were continuously recorded from silver-silver chloride electrodes at sites F7, F3, FZ, F4, F8, FC3, FC4, T7, C3, CZ, C4, P7, CP5, CP6, T8, P3, PZ, P4, P8, O1, O2, A1, and A2 (according to the 10-20 International System of Electrode

Placement) (see Figure 4). The electrodes were secured in an elastic electrode cap (Easy Cap, Falk Minow). In addition, an EOG was recorded from two electrodes at the outer canthi of both eyes (horizontal EOG) and from single electrodes on the infraorbital and supraorbital ridges of the right eye (vertical EOG). The recordings were referenced to CZ, and an additional electrode served as common ground (placed at FP1 for children and on the sternum for adults). For children, electrode impedances were kept below 10kΩ in most cases (at least below 20kΩ), and in all cases for adults, it was below 5kΩ. EEG data were digitized on-line at a rate of 500 Hz and stored on a hard drive for further analyses.

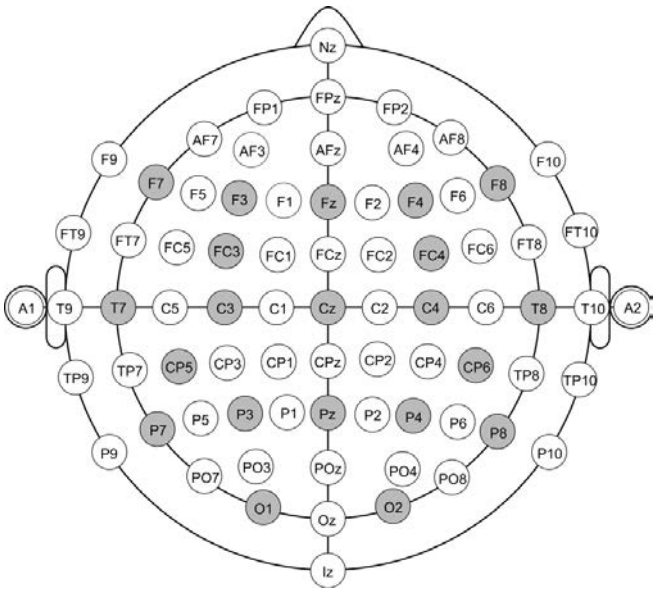


Figure 4. Electrode placement of the international 10-10 System. Gray electrode positions mark the positions used in the present work.

During the EEG experiments, children sat on their parent's lap in a comfortable chair in an electrically shielded and sound-attenuated EEG cabin. Parents were instructed to sit still and to remain silent. Stimuli were presented via a loudspeaker; children listened passively to the sentences while watching an undemanding video without sound (fire in a fireplace). The video was intended to prevent extreme eye movements and boredom. The whole experimental session was divided into two blocks, each containing 48 sentences in a pseudo-randomized order. Each block lasted about 4.5 minutes. A break was included between blocks if necessary. Between each sentence (2030-2610 ms of length), there was an inter-stimulus interval of 2500 ms. In total, one complete experimental session took around nine minutes. Pseudo-

randomization ensured that no more than three structural equal sentences or more than two equal verbs followed in sequence. Eight sets of pseudo-randomized stimuli resulted. Adults were tested in the EEG in the same way.

5.6 Language Testing: TROG-D

After the behavioral test, children participated in a language development test. All age groups (three, 4;6, and six-years) performed the TROG-D (Fox, 2008), which is standardized for three- to ten-year-olds. The test employs a sentence-picture matching task and assesses the receptive grammatical development of children. All children included in our behavioral and ERP samples were normally linguistically developed according to the standardized t-values of the TROG-D (i.e., performed above a t-value of 40).

Behavioral tests and the EEG experiment or eye-tracking experiment, respectively, were counterbalanced, with half the children first tested behaviorally and then in the EEG/eye-tracking experiment, and half the children tested in the opposite order.

5.7 Data Processing and Analysis

In order to analyze *the behavioral experiment*, every answer (correct/incorrect/no answer) per trial and child was translated into a number code and entered into SPSS. Besides descriptive statistics, analysis of the correct identification of the corresponding picture in the sentence-picture matching task in relation to chance level (50%) was performed by a one-sample t-test per condition (subject-initial/object-initial). The development across age groups of correct responses to the subject-initial and object-initial condition, respectively, was calculated by a t-test for independent samples.

The eye tracking data provides information about the position of the left and right eye on the x- and y-axis of the screen in each case at every given recorded point in time over the course of the experiment (sampling rate at 60 Hz) in a text file. These data were transferred into spreadsheets (Excel) for every single participant and further analyzed with a Matlab script. The program computed the average of both eyes. In cases of data with one eye missing at a certain point in time the data of the other eye, respectively, was solely taken as fixation point. Two areas of interest (AOI) were defined comprising the two pictures in rectangles with the outer limits exactly bordering the black surrounding of each picture (for an example see Appendix B). Averages were computed for fixation durations to the correct picture for each participant and condition in relation to NP1 onset (until verb offset, 1.5s of length) and to NP2 onset (2.0s

of length). Trials were considered valid if participants fixated every picture at least for 200 ms. Participants revealing a preference to look to either side of the screen over the course of the experiment were excluded given that they fixated the left or right picture for more than five consecutive trials. A minimum of six trials per child was eventually necessary to enter the final sample. Additionally, averages of fixation duration were calculated for sliding time windows of 200 ms over the whole course of the experiment (trial course analysis) for each participant and condition. In turn, for each participant and condition per 200 ms, the criterion of a minimum of six trials had to be met. Due to an insufficient number of trials, the first 200 ms of every trial course were excluded from further analysis. Moreover, the analysis of first look latencies after NP1 and NP2 onset resulted in too few trials per participant and could not be further pursued. Given that first look latencies could only be calculated if a participant changed gaze from the incorrect to the correct picture, too few trials even resulted to begin with the first look latency analysis.

Statistical analysis of gaze duration after NP1 and NP2 onset, respectively, to the correct corresponding picture in relation to chance level (50%) was performed by a one-sample t-test per condition (subject-initial/object-initial). The development across age groups of the gaze duration to the correct corresponding picture for both conditions was calculated by a t-test for independent samples.

Initial statistical trial course analysis was computed by a two-way ANOVA with the factors *Condition* (subject-initial and object-initial) and *Time window* (44 time windows, each 200 ms of length) with age serving as a covariate. As a next step, a two-way ANOVA with the same factors was calculated for every age group separately. Significant interactions involving the factor *Condition* were further analyzed for each time window using a one-way ANOVA with *Condition* as factor. Besides, differences between two age groups were calculated for every time window separately employing a t-test for independent samples. Additionally, for every single condition in every single time window, the gaze duration to the correct corresponding picture in relation to chance level (50%) was performed by a one-sample t-test.

Analysis of ERP data. Off-line, the EEG data were processed using the EEP 3.2.1 software package (Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany). The data was initially algebraically re-referenced to the average of both mastoids (A1, A2). To remove very slow drifts and muscle artifacts from the EEG, a digital band-pass filter ranging from 0.3 to 20 Hz (-3 dB cutoff frequencies of 0.37 and 19.91 Hz) was applied. Time segments of 900 ms (the stimulus duration from sentence onset to the onset of the second noun phrase) relative to the onset of the first noun phrase, and time segments of 1700 ms, relative to the

onset of the second noun phrase, were extracted from the continuous EEG signal and adjusted to a pre-stimulus baseline of 100 ms, respectively.

In toddlers, EEG responses exceeding an SD of 60 µV and adults' responses exceeding an SD of 35 µV in a sliding window of 500 ms were considered invalid and were excluded. The remaining trials were separately averaged for each condition (subject-initial / object-initial) and each subject. At least eight artifact-free trials for children and 12 for adults were required per condition for an individual average to enter the final sample.

Statistical analyses were performed separately for mean amplitudes on midline and lateral electrode sites. For midline sites (FZ, CZ, and PZ), a two-way ANOVA was computed with the factors *Condition* (subject-initial and object-initial or subject-initial and double nominative or object-initial and double accusative) and *Region* (anterior, central, and posterior). For lateral sites, a three-way ANOVA was performed with the factors *Condition*, *Site* (F7, F3, F4, F8, FC3, FC4, T7, C3, C4, P7, CP5, CP6, T8, P3, P4, P8, O1, O2), and *Hemisphere* (left and right). Significant interactions involving the factor *Condition* were further analyzed for each *Site*/*Region* using a one-way ANOVA with *Condition* as factor. All ANOVAs were calculated for mean amplitudes in defined time windows (TWs) (see the Results section); the Greenhouse-Geisser correction (Greenhouse & Geisser, 1959) was applied when there was more than one degree of freedom in the numerator to account for potential violations of sphericity.

Statistical analysis of the ERP data was performed relative to the onset of the first noun phrase (NP1) and to the onset of the second noun phrase (NP2). Initial ANOVAs were performed for eight different TWs relative to the NP1 onset: TW1 (100-200 ms), TW2 (200-300 ms), TW3 (300-400 ms), TW4 (400-500 ms), TW5 (500-600 ms), TW6 (600-700 ms), TW7 (700-800 ms), and TW8 (800-900 ms) and for sixteen different TWs relative to the NP2 onset: TW1 (100-200 ms), TW2 (200-300 ms), TW3 (300-400 ms), TW4 (400-500 ms), TW5 (500-600 ms), TW6 (600-700 ms), TW7 (700-800 ms), TW8 (800-900 ms), TW9 (900-1000 ms), TW10 (1000-1100 ms), TW11 (1100-1200 ms), TW12 (1200-1300 ms), TW13 (1300-1400 ms), TW14 (1400-1500 ms), TW15 (1500-1600), and TW16 (1600-1700 ms).

6 Study I: Adults

As a starting point of the current research, study I aimed to investigate syntactic processing mechanisms in adults. The data collected in this study compared with the toddler and preschool children data in response to identical stimulus material will serve to give detailed insights into developmental changes regarding syntactic and thematic processing. Hence, the same methods, stimuli, and testing procedures were employed for adults as for all groups of children in order to assure maximal possible comparison of the behavioral, neuropsychological as well as neurophysiological mechanisms.

Specifically, in experiment 1, the method of looking-while-listening with the eye tracker was used. To investigate word order processing and correct thematic role assignment based on case-marking, the response to subject-initial versus object-initial structures in simple transitive German main clauses that were unambiguous was tested. Adults listened to sentences while two pictures, one with correct Agent and Patient and one with reversed actors' roles, were displayed simultaneously. In the same line, adults listened to the same kind of sentences including object-initial and subject-initial structures in ERP-Experiment I while their EEGs were recorded. Based on previous research (Frisch & Schlesewsky, 2005; Frisch et al., 2002; Schlesewsky et al., 1999) it was hypothesized that adults do not show any processing differences between the two conditions in their ERPs or their looking behavior. Since case marking already unambiguously indicates the Patient at NP1 in the object-initial condition, it was furthermore assumed that adults' gaze should shift shortly after NP1 to the correct picture in the eye tracking experiment. However, to the author's knowledge, only one study employed a comparable paradigm for adults so far which observed gaze shift to the correct picture only at the point of NP2 (Hanne et al., 2009).

Children additionally received a behavioral experiment testing the interpretation of word order (i.e., subject-initial and object-initial constructions). The same experiment was carried out with adults in the course of a different study (Knoll, Brauer, & Friederici, 2011; please, also compare Knoll, Obleser, Schipke, Friederici, & Brauer, in press) and not in the present one. These results will be briefly summarized in the discussion for further comparison with the children's results.

To further examine not only word order processing but also thematic hierarchically ordering and argument expectation mechanisms, ERP-Experiment II exploited a case violation paradigm. Here, the aim was also to replicate the study by Frisch and Schlesewsky (2005) and thus double nominative violations as well as double accusative violations were presented (i.e., the two arguments of a simple transitive construction were identically case-marked in both

conditions). In the same experiment, subject-initial and object-initial structures were also included. The processing of the incorrect conditions was subsequently compared to their correct counterparts. A biphasic N400-P600 response to both violations was expected signaling thematic and syntactic integration difficulties (Frisch & Schlesewsky, 2005).

6.1 Eye-tracking Data

6.1.1 Methods

6.1.1.1 Subjects

21 adults (10 female) participated in the eye tracking study; no participant had to be excluded from further analysis.

6.1.1.2 Stimuli

Adults were presented with auditory stimulus material including sentences constructed in the subject-first and object-first structure while two pictures per trial were presented on a screen, one depicting the corresponding thematic roles and the other one showing reversed Actor and Patient roles (see 5.1 Experimental Design and Material). The participants listened passively to the stimuli; there was no task introduced in order to retain comparability with the children's eye tracking experiments.

6.1.1.3 Data analysis

The mean number of trials for the analysis of both time windows, beginning at NP1 and NP2, amounted to 12 trials and did not differ between conditions. The averaged mean number of trials across all time windows included in the trial course analysis resulted in 11.5 for all conditions.

As explained in detail in Section 5.7, fixation durations to the picture that corresponded with the auditory stimulus presented were averaged and analyzed according to NP1 onset (until verb offset, 1.5s of length), to NP2 onset (2s of length) and in sliding windows of 200 ms across the whole trial (trial course analysis). Within these different analyses, every condition (subject-first/object-first) was statistically analyzed in relation to chance-level (50%). In addition, trial-course statistics were computed employing two-way ANOVAs with condition (subject-first/object-first) and time window (44 time windows, each 200 ms in length) as factors.

6.1.2 Results

NP1

Adults performed above chance-level in both conditions concerning correct gaze durations to the corresponding picture in a 1.5s time window relative to NP1 onset with 58.92% in the subject-first condition ($t(20) = 3.156$, $p \leq 0.01$) and 58.83% in the object-first condition ($t(20) = 3.303$, $p \leq 0.01$). Fixation durations did not differ between conditions in this analysis as a paired t-test confirmed ($t(20) = 0.029$, $p > 0.10$).

NP2

Regarding the analysis in a 2s time window relative to NP2 onset, adults' gaze durations to the corresponding picture revealed above chance-level results for both conditions (see Figure 5). In the subject-first condition, correct fixation durations amounted to 88,84% ($t(20) = 16.167$, $p \leq 0.001$) and in the object-first condition to 82.00% ($t(20) = 8.976$, $p \leq 0.001$). A paired t-test, however, resulted in significant differences between the two conditions ($t(20) = 3.197$, $p \leq 0.01$).

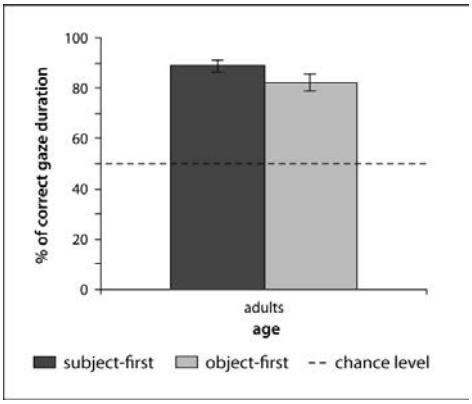


Figure 5. Adults: Averages of the correct fixation duration per condition in a 2 second time window beginning at NP2.

Trial Course Analysis

An increase in correct fixation durations in both conditions, subject-first and object-first, is clearly visible over the course of the trial in adults (see Figure 6). However, a two-way ANOVA analysis found neither a main effect of condition nor significant interactions of condition and time windows. Hence, no further one-way ANOVAs were calculated and consequently, no differences between the two conditions can be stated.

The one-sample t-test for every time window of 200 ms revealed very similar outcomes for both conditions. Specifically, gaze durations in both conditions resulted in above chance-level findings starting at time window 20 until the end of the trial, namely time window 45, (subject-first condition: t(20) = between 2.815 and 25.757, p = between 0.011 and 0.000; object-first condition: t(20) = between 2.518 and 11.340, p = between 0.02 and 0.000; for exact values in the respective TWs, please see Appendix D). Hence, while no condition differences could be confirmed, adults perform between 3800-9000 ms relative to trial onset above chance in both conditions implying an increase of correct fixation durations right after NP1 offset.

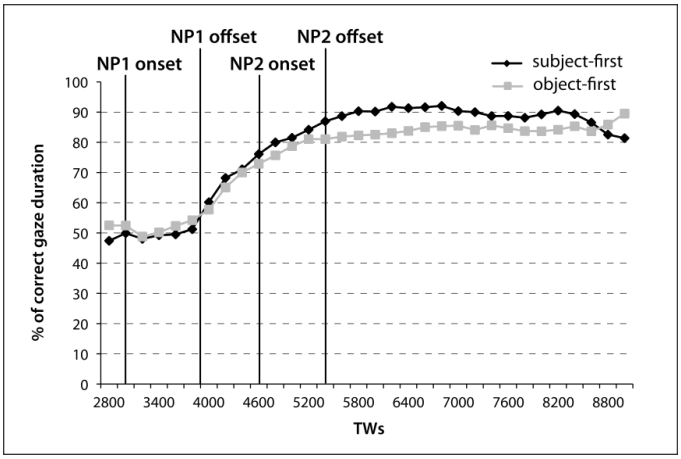


Figure 6. Adults: Averages of the correct fixation duration per condition over the course of a trial in 200 ms windows starting 2800 ms after trial onset.

6.1.3 Interim Summary: Eye-tracking Data

In sum, adults performed above chance in both conditions, subject-first and object-first, already in the 1.5s time window relative to NP1 onset with increasing results in the 2s time window relative to NP2 onset. As visible in the trial course analysis, they fixated the picture that matched the auditory stimulus significantly above chance-level starting right after NP1 offset until the end of the trial. This was true for both conditions, which did not differ. These results imply that adults show the same response to the object-first as to the subject-first sentences in the eye tracker revealing effortless and accurate processing of unambiguously case-marked object-initial sentences.

6.2 ERP-data I: Processing of Object-First Structures

6.2.1 Methods

6.2.1.1 Subjects

The number of adults tested in ERP experiment I amounted to 33 (16 female). They were aged between 21 and 27. In order to guarantee equal conditions for adults and children, the adult group listened passively to the sentences in the ERP experiment as well. This made the experiment less demanding than experiments requiring a task and led to high artifact rates in 11 adults in the NP2 analysis. These were excluded from further analysis. The final analysis involved (for NP1/NP2, respectively) 33/22 participants (16/10 female).

6.2.1.2 Stimuli

Adults listened passively to stimuli material including subject-first and object-first sentences (see 5.1 Experimental Design and Material).

6.2.1.3 Data analysis

The resulting mean number of averaged trials across adult participants was 22/19 for NP1 and NP2, respectively. These numbers did not differ between conditions.

Statistical analyses were performed separately for mean amplitudes on midline and lateral electrode sites. For midline sites (FZ, CZ, and PZ), a two-way ANOVA was computed with the factors *Condition* (subject-initial and object-initial) and *Region* (anterior, central, and posterior). For lateral sites, a three-way ANOVA was performed with the factors *Condition*, *Site* (F7, F3, F4, F8, FC3, FC4, T7, C3, C4, P7, CP5, CP6, T8, P3, P4, P8, O1, O2), and *Hemisphere* (left and right). Significant interactions involving the factor *Condition* were further analyzed for each *Site*/*Region* using a one-way ANOVA with *Condition* as a factor.

6.2.2 Results

<u>NP1</u>

In adults, the processing of the first nominal phrase at sentence onset in the object-initial structure is reflected by a more negative wave compared to the subject-initial structure (Figure 7, left panel). The interaction condition and site was statistically significant in TW2 ($F(8,256) = 4.298$, $p \leq 0.05$) at lateral sites, as was the interaction condition and region at midline ($F(2,64) = 5.236$, $p \leq 0.05$), but could be proven only at one single electrode, F7: ($F(1,32) =$

5.310, $p \leq .005$). A main effect of condition was apparent for TW3 at lateral sites ($F(1,32)= 5.083$, $p \leq 0.05$) and for TW5 at midline ($F(1,32) = 4.314$, $p \leq 0.05$). In short, the ERPs revealed processing differences at NP1 between the object-initial and subject-initial condition shown by a negative shift between 200-600 ms over fronto-central brain regions as reaction to the object-initial sentences.

NP2

ERPs (Figure 7, right panel) display very small differences in response to object-initial compared to subject-initial structures relative to NP2 onset in adults. Hence, statistical analysis revealed no significant differences between the two conditions. However, in TW7, an interaction of condition and hemisphere ($F(1,21) = 5.939$, $p \leq 0.05$) and of condition and region at midline ($F(2,42) = 3.646$, $p \leq 0.05$) occurred. In TW12 and TW13, an interaction of condition and region at midline ($F(2,42) = 3.265$, $p \leq 0.05$ and $F(2,42) = 3.887$, $p \leq 0.05$) and additionally in TW13, of condition and electrode sites ($F(8,168) = 3.667$, $p \leq 0.05$) was observed, but further analyses revealed no significant differences at individual electrode sites or in different time window scales.

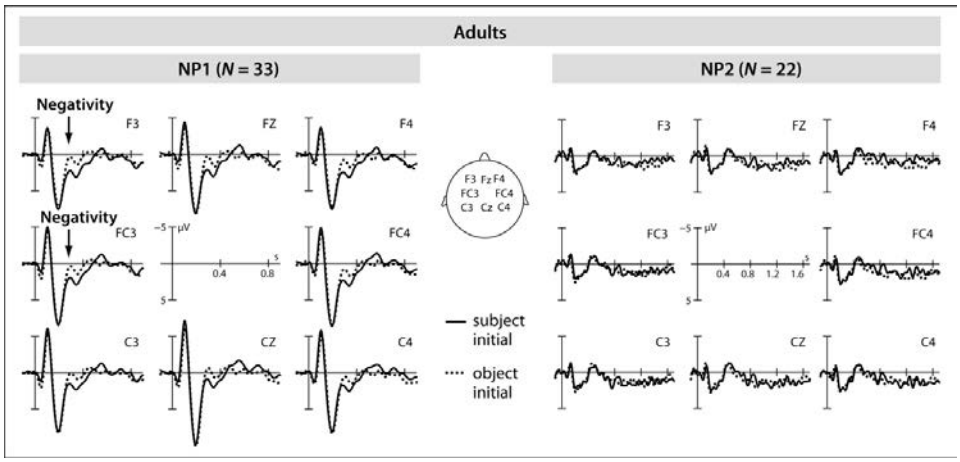


Figure 7. Grand-average ERPs of adults for selected electrodes, object-initial versus subject-initial, relative to the onset of NP1 (left panel) / NP2 (right panel). The subject-initial condition (solid line) is plotted against the object-initial condition (dotted line). Negative voltage is plotted upwards.

6.2.3 Interim Summary: ERP-data I

The adults' ERPs in response to the object-initial condition compared to the subject-initial condition reveal an additional processing effort at NP1 in form of a fronto-central negativity for the object-initial condition. Following the processing of the object noun in initial position,

processing of the rest of the sentence is effortless as indicated by the absence of any effect at NP2 for the object-initial condition.

6.3 ERP-Data II: Processing of Argument Violations

6.3.1 Methods

6.3.1.1 Subjects

The same number of adults as for the ERP-Experiment I were tested (33 participants, 16 female). They were aged between 21 and 27. As already described for the subjects in ERP-Experiment I, the adult group listened passively to the sentences in the experiment. This made the experiment less demanding than experiments requiring a task and led to high artifact rates in 11 adults in the analysis. These were excluded from further analysis. The final analysis involved 22 participants (10 female).

6.3.1.2 Stimuli

Adults listened passively to the stimulus material that contained subject-first, double-nominative, object-first and double-accusative structures (see 5.1 Experimental Design and Material).

6.3.1.3 Data Analysis

The resulting mean number of averaged trials across participants accounted for 19 in adults. These numbers did not differ between conditions. The same statistical analysis as in ERP-Experiment I was conducted.

ERP responses to the subject-initial and double-nominative condition and also to the object-initial and double-accusative condition were only compared at NP2. Given that subject-initial and double nominative structures consist equally of an NP1 in the nominative case, it seemed plausible to compare these structures only at NP2. The same is true for the object-initial and double accusative condition that both start with an initial NP in the accusative case. In order to keep the precondition of an equal sentence beginning constant, comparisons across these two pairings were abandoned and not considered meaningful.

Given that the ERP-Experiments were designed for preschoolers, they consequently lacked a task and were very low demanding for adults. As a consequence, adults were bored and often even drowsy during the experiment, which resulted in high artifact rates and, due to a lot of

alpha waves, very noisy overall data. For this reason, statistical analysis emerged to be very difficult. To give an overview of the statistical tendencies found, p-values of 0.10 will also be reported in ERP-Experiment II.

6.3.2 Results

Experiment I: Double-Nominative Violation

Visual inspection of adults' ERP-data in response to the double-nominative violation compared to the subject-initial structure suggested an early negativity over fronto-central regions and a later centro-parietal positivity (see Figure 8). In accordance with this impression, statistical analysis revealed a significant interaction of condition and hemisphere in TW3 ($F(1,21) = 20.965$, $p \leq 0.05$). Subsequent single electrode analysis, however, was mainly only marginally proven significant over frontal, central and left temporal brain regions (see Table 4, upper panel). The positivity was confirmed significant by an interaction of *Condition* and *Site* in TW5 ($F(8,168) = 3.279$, $p \leq 0.05$). *Condition* main effects of single electrodes, in turn, could mainly only be marginally attested over a right centro-parietal region (see Table 4, lower panel).[5] In sum, statistical analysis revealed the tendency of a fronto-central negativity between 300-400 ms and a centro-parietal positivity between 500-600 ms.

Table 4. Condition Main Effects of adults' ERPs in different TWs, double nominative compared to subject-initial sentences; listed electrodes reflect the distribution of the negativity (upper panel) and the positivity (lower panel).

TW (ms)	F(1,21)	Electrode Site
3: 300-400	3.303-7.056	T7*, F7, F3, FC3, F8, C3
5: 500-600	3.056-4.528	CP6*, P4

*$p \leq 0.05$, electrodes not marked by an asterisk are marginally significant on the level $p \leq 0.10$.

[5] Additionally, in TW15, an interaction of *Condition* and *Hemisphere* was also observed ($F(1,21) = 4.382$, $p \leq 0.05$). However, since no significant or marginally significant differences at single electrode sites could be detected, this effect was disregarded.

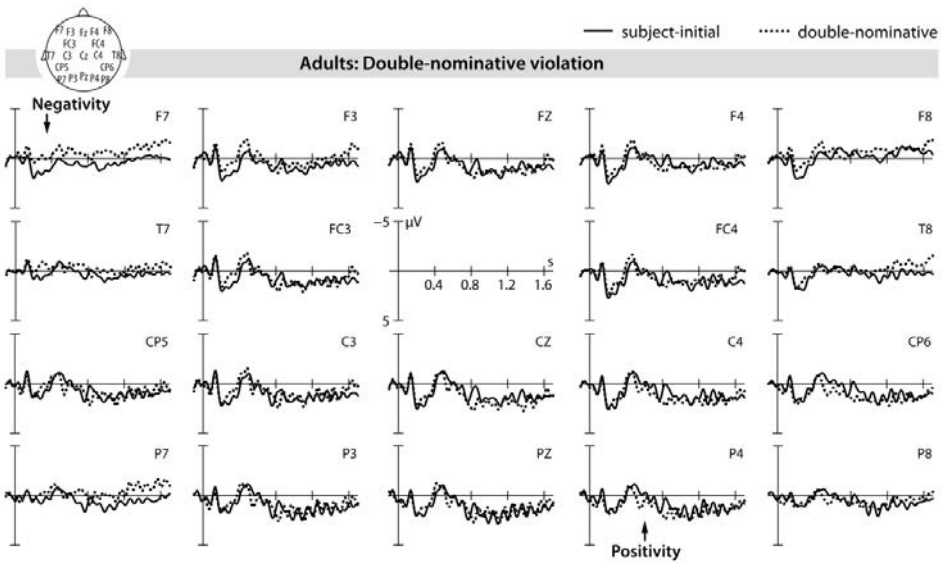


Figure 8. Grand average ERPs relative to NP2 onset for subject-initial (solid line) sentences versus double nominative (dotted line) constructions for adults. ERPs to the double nominative violation show a frontal negative shift and a parietal positive shift.

Experiment II: Double-accusative violation

The ERP-response to the double-accusative violation compared to the object-initial condition in adults appeared to display also an early negativity and a late positivity as assessed by visual inspection (see Figure 9). The negativity was proven statistically significant in TW1 by an interaction of *Condition* and *Site* at lateral sites ($F(8,168) = 6.123$, $p \leq 0.01$) and of *Condition* and *Region* at midline ($F(2,42) = 6.504$, $p \leq 0.01$). Subsequent single electrode analysis, appeared to be significant at only one single electrode, namely at F8 ($F(1,21) = 6.295$, $p \leq 0.05$). In the following TW2, also significant interaction of *Condition* and *Site* at lateral sites ($F(8,168) = 3.820$, $p \leq 0.05$) and of *Condition* and *Region* at midline ($F(2,42) = 3.327$, $p \leq 0.05$) occurred. Analysis of condition main effects in single electrodes proved significant tendencies at F3 ($F(1,21) = 4.118$, $p \leq 0.10$) and C3 ($F(1,21) = 3.483$, $p \leq 0.10$).

In TW7, the statistical analysis revealed significance in an interaction of *Condition* and *Region* at midline ($F(2,42) = 3.802$, $p \leq 0.05$). Subsequent single electrode analysis, in turn, confirmed a marginally significant condition main effect at PZ ($F(1,21) = 2.987$, $p \leq 0.10$).

In sum, statistical analysis revealed the tendency of a frontal negativity between 100-300 ms and a parietal positivity between 700-800 ms.

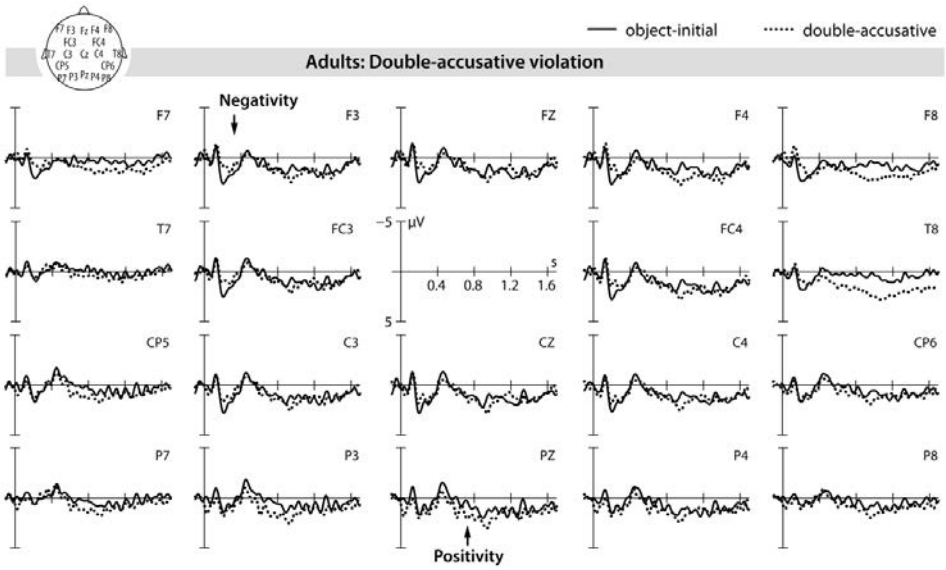


Figure 9. Grand average ERPs relative to NP2 onset for object-initial (solid line) sentences versus double-accusative (dotted line) constructions for adults. ERPs to the double-accusative violation show a frontal negative shift and a parietal positive shift.

6.3.3 Interim Summary: ERP-data II

In sum, both, the double-nominative violation compared to the subject-initial condition and also the double-accusative violation compared to the object-initial condition in ERP-study II elicited a fronto/fronto-central early negativity and a later centro-parietal/parietal positivity. These effects indicate a biphasic LAN-P600 pattern in response to both case-marking violations revealing correct argument expectations in adults, although statistical results revealed rather general tendencies of the observed pattern.

6.4 Summary and Interim Discussion

The main purpose of the present study in adults was to attain results for all experiments conducted in children for a reliable and direct comparison between children and adults regarding the processing of word order, case marking, thematic role assignment, and argument expectations.

For the behavioral test employed in children, a study was conducted in adults with the exact stimuli and paradigm used in children in the behavioral experiments reported here (Knoll et al., 2011). 24 adults were tested in a sentence-picture matching task (see 5.3 Behavioral Method: Sentence-picture Matching). In the subject-first condition, adults identified the correct picture

in 99.65% of the trials and 98.26% in the object-first condition. Thus, adults are perfectly able to identify the corresponding picture in both conditions in the present behavioral paradigm showing no significant differences between the two conditions and thus revealing no subject-first preference in this regard (as stated in Beim Graben et al., 2000; Friederici & Mecklinger, 1996; Mecklinger et al., 1995).

In the eye tracking experiment, adults performed above chance in both conditions, subject-first and object-first, already in the 1.5s time window relative to NP1 onset with increasing results in the 2s time window relative to NP2 onset. The trial course analysis in sliding time windows of 200 ms over the whole trial depicted the time sequence of correct gaze durations to the corresponding picture in more detail. Adults fixated the picture that matched the auditory stimulus significantly above chance-level starting right after NP1 offset until the end of the trial. This was true for both conditions, which did not differ. These results imply that adults show the same response to the object-first as to the subject-first sentences in the eye tracker revealing no additional processing costs that could have been detected in less accurate fixation durations or a later onset in correct gaze durations in the object-first condition. Furthermore, the trial course analysis illustrates additionally that adults conclude as to who is the agent and who is the patient in the respective sentence already after unambiguously case-marked NP1. This result contradicts Hanne et al. (2009) who found correct gaze shift in a similar paradigm only at the point of NP2.

In ERP experiment I, a negative ERP response for the processing of case-marked objects in initial sentence position compared to subject-initial sentences was observed for adults, who demonstrated no differences between these two conditions in the behavioral or eye tracking experiments. This finding is nevertheless in line with other ERP studies comparing case-marked object-initial with subject-initial structures in German (Matzke et al., 2002; Rösler et al., 1998; Schlesewsky, Bornkessel, et al., 2003), which interpreted this negativity as a LAN and assigned it to either morphosyntactic processes or enhanced working memory load. Due to the use of correct structures in the present experiment, the negativity observed in relation to the topicalized object cannot be seen as a reaction to a morphosyntactic violation (usually expressed in a LAN) or a reaction to semantic unexpectedness or violation (usually expressed in an N400). Therefore, the present negativity should rather be attributed to parsing mechanisms that compute the first noun as a subject (De Vincenzi, 1991, 1996) meaning that the parser expects a nominative at NP1, and the processing of the accusative in this position leads to a negativity. This is a very similar process as Bornkessel and Schlesewsky (2006a) found for the expectation-driven processing of scrambled structures in middle-field sentence position. Moreover, since the negativity to topicalized object noun phrases does not match the

topography of either the LAN nor the N400, this negativity could be called 'topicalization negativity' according to the 'scrambling negativity' as described in Bornkessel and Schlesewsky (2006a). Thus, the fronto-centrally distributed negativity for NP1 in adults should be viewed as a 'topicalization negativity'. Following the processing of the object noun in initial position, processing of the rest of the sentence is effortless as indicated by the absence of any effect at NP2. This can be taken as further evidence of the often-cited subject-first preference in German speakers (Beim Graben et al., 2000; Friederici & Mecklinger, 1996; Frisch & Schlesewsky, 2005; Mecklinger et al., 1995), which, however, is not visible in behavioral or physiological adult responses in the present study. Thus, the additional effort in processing the topicalized object shown in the ERP experiment I neither equals nor has consequences in less accurate or delayed responses in the behavioral or eye tracking experiments.

In ERP-Experiment II, a biphasic LAN-P600 pattern in response to both, double nominative and double accusative violations compared to their correct counterparts (subject-initial and object-initial constructions, respectively) resulted. Statistical results revealed rather general tendencies of the observed pattern. The absence of more pronounced ERP effects might be due to the absence of a task and child-directed speech employed in the experiment which often produces boredom and distracted listening behavior in adults.

The biphasic N400-P600 response to double case violation reported by Frisch and Schlesewsky (2005) could not be replicated in the present study. While the P600 occurred in both experiments and is taken to indicate a response to the overall syntactic ill-formedness of the construction, adults displayed an N400 in the former and a LAN in the latter study. Hence, the present results indicate an error-detecting on the morphosyntactic level rather than on the semantic-thematic level for double case violations. Furthermore, they replicate the findings on double case violation in English (Coulson et al., 1998). These results are in line with the assumption of Friederici and Weißenborn (2007) that in languages with a rich case system as German the LAN occurs more often in response to morphosyntactic violations. The difference with the study that reported an N400 (Frisch & Schlesewsky, 2005) could be attributable to the presence of a task in the latter; hence the attempt to thematically hierarchically order the two arguments might only take place when adults are called upon it and their attention is drawn to the interpretation of the sentences.

6.5 Interim Conclusion

Adults displayed neither additional processing costs for object-initial sentences compared to subject-initial sentences in the behavioral and eye tracking experiment nor at NP2 in the ERP-

Experiment I. However, a ‘topicalization negativity’ occurred at NP1 in the same ERP-Experiment pointing towards subject-initial preferences in adults. Regarding the processing of double case violations in ERP-Experiment II, thematic hierarchically ordering indicated by an N400 could not be confirmed. Rather, a biphasic LAN-P600 pattern was observed signaling processing on the morphosyntactic and the syntactic level.

7 Study II: Children

In Study II, the developmental steps taken in language acquisition between the age of three and six years towards the previously described adult processing mechanisms and sequences will be investigated. Regarding thematic role assignment, it is of particular interest, at which age children are sensitive to which morphosyntactic cues. Especially, the point of commencement in language development of sensitivity to the most reliable cue in German, namely the case-marking cue, will be in focus. Moreover, the repair mechanisms for thematic hierarchical ordering that will give information about the development of the ability to abide to the theta criterion in children aged three, 4;6, and six years will be likewise studied.

The same studies, procedures, and testing material as in adults will be applied for all groups of children. The behavioral sentence-picture matching experiment only shortly reported for adults was also conducted with all preschoolers.

The competition model assumes that if all cues for thematic role assignment appear in coalition and build a prototypical structure, children will be able to interpret and process these instances the easiest (Bates & MacWhinney, 1987). In the present study, the subject-initial condition contains sentences that meet exactly this criterion in exhibiting subject-verb-object word order accompanied by overtly unambiguously case-marked noun phrases for nominative and accusative. It follows that the interpretation of the subject-initial condition will represent much less processing effort for children from the youngest age group on than the object-initial condition. In addition, according to the model, it is predicted that the usage of the word-order cue will occur in language acquisition before the usage of the case-marking cue for thematic role assignment in German (MacWhinney et al., 1989) (Chapter 3.2).

Commensurate to these theoretical assumptions and previous behavioral studies (see below), the development of the cue-usage and the interpretational accuracy of the two conditions reflected in the present behavioral study is hypothesized in the following way. From the youngest age group on, subject-initial sentences will be interpreted more accurate than object-initial sentences while the accuracy will increase over age and reach adult-level in 6-year-olds. Since the model furthermore predicts the usage of the word-order cue in younger age groups, it seems plausible to hypothesize a systematic misinterpretation of object-initial sentences in three-year-olds by assigning the Agent role to the first argument in the sentence. This strategy will lead to below chance outcome in the object-initial condition in three-year-olds. The same is true for 4;6-year-olds as Chan, Lieven, and Tomasello (2009) demonstrated the highest word-order cue usage at that age. For the subsequent development, contradictory results are found in several studies (Chapter 3.1) that either children start to use the case-marking cue

long before their sixth birthday (Lindner, 2003; Mills, 1977; Schaner-Wolles, 1989; Watermeyer, 2010) or long after it (Dittmar et al., 2008a). It remains to be seen which findings can be confirmed in the present study and whether six-year-old children will perform above chance in the interpretation of non-canonical sentences.

In general, the same hypotheses hold for the correct gaze duration to the corresponding picture in the eye tracking study. It is additionally hypothesized that attunement to the case-marking cue and hence longer fixation durations to the corresponding object-initial picture might be shown at an earlier age than in the behavioral paradigm in this study (please, compare Gertner et al., 2006).

Previous evidence on the processing of object-initial structures in children has only been obtained for three- and eight-year-old children. Mahlstedt (2008) found a positivity to NP1 and a biphasic early positivity - late negativity for the ERP time-locked to NP2 for the processing of object-initial compared to subject-initial structures in children at the age of three. The same effects are expected in the current study for three-year-olds, however, the hypothesis will be treated with some caution as Mahlstedt (2008) also included animacy as a variable in her stimuli, which will be excluded in the current. Hence, the sensitivity to objects in initial positions might be shown in ERPs at that age, but the behavioral competence to interpret these structures should be evidenced only later in development. As for the results for 4;6-year-olds in ERP study I, it is hypothesized that children at this age might either show a similar sensitivity to object-initial structures as three-year-olds, or that the change to reliance on the case-marking cue can be shown in ERPs earlier. In the latter case, they should not display any additional effort to process object-initial compared to subject-initial structures as adults – a hypothesis that holds definitely for children at the age of six in this study.

Concerning ERP study II, Frisch and Schlesewsky (2005) have shown a biphasic N400-P600 response to case-marking violations. As outlined in Chapter 3.1, the N400 on the sentential level was already detected in 19-month-olds (Friedrich & Friederici, 2005) and the P600 in 24-month-olds (Oberecker & Friederici, 2006). Therefore, the adult-like pattern might already be able to be shown in three-year-olds in the present case-marking violation study. However, since the accusative function is only acquired later, the N400-P600 response might occur later for the double-accusative violation than for the double-nominative violation. In particular, for the reason that 4;6-year-olds have not yet established full thematic dependencies (Dittmar et al., 2008a), three- and 4;6-year-olds might only exhibit a P600 for syntactic error detection in response to this condition while six-years-old will show the adult-like biphasic N400-P600 pattern.

7.1 Three-Year-Olds

The production of the accusative case marking commences at the age of three as explained in further detail in Chapter 3.1. As the acquisition of the accusative form only starts at this age, it seems plausible to test three-year-old children regarding the processing and interpretation of arguments in simple transitive structures as the youngest age group of the current investigation.

7.1.1 Behavioral Data

7.1.1.1 Methods

7.1.1.1.1 Subjects

Out of all children tested (51 three-year-olds, 28 female) in the behavioral experiment, the data of four were excluded because children did not finish the test or did not display age-appropriate language development in the TROG-D (Fox, 2008). The final sample of the behavioral experiment consisted of 47 three-year-olds (25 female).

7.1.1.1.2 Stimuli

Toddlers were presented with subject-first and object-first sentences that they had to match to corresponding pictures (see Section 5.1 Experimental Design and Material). In each trial, they had to choose the correct picture out of two shown.

7.1.1.1.3 Data Analysis

As explained in detail in Section 5.7 Data Processing and Analysis, correct identifications of the corresponding picture per condition were averaged and statistically analyzed against chance level (50%).

7.1.1.2 Results

Three-year-old children performed above chance in the subject-initial condition with 64.72% correct identification of the corresponding picture ($t(46) = 5.252$, $p \leq 0.001$). In contrast, three-year-olds performed significantly below chance in the object-initial condition with 44.86% correct identification of the matching picture ($t(46) = -2.260$, $p \leq 0.05$) (see Figure 10).

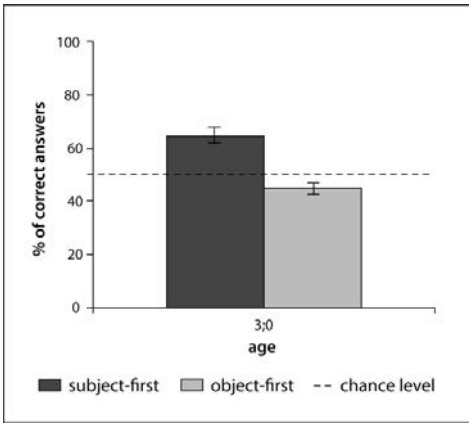


Figure 10. Three-year-olds: Results of the behavioral task to identify which picture corresponded to each sentence.

7.1.1.3 Interim Summary: Behavioral data

In sum, 3-year-olds pointed systematically to the correct picture in the subject-initial condition. In the object-initial condition, however, they identified systematically the incorrect picture.

7.1.2 Eye-Tracking Data

7.1.2.1. Methods

7.1.2.1.1 Subjects

In the group of three-year-olds, 39 (18 female) children were tested. Due to either fuzziness, an insufficient trial number, a clear looking preference for one side of the screen (see Section 5.7 Data Processing and Analysis), or a substandard performance in the TROG-D (Fox, 2008) (see Section 5.6 Language Testing: TROG-D), the data of six children had to be excluded from the analysis of gaze duration from NP1/NP2 onset resulting in 33 (16 female) three-year-olds for these samples. Regarding the trial course analysis, an additional three children did not enter the final sample because of an insufficient number of trials in one or more of the 44 time windows (each 200 ms of length). Thus, 30 (14 female) children were analyzed in the final sample of the trial course.

7.1.2.1.2 Stimuli

Children listened to sentences constructed in the subject-first and object-first structure while two pictures per trial were presented on a screen, one depicting the corresponding thematic

roles and the other one showing reversed actor and patient roles (see Section 5.1 Experimental Design and Material).

7.1.2.1.3 Data Analysis

The mean number of trials for the analysis of both time windows, beginning at NP1 and NP2, respectively, amounted to 11 trials and did not differ between conditions. The averaged mean number of trials across all time windows included in the trial course analysis resulted in 10.5 for all conditions.

As explained in detail in Section 5.7 Data Processing and Analysis, fixation durations to the picture that corresponded with the auditory stimulus presented were averaged and analyzed according to NP1 onset (until verb offset, 1.5s of length), to NP2 onset (2s of length) and in sliding windows of 200 ms across the whole trial (trial course analysis). Within these different analyses, every condition (subject-first/object-first) was statistically analyzed in relation to chance-level (50%). In addition, trial-course statistics were computed employing two-way ANOVAs with condition (subject-first/object-first) and time window (44 time windows, each 200 ms of length) as factors.

7.1.2.2 Results

NP1

Regarding the gaze duration from NP1 onset until verb offset (1.5s), three-year-olds performed on chance level with 48.69% fixation duration to the corresponding picture in the subject-first condition ($t(32) = -0.598$, $p > 0.10$). In the object-first condition, in turn, performance was shown on chance level with fixation duration to the correct picture accounting for 47.53% ($t(32) = -1.145$, $p > 0.10$).

NP2

Similar to the results regarding gaze duration from NP1 onset, three-year olds performed on chance level in both conditions (subject-first/object-first) considering the time window of two seconds after NP2 onset (see Figure 11). In the subject-first condition, fixation duration to the corresponding picture amounted to 50.70% ($t(32) = 0.264$, $p > 0.10$); in the object-first condition, fixation duration to the correct picture accounted for 49.61% ($t(32) = -0.166$, $p > 0.10$).

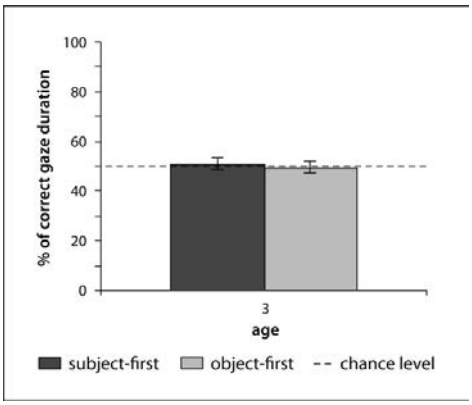


Figure 11. Three-year-olds: Averages of the correct fixation duration per condition in a two second time window beginning at NP2.

Trial Course Analysis

As expected from visual inspection of the trial course analysis of correct fixations within 200 ms time windows (see Figure 12), neither a main effect condition nor interactions involving the factor condition were found in the statistical analysis employing a two-way ANOVA. Consequently, no further one-way ANOVAs with the factor condition could be calculated.

The one-sample t-test revealed no significant differences in relation to chance level (50%) for either of the two conditions subject-first and object-first. As one exception, in the subject-first condition, fixation duration to the corresponding picture in the time window between 7800-8000 ms after trial onset revealed significant outcome below chance amounting to 43.35%, ($t(29) = -2.115$, $p \leq 0.05$).

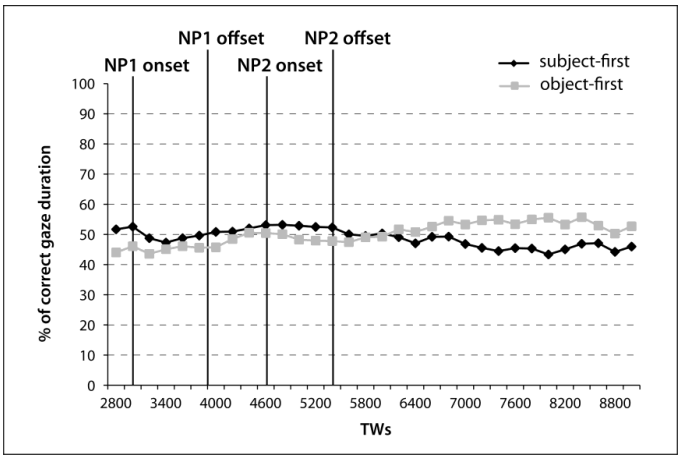


Figure 12. Three-year-olds: Averages of the correct fixation duration per condition over the course of a trial in 200 ms windows.

7.1.2.3 Interim Summary: Eye-tracking data

In the time window starting at NP1, starting at NP2, and mainly also in the trial course analysis, children's fixation durations at the age of three demonstrated performance on chance-level in the object-initial and in the subject-initial condition. This means, the eye-tracking data revealed no processing differences between the conditions in three-year-olds, and, furthermore, no systematic gaze durations to the correct or incorrect picture in either condition.

7.1.3 ERP-Data I: Processing of Object-First Structures

7.1.3.1. Methods

7.1.3.1.1 Subjects

The data of approximately one quarter of all children tested (51 three-year-olds, 28 female) in the EEG experiment were excluded because they contained disproportionate numbers of artifacts caused by exaggerated movement and/or perspiration (skin potentials) or the subject did not display age-appropriate language development in the test for reception of grammar (TROG-D; (Fox, 2008) (see Section 5.6 Language Testing: TROG-D). The final sample of the EEG experiment consisted (for NP1/NP2, respectively) of 39/37 three-year-olds (23/22 female). Subject numbers differed for NP1/NP2 analysis because processing procedures concerning rejection of trials were kept constant across all analyses (see Section 5.7 Data Processing and Analysis).

7.1.3.1.2 Stimuli

Toddlers were presented with auditory stimulus material including sentences of the subject-first and object-first structure (see Section 5.1 Experimental Design and Material).

7.1.3.1.3 Data Analysis

The resulting mean number of averaged trials across subjects, both for NP1 and NP2, was 14 in three-year-olds. These numbers did not differ between conditions.

Statistical analyses were performed separately for mean amplitudes on midline and lateral electrode sites. For midline sites (FZ, CZ, and PZ), a two-way ANOVA was computed with the factors *Condition* (subject-initial and object-initial) and *Region* (anterior, central, and posterior). For lateral sites, a three-way ANOVA was performed with the factors *Condition*, *Site* (F7, F3, F4, F8, FC3, FC4, T7, C3, C4, P7, CP5, CP6, T8, P3, P4, P8, O1, O2), and

Hemisphere (left and right). Significant interactions involving the factor *Condition* were further analyzed for each *Site*/*Region* using a one-way ANOVA with *Condition* as factor.

7.1.3.2 Results

NP1

In the youngest age group, the statistical analysis revealed a main effect for *Condition* at midline in TW1 for the object-initial condition compared to the subject-initial *Condition* at sentence onset ($F(1,38) = 5.261$, $p \leq 0.05$). In TWs 7 and 8, several interactions were found. In TW7, an interaction of *Condition* and *Hemisphere* ($F(1,38)$, $= 5.685$, $p \leq 0.05$) and an interaction of *Condition*, *Hemisphere* and *Site* ($F(8,304) = 2.535$, $p \leq 0.05$) were present, with the latter continuing in TW8 ($F(8,304) = 3.268$, $p \leq 0.01$). Separate analyses of single electrode sites in TW7 revealed significant condition effects distributed over frontal, central, and temporal brain regions (Table 5). In sum, three-year-olds react to the object-initial condition at sentence onset with positivity at an early (100-200 ms) and a later latency (700-900 ms) (Figure 13, left panel).

Table 5. Condition Main Effects of Three-year-olds' ERPs in Different TWs Relative to NP1 Onset

TW (ms)	F(1,38)	Electrode Site
7: 700-800	4.294-6.617	FC4*, F4*, F8*, C4*, T8*
8: 800-900	4.320	F8*

*$p \leq 0.05$

NP2

At the onset of NP2, statistical analysis confirmed that the processing of object-initial structures is reflected by negativity in three-year-olds compared to their processing of subject-initial structures (Figure 13, right panel). In TW1, an interaction between *Condition* and *Site* occurred ($F(8,288) = 3.201$, $p \leq 0.05$), but was not significant at single electrode analyses. In TW4, an interaction of *Condition* and *Hemisphere* was present ($F(1,36) = 6.277$, $p \leq 0.05$). This interaction continued in TW5 ($F(1,36) = 4.617$, $p \leq 0.05$). In TW6, an interaction of condition and electrode sites was found ($F(8,288) = 3.467$, $p \leq 0.05$). One-way ANOVAs for single electrode sites demonstrated significant condition effects for this negativity over a right-lateralized brain region, but not over the left hemisphere (Table 6). No effect was found on midline electrodes. In sum, three-year-olds' response in processing object-initial structures displays a negativity between 400-700 ms over the right hemisphere.

Table 6. Condition Main Effects of three-year-olds' ERPs in Different TWs Relative to NP2 Onset

TW (ms)	F(1,36)	Electrode Site
4: 400-500	4.652-4.797	Cp6*, P4*
6: 600-700	4.910	FC4*

*p ≤ 0.05

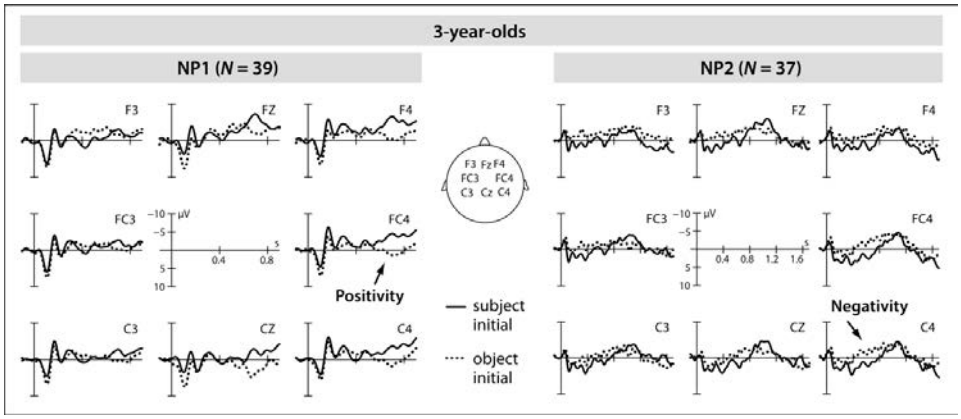


Figure 13. Grand-average ERPs of three-year-olds for selected electrodes, object-initial versus subject-initial, relative to the onset of NP1 (left panel) / NP2 (right panel). The subject-initial condition (solid line) is plotted against the object-initial condition (dotted line). Negative voltage is plotted upwards.

7.1.3.3 Interim Summary: ERP-data I

In sum, three-year-olds' ERPs in response to the object-initial compared to the subject-initial condition displayed an early and a late positivity at NP1 onset and a negativity between 400-700 ms at NP2 onset. This indicates a sensitivity to the object-initial structure at both positions in the sentence in children at the age of 3;0.

7.1.4 ERP-Data II: Processing of Argument Violations

7.1.4.1. Methods

7.1.4.1.1 Subjects

The data of approximately one-quarter of all children tested (51 three-year-olds, 28 female) in the EEG experiment were excluded because they contained disproportionate numbers of artifacts caused by exaggerated movement and/or perspiration (skin potentials) or the subject did not display age-appropriate language development in the test for reception of grammar

(TROG-D; (Fox, 2008) (see Section 5.6 Language Testing: TROG-D). The final sample of the EEG experiment consisted of 37 three-year-olds (22 female).

7.1.4.1.2 Stimuli

Toddlers were presented with auditory stimulus material including sentences of the subject-first, object-first, double-nominative, and double-accusative structure (see Section 5.1 Experimental Design and Material).

7.1.4.1.3 Data Analysis

The mean number of averaged trials across subjects amounted to 14 in three-year-old toddlers. These numbers did not differ between conditions.

Separately, statistical analyses were calculated for mean amplitudes on midline and lateral electrode sites. For midline sites (FZ, CZ, and PZ), a two-way ANOVA was computed with the factors *Condition* (subject-initial and double nominative in experiment 1 and object-initial and double accusative in experiment 2) and *Region* (anterior, central, and posterior). For lateral sites, a three-way ANOVA was performed with the factors *Condition*, *Site* (F7, F3, F4, F8, FC3, FC4, T7, C3, C4, P7, CP5, CP6, T8, P3, P4, P8, O1, O2), and *Hemisphere* (left and right). Significant interactions involving the factor *Condition* were further analyzed for each *Site*/*Region* using a one-way ANOVA with *Condition* as factor.

Given that subject-initial and double nominative structures consist equally of an NP1 in the nominative, it seemed plausible to compare these structures only at NP2. The same is true for the object-initial and double accusative condition that both start with an initial NP in the accusative. In order to keep the precondition of an equal sentence beginning constant, comparisons across these two pairings were abandoned and furthermore not considered meaningful.

7.1.4.2 Results

Experiment 1: Double-Nominative Violation

As visible in Figure 14, three-year-olds reflect the processing of the double nominative construction compared to the subject-initial construction by an early negativity and a late positivity. In TW5, the interaction condition and site was marginally statistically significant ($F(8,288) = 2.628$, $p = 0.051$). Statistical analysis revealed significances in the two subsequent TWs 6 and 7 also for the interaction *Condition* and *Site* ($F(8,288) = 5.257$, $p \leq 0.01$, $F(8,288) = 2.840$, $p \leq 0.05$, respectively)[6]. Separate analyses of single electrode sites revealed significant

[6] Additionally, in TW1, an interaction of condition and region at midline was also observed ($F(2,32) = 4.567$, $p \leq 0.05$). However, since no significant differences at single electrode sites could be detected, this effect was disregarded.

condition effects for the negativity over fronto-central brain regions of the left and right hemisphere (see Table 7). The observed positivity could be proven significant in TW10 by a condition main effect at midline ($F(1,36) = 6.186$, $p \leq 0.05$) and in TW15 also by a condition main effect at midline ($F(1,36) = 4.816$, $p \leq 0.05$). Additionally, in TW15, a condition main effect at lateral sites was marginally significant ($F(1,36) = 4.067$, $p = 0.051$). In sum, a negativity was observed from 500-800 ms at fronto-central brain regions and a positivity between 1000-1100 ms and 1500-1600 ms for the processing of double nominative structures compared to subject-initial structures.

Table 7. Condition Main Effects of Three-year-olds' ERPs in Different TWs, double nominative compared to subject-initial sentences; listed electrodes reflect the distribution of the negativity.

TW (ms)	F(1,36)	Electrode Site
5: 500-600	4.167-5.091	FC4*, F4*
6: 600-700	4.110-13.098	F7*, F3*, FC4*, F4***
7: 700-800	4.357-10.662	F7*, FC4*, F4**

*p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001

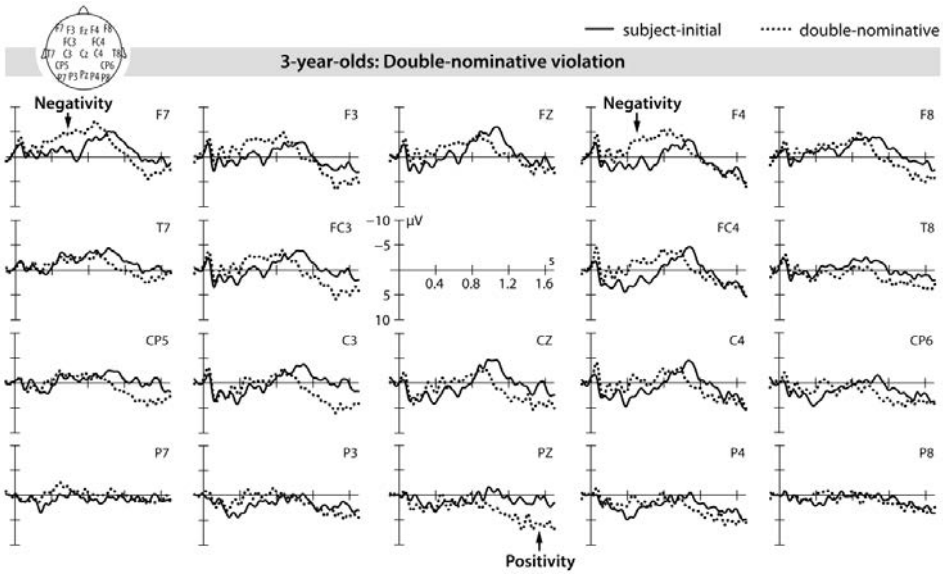


Figure 14. Grand average ERPs relative to NP2 onset for subject-initial (solid line) sentences versus double nominative (dotted line) constructions for 3-year-olds. ERPs to the double nominative violation show a frontal negative shift and a parietal positive shift.

Experiment 2: Double-Accusative Violation

Three-year-olds' ERPs displayed an early positivity regarding the processing of the double accusative compared to the object-initial structure (see Figure 15). In TW1, the interaction of *Condition*, *Hemisphere*, and *Site* was found to be marginally significant ($F(8,288) = 2.248$, $p = 0.058$). Subsequent analysis of single site electrodes attested significance at F7 ($F(1,36) = 4.336$, $p \leq 0.05$) and FC3 ($F(1,36) = 4.469$, $p \leq 0.05$). In TW2, there was found a main effect of *Condition* ($F(1,36) = 5.454$, $p \leq 0.05$), which was only marginally significant in TW3 ($F(1,36) = 3.936$, $p = 0.055$). Again, in TW4, the main effect of condition was proven significant, both at lateral sites ($F(1,36) = 4.846$, $p \leq 0.05$) and at midline ($F(1,36) = 5.261$, $p \leq 0.05$)[7]. In addition, at a later point in time, in TW10 we observed a significant interaction of *Condition* and *Hemisphere* ($F(1,36) = 4.255$, $p \leq 0.05$), which was significant in the following single site analysis at only one electrode, namely P8 ($F(1,36) = 4.251$, $p \leq 0.05$). In sum, statistical analysis demonstrated an early, merely fronto-central distributed, positivity in response to the double accusative compared to the object-initial sentences in three-year-olds that lasted from 100-500 ms.

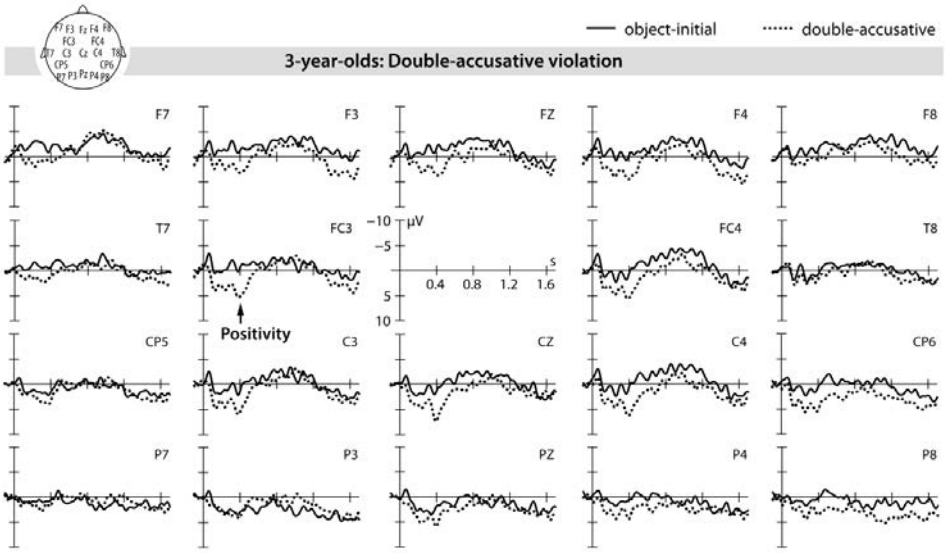


Figure 15. Grand average ERPs relative to NP2 onset for object-initial (solid line) sentences versus double accusative (dotted line) constructions for 3-year-olds. ERPs to the double accusative violation show a fronto-central positive shift.

[7] Additionally, in TW5, an interaction of *Condition*, *Hemisphere*, and *Site* was also observed ($F(8,288) = 2.643$, $p \leq 0.05$). However, since no significant differences at single electrode sites could be detected, this effect was disregarded.

7.1.4.3 Interim Summary: ERP-data II

In the double nominative condition compared to the subject-initial structures in ERP-Study II, three-year-olds showed an adult-like response by a negativity-positivity pattern. Thus, already children at the age of 3;0 display correct argument expectations for subject-initial structures. However, in the double accusative condition compared to the object-initial structures, an early positivity occurred in three-year-olds' ERPs indicating an immature violation detection at that age.

7.1.5 Summary and Interim Discussion

The objective of the behavioral and eye-tracking study, as well as of the ERP-Study I, was to investigate the processing of object-initial structures in three-year-olds. More specifically, the study sought to examine which linguistic cues children at that age draw on during processing and interpretation of sentences of this type. While the ERP-study mainly scrutinizes the processing aspect on a neurophysiological level, the behavioral experiment sheds more light on the interpretational strategies that are used. Eventually, the eye-tracker study combines both aspects in capturing eye-movements as a physiological dimension of processing on the one hand, and monitoring real-time interpretational behavior by linking saccades to the stimuli of the experiment on the other hand.

As one further characteristic of syntactic-thematic processing, the ERP-Study II investigated argument expectations by means of a violation paradigm, in which a double nominative and a double accusative condition were presented. The purpose of this study was to examine whether three-year-old children detect these violations and on which linguistic level (e.g., morphological/syntactic/semantic) as an indication of established argument and thematic role expectation.

The age group of three-year-olds, who are the youngest children who produce accusative case-marking in the course of German language acquisition (Clahsen, 1984; Szagun, 2004, 2006), seemed most suitable in order to start these investigations described above.

Behaviorally, three-year-olds performed significantly above chance in the subject-initial condition and significantly below chance in the object-initial condition. This pattern points towards a clear subject-first word order strategy (Chan et al., 2009). While case marking constitutes the most reliable cue in German, the word order cue carries the highest availability (Bates & MacWhinney, 1987, 1989). Moreover, as the majority of children's input is uttered in an SVO structure, it is very plausible that children first rely on the word order cue (Dittmar et

al., 2008a). Thus, the behavioral strategy might be that the first NP in a clause is interpreted as the subject and consequently as the agent of the action regardless of its case-marking. This approach would lead exactly to the results observed in the current behavioral study. If the subject-initial structure is interpreted employing the word-order strategy, the outcome in the experimental results will be above-chance performance; and if, in turn, the object-initial structure is also interpreted using the word-order strategy in the majority of times, results will be below chance. Hence, although three-year-olds have acquired the forms of accusative case marking, they do not use case marking as an interpretational cue for thematic role attribution. Rather, they start to use a word order strategy as the behavioral results attested. Although statistics prove the usage of this cue, toddlers do not yet proceed in a consistent manner in this regard, because otherwise the difference between the two conditions would be even greater.

In the eye tracking experiment, children's fixation durations at the age of three demonstrated performance on chance-level in all three analyses: in the time window starting at NP1, in the time window starting at NP2, and mainly also in the trial course analysis. The question arises, why the subject-first condition resulted in above-chance performance and the object-first condition in below-chance performance in the behavioral data but not in the eye tracker data? Presumably, the eye tracker response is much more automatic and does not depict controlled linguistic processes. If, however, three-year-olds are forced to choose the agent as in the behavioral task, they rely mainly on the word order cue. As a consequence, the two different methods might illustrate different processes that they call forth at the same time (see 8.3 Methodological comparison).

It is not the case, however, that three-year-olds are completely insensitive to case-marking information, as indicated by the ERPs of ERP-Study I. They showed an effect at both NP1 and NP2 for the object-initial compared to the subject-initial condition, namely an early and a late positivity at NP1 and negativity at NP2. These results are partly in line with Mahlstedt (2008), who also found a positivity at NP1 but a positivity and negativity at NP2. Her testing material, however, included animacy as a dependent variable and hence might have induced different ERP-effects, as one more cue was available for the toddlers.

Tentatively interpreting the findings in three-year-olds functionally, one might speculate that three-year-olds process the accusative marking in sentence initial position as a morphosyntactic violation. This is based on the fact that that Silva-Pereyra et al. (2005) also reported an early and a late positivity in response to morphosyntactic violations at this age. Concluding from the ERP data, one can infer that three-year-olds distinguish between

accusative and nominative case marking in transitive sentences, but the behavioral data demonstrate that this information is not used to interpret these transitive sentences.

In the double nominative condition compared to the subject-initial structures in ERP-Study II, three-year-olds showed an adult-like response by a negativity-positivity pattern. The positivity equals the P600 in adults and indicates syntactic integration difficulties and the attempt to repair the second nominative already in children at an age of three years (Friederici, 2002; Oberecker & Friederici, 2006; Oberecker et al., 2005). The negativity, distributed over frontal brain regions, appears between 500-800 ms in three-year-olds. The ERP component of the LAN, distributed over left frontal brain regions, is usually found at an earlier time-window (between 300-500 ms) as a reaction to morphosyntactic violations (Fiebach et al., 2002; Friederici, 2002). It is known, however, that ERP components occur with a delayed latency in children (Friederici & Oberecker, 2008). Although the negativity in the present study is not as focal, but more broadly distributed over frontal brain regions than the LAN usually is, this effect is also functionally consistent with the test material because it occurs in relation to a morphosyntactic violation. Interestingly, in the present study, the LAN could be shown already in three-year-olds. Until today, the LAN was not found at that age in response to morphosyntactic violations (Silva-Pereyra, Rivera-Gaxiola, et al., 2005).

Hence, for the SVO argument order, correct and established argument expectancies already exist in three-year-olds, as evident in the attempt to repair the second nominative (indicated by the P600) and the notion of a morphological violation (as indicated by the LAN). Certainly, this expectation is closely connected with the word-order strategy. However, beyond this interpretational strategy, a clear expectation of an accusative at NP2 is apparent because otherwise the repair mechanism indicated by the P600 component would not be present.

In the double accusative condition compared to the object-initial structure in ERP-Study II, an early positivity (100-500 ms) occurred. In line with Silva-Pereyra et al. (2005), it is plausible to interpret the positivity in three-year-olds as a response to morphosyntactic violations and therefore as a precursor to the LAN that is found in adults when confronted with morphosyntactic violations. Given that three-year-olds' ERPs did show a LAN for the double nominative condition in the present study, it follows that the double accusative condition represents higher processing difficulties at that age. Hence, certain ERP components are found in children depending on the difficulty of the presented constructions; for instance, the ELAN could already be shown in 32-month-olds in response to phrase-structure violations in active sentences (Oberecker et al., 2005). In contrast, the same violations presented in passive structures did not deliver an ELAN in children until the age of 7 years (Hahne et al., 2004).

Instead of the morphosyntactic violation detection that produces a LAN in adults, the processing of the double accusative violation is thus not yet as mature in three-year-olds. The youngest age group also shows no attempt of syntactic integration or repair and no expectancies of the specific nominative argument in this case. As it is also demonstrated in the experiments presenting object-initial structures, an SVO argument order is expected at that age. Nevertheless, a second accusative argument in simple transitive structures is perceived as a morphological violation in three-year-olds.

7.1.6 Interim Conclusion

In conclusion, three-year-olds distinguish between accusative and nominative case marking as apparent in distinct processing patterns in ERP-Study I. However, they are not sensitive to the case marking for the interpretation of agents and patients roles in transitive structures as demonstrated in the eye tracker experiment; rather, they use a word-order strategy as proven by the behavioral study. The word order strategy goes beyond interpreting the NP1 as the agent despite the case marking, since it was shown in ERP-Study II that argument expectations with regard to the NP2 for the SVO order obviously already exist in three-year-olds.

7.2 4;6-Year-Olds

Regarding the interpretational strategies of transitive sentences, an increase in reliance on word order from 2;6 to 3;6 to 4;6 was shown by Chan et al. (2009) in a behavioral paradigm with the latter age group displaying the highest use of word order. At the age of five, several authors found evidence for more attendance to the case-marking cue (Lindner, 2003; Mills, 1977; Schaner-Wolles, 1989) in preschoolers. These findings contradict the study by Dittmar et al. (2008a) as it was not until children were seven years of age that they were able to correctly use the case-marking cue. Further evidence is necessary to clarify at which age children rely on the word order and case-marking cue, respectively. To this end, 4;6-year-old preschoolers are the most suitable age group to clarify this debate. Given previous studies (see above), the age of 4;6 represents the youngest age group in which a change from reliance on word-order cues to case-marking cues might be expected.

7.2.1 Behavioral Data

7.2.1.1 Methods

7.2.1.1.1 Subjects

The data of two children tested in the behavioral experiment were excluded because they did not display age-appropriate language development in the TROG-D (Fox, 2008). The final sample of the behavioral experiment consisted of 36 4;6-year-olds (23 female).

7.2.1.1.2 Stimuli

Preschoolers were presented with subject-first and object-first sentences. The task was to match these sentences to corresponding pictures (see Section 5.1 Experimental Design and Material) while two (one correct, one incorrect) were shown at the same time.

7.2.1.1.3 Data Analysis

As explained in detail in Section 5.7 Data Processing and Analysis, correct identifications of the corresponding picture per condition were averaged and statistically analyzed against chance level (50%). Developmental differences of 4;6-year-olds compared to the behavioral data of three-year-olds already presented in this study were computed with a t-test for independent samples.

7.2.1.2 Results

In the subject-initial condition, 4;6-year-olds displayed above-chance performance identifying the corresponding picture in 89.12% of the trials correctly ($t(35) = 23.189$, $p \leq 0.001$). In the object-initial condition, however, the same age group showed an outcome on chance-level as they demonstrated the identification of the correct picture in 48.15% of the experiment (see Figure 16).

From a developmental perspective, correct responses to the subject-initial condition increased from 64.72% to 89.12% significantly between the age of 4;6 and three years of age ($t(72.819) = -7.462$, $p \leq 0.001$). Significant improvement between these two age groups in the object-initial condition was not evident.

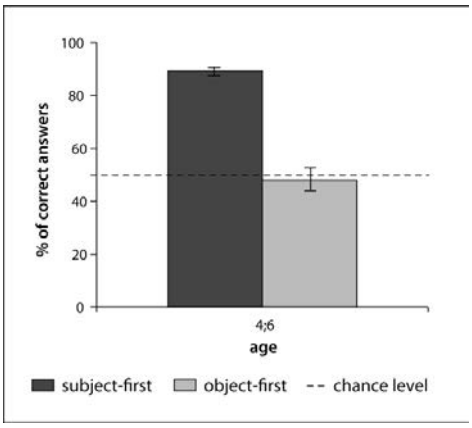


Figure 16. 4;6-year-olds: Results of the behavioral task to identify which picture corresponded to each sentence.

7.2.1.3 Interim Summary: Behavioral data

In sum, 4;6-year-olds systematically identified the corresponding picture in the subject-initial condition correctly and also significantly more frequently than three-year-olds. In the object-initial condition, however, 4;6-year-olds neither pointed systematically to the correct nor to the incorrect picture.

7.2.2 Eye-Tracking Data

7.2.2.1 Methods

7.2.2.1.1 Subjects

30 (14 female) children at the age of 4;6 years were tested. Due to an insufficient trial number or a clear looking preference for one side of the screen (Section 5.7 Data Processing and Analysis), the data of three children had to be excluded from the analysis of gaze duration from NP1/NP2 onset resulting in 27 (11 female) 4;6-year-olds for these samples. One additional child could not be included in the trial course analysis because of an insufficient number of trials in several of the 44 time windows (each 200 ms of length). Consequently, 26 (10 female) children entered the final analysis of the trial course.

7.2.2.1.2 Stimuli

Children listened to sentences constructed in the subject-first and object-first structure while two pictures per trial were presented on a screen, one depicting the corresponding thematic roles and the other one showing reversed actor and patient roles (Section 5.1 Experimental Design and Material).

7.2.2.1.3 Data Analysis

The mean number of 11.3 trials entered the analysis of both time windows, beginning at NP1 and NP2, respectively. These numbers did not differ significantly between conditions. The averaged mean number of trials across all time windows included in the trial course analysis resulted in 10.6.

As explained in detail in Section 5.1 Experimental Design and Material, fixation durations to the picture that corresponded with the auditory stimulus presented were averaged and analyzed according to NP1 onset (until verb offset, 1.5s of length), to NP2 onset (2s of length) and in sliding windows of 200 ms across the whole trial (trial course analysis). Within these different analyses, every condition (subject-first/object-first) was statistically analyzed in relation to chance-level (50%). In addition, trial-course statistics were computed employing two-way ANOVAs with condition (subject-first/object-first) and time window (44 time windows, each 200 ms of length) as factors. Differences between the eye tracker data of the three-year-olds already presented and 4;6-year-olds were calculated with t-tests for independent samples.

7.2.2.2 Results

NP1

4;6-year-olds correct fixation duration to the corresponding picture in relation to NP1 onset until verb offset (1.5s) accounted for 50.14% in the subject-first condition and 48.31% in the object-first condition. Hence preschoolers at the age of 4;6 acted upon chance-level in both conditions ($t(26) = 0.085$, $p > 0.10$ for the subject-first condition and $t(26) = -0.756$, $p > 0.10$ for the object-first condition). Consequently, performances of three- and 4;6-year-olds did not differ with regard to NP1 onset since toddlers at the age of three also presented an outcome on chance-level in both conditions (subject-first condition: $t(58) = -0.510$, $p > 0.10$; object-first condition, $t(58) = -0.251$, $p > 0.10$).

NP2

The results of 4;6-year-olds' summed gaze duration to the corresponding picture in relation to NP2 (2s time window) accounted for 57.56% in the subject-first condition and for 47.99% in the object-first condition (see Figure 17). Statistical analysis revealed significance above chance for the subject-first condition ($t(26) = 3.742$, $p \leq 0.001$) while no significant difference from chance was found in the object-first condition ($t(26) = -1.030$, $p > 0.10$). Subsequently, the two conditions differed significantly in 4;6-year-olds as shown in a paired t-test ($t(26) = 3.359$, $p \leq 0.010$). Statistical comparison between the toddlers at the age of three in this study with 4;6-year-olds delivered marginally significant differences for the subject-first condition ($t(58) = -1.985$, $p = 0.052$), but no significant differences for the object-first condition ($t(58) = 0.520$, $p > 0.10$). In sum, preschoolers at the age of 4;6 years revealed significant results above chance in the subject-first condition in relation to NP2 onset and significantly increased performance in comparison to three-year-olds in the same condition.

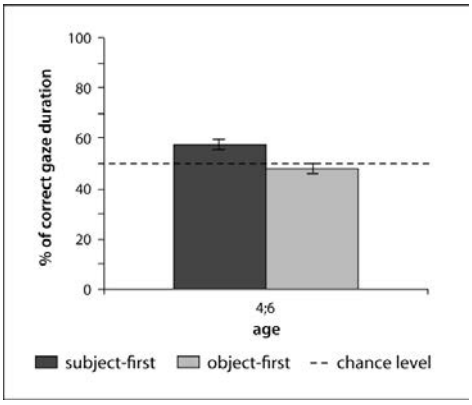


Figure 17. 4;6-year-olds: Averages of the correct fixation duration per condition in a two seconds time window beginning at NP2.

Trial Course Analysis

Statistical analysis of fixation durations to the corresponding pictures over the trial course within TWs of 200 ms (see Figure 18) delivered a condition main effect ($F(1,24) = 11.493$, $p \leq 0.01$) and a time window main effect ($F(44,1056) = 2.651$, $p \leq 0.05$). No interactions were found and hence no further one-way ANOVAs were computed.

One-sample t-tests, calculated separately for every TW, revealed significant outcome above chance in the subject-first condition between 5200-6800 ms, and between 7600-8600 ms relative to trial onset (see Table 8). In the object-first condition, significant fixation durations below chance were found in the statistical analysis between 4200-5000 ms, relative to trial onset (see Table 9).

Table 8. Significant t-values (one-sample t-test calculated against chance-level) of 4;6-year-olds' fixation durations in different TWs of the trial course analysis in the subject-first condition

TW (ms)	t(25)	p-value
5200-5400	2,155	≤ 0.05
5400-5600	2,283	≤ 0.05
5600-5800	2,254	≤ 0.05
5800-6000	2,526	≤ 0.05
6000-6200	3,120	≤ 0.01
6200-6400	3,444	≤ 0.01
6400-6600	3,731	≤ 0.001
6600-6800	3,014	≤ 0.01
7600-7800	2,748	≤ 0.05
7800-8000	2,838	≤ 0.01
8000-8200	3,354	≤ 0.01
8200-8400	2,164	≤ 0.05
8400-8600	2,614	≤ 0.05

Table 9. Significant t-values (one-sample t-test calculated against chance-level of 50%) of 4;6-year-olds' fixation durations in different TWs of the trial course analysis in the object-first condition

TW (ms)	t(25)	p-value
4200-4400	-2,099	≤ 0.05
4400-4600	-3,678	≤ 0.001
4600-4800	-3,727	≤ 0.001
4800-5000	-2,645	≤ 0.05

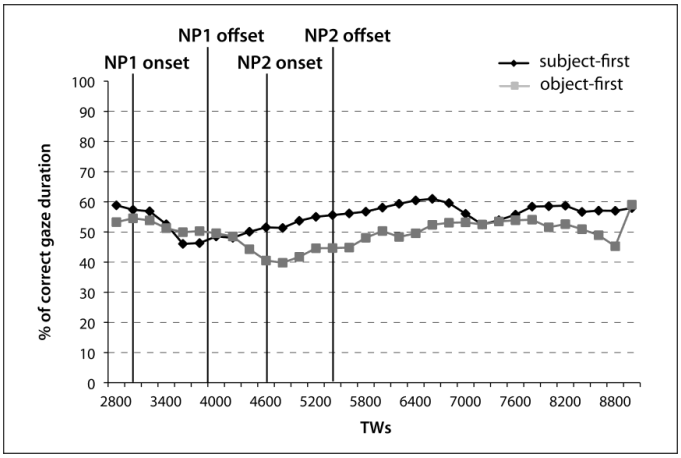


Figure 18. 4;6-year-olds: Averages of the correct fixation duration per condition over the course of a trial in 200 ms windows.

7.2.2.3 Interim Summary: Eye-tracking data

In sum, children at the age of 4;6 years fixated the corresponding object-initial picture significantly below chance in an 800 ms long time window right after NP2 onset and the subject-initial picture significantly above chance right after NP2 offset as evident in the trial course analysis. Consequently, results on fixation durations in the time window after NP1 onset were on chance-level in both conditions as they only started to shift gaze after NP2 onset. Thus, in the time window after NP2 onset, summed gaze duration revealed above-chance outcome in the subject-first condition, but on chance-level results in the object-first condition. These results show systematic correct gaze-shift in the subject-initial condition and systematic incorrect gaze-shift in the object-initial condition at the age of 4;6.

7.2.3 ERP-Data I: Processing of Object-First Structures

7.2.3.1. Methods

7.2.3.1.1 Subjects

In the EEG experiment, 40 (23 female) children at the age of 4;6 were tested. The data of approximately one-quarter of all children were excluded because they either contained disproportionate numbers of artifacts caused by exaggerated movement and/or perspiration (skin potentials), did not finish the experiment, or did not show age-appropriate language development according to the TROG-D (Fox, 2008) (see Section 5.6 Language Testing: TROG-D). The final sample of the EEG experiment consisted of (for NP1/NP2, respectively) 30/29 4;6-year-olds (14/13 female). Subject numbers differed for NP1/NP2 because processing procedures concerning rejection of trials were kept constant across all analyses (see Section 5.7 Data Processing and Analysis).

7.2.3.1.2 Stimuli

Preschoolers listened to auditory stimulus material including sentences of the subject-first and object-first structure (see Section 5.1 Experimental Design and Material).

7.2.3.1.3 Data Analysis

In 4;6-year-olds, the resulting mean number of averaged trials across participants was 15/16 for NP1 and NP2, respectively. These numbers did not differ between conditions.

Statistical analyses were performed separately for mean amplitudes on midline and lateral electrode sites. For midline sites (FZ, CZ, and PZ), a two-way ANOVA was computed with the factors *Condition* (subject-initial and object-initial) and *Region* (anterior, central, and posterior). For lateral sites, a three-way ANOVA was performed with the factors *Condition*, *Site* (F7, F3, F4, F8, FC3, FC4, T7, C3, C4, P7, CP5, CP6, T8, P3, P4, P8, O1, O2), and *Hemisphere* (left and right). Significant interactions involving the factor *Condition* were further analyzed for each *Site*/*Region* using a one-way ANOVA with *Condition* as factor.

7.2.3.2 Results

<u>NP1</u>

In 4;6-year-olds, visual inspections suggested a negativity for the object-initial condition at sentence onset (Figure 19, left panel). However, statistical analysis did not confirm this, as no main effects of condition were significant. At lateral sites, an interaction of condition and site

was found (TW1: $F(8,232) = 3.314$, $p \leq 0.05$; TW2: $F(8,232) = 4.603$, $p \leq 0.05$). Likewise, the same interaction was present at midline (TW1: $F(2,58) = 3.849$, $p \leq 0.05$; TW2: $F(2,58) = 3.866$, $p \leq 0.05$). Further analyses, however, revealed no significant differences of the factor condition at single electrode sites. Hence, concerning children at the age of 4;6, processing differences between object-initial and subject-initial structures cannot be affirmed at the first nominal phrase.

NP2

ERP responses in 4;6-year olds appeared to show a slightly late positive shift in left centro-lateral regions in response to the object-initial compared to the subject-initial condition after visual inspection (Figure 19, right panel). Statistical analysis, however, demonstrated that a main effect for condition was only significant in TW13 for lateral sites ($F(1,28) = 5.615$, $p \leq 0.05$) and at midline ($F(1,28) = 4.445$, $p \leq 0.05$).

Thus, 4;6-year-olds show a late centro-parietal positivity when processing object-initial structures only for a single TW.

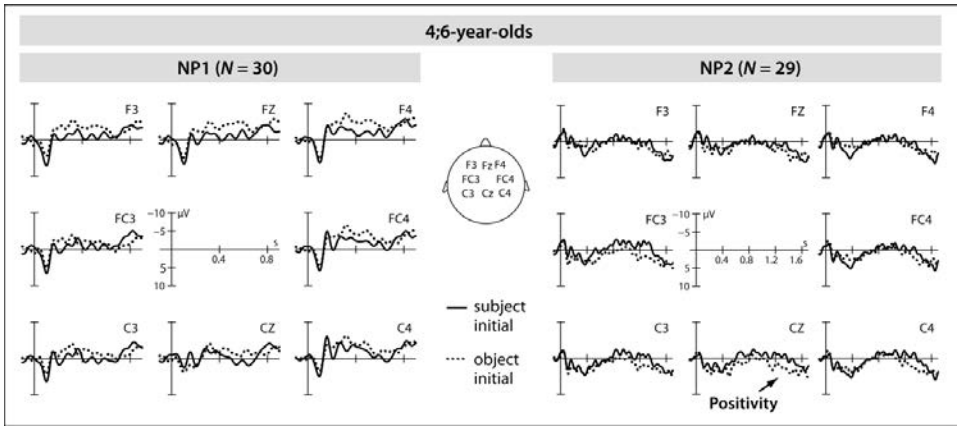


Figure 19. Grand-average ERPs of 4;6-year-olds for selected electrodes, object-initial versus subject-initial, relative to the onset of NP1 (left panel) / NP2 (right panel). The subject-initial condition (solid line) is plotted against the object-initial condition (dotted line). Negative voltage is plotted upwards.

7.2.3.3 Interim Summary: ERP-data I

ERP-data of the object-initial compared to the subject-initial condition revealed no processing differences at NP1 onset in 4;6-year-olds, while a weakly pronounced P600 occurred at NP2 onset. These results indicate that children at the age of 4;6 do not detect case-marking differences at NP1 but at NP2 in the object-first sentences.

7.2.4 ERP-Data II: Processing of Argument Violations

7.2.4.1. Methods

7.2.4.1.1 Subjects

As in the previous reported ERP-Data I, 40 (23 female) 4;6-year-olds participated in the EEG experiment. Due to numerous artifacts, mainly for movement reasons, or due to age-inappropriate performance in the TROG-D (Fox, 2008) (see Section 5.6 Language Testing: TROG-D), the data of approximately one quarter of all children tested had to be rejected. In the end, the sample of the ERP-Data II comprised 29 4;6-year-olds (13 female).

7.2.4.1.2 Stimuli

Preschoolers were presented with auditory stimulus material including sentences of the subject-first, object-first, double-nominative, and double-accusative structure (see Section 5.1 Experimental Design and Material).

7.2.4.1.3 Data Analysis

The resulting mean number of averaged trials across participants accounted for 16 in 4;6-year-olds. These numbers did not differ between conditions.

Statistical analyses for mean amplitudes on midline and lateral electrode sites were computed separately. For midline sites (FZ, CZ, and PZ), a two-way ANOVA was calculated with the factors *Condition* (subject-initial and double nominative in experiment 1 and object-initial and double accusative in experiment 2) and *Region* (anterior, central, and posterior). For lateral sites, a three-way ANOVA was performed with the factors *Condition*, Site (F7, F3, F4, F8, FC3, FC4, T7, C3, C4, P7, CP5, CP6, T8, P3, P4, P8, O1, O2), and *Hemisphere* (left and right). Significant interactions involving the factor *Condition* were further analyzed for each *Site*/*Region* employing a one-way ANOVA with *Condition* as factor.

As already explained in Section 7.1.4.1.3 Data Analysis, regarding the analysis of the three-year-olds' data, ERP responses to the subject-initial and double-nominative condition and also to the object-initial and double-accusative condition were only compared at NP2.

7.2.4.2 Results

Experiment 1: Double-Nominative Violation

Similar to three-year-olds' processing patterns, visual inspection of the 4;6-year-olds' ERPs (see Figure 20) suggests an early negativity and a late positivity in response to the double nominative violation. Statistical analysis attested this impression and revealed a significant condition main effect in TW3 ($F(1,28) = 4.460$, $p \leq 0.05$), along with a significant interaction of condition and site ($F(8,224) = 3.455$, $p \leq 0.05$). In the subsequent TWs 4 and 5, the three-way interaction *Condition*, *Hemisphere*, and *Site* was proven significant ($F(8,224) = 3.000$, $p \leq 0.05$, $F(8,224) = 2.678$, $p \leq 0.05$). Separate analyses of single electrode sites in TWs 3, 4, and 5 revealed significant condition effects distributed over frontal and central brain regions (Table 10, upper panel).

The positivity was confirmed by a condition main effect at midline in TW12 ($F(1,28) = 4.853$, $p \leq 0.05$) and TW13 ($F(1,28) = 7.076$, $p \leq 0.05$), and also by a marginally significant condition main effect at lateral sites in TW13 ($F(1,28) = 3.977$, $p = 0.056$). In addition, an interaction of *Condition* and *Site* was significant in TW15 ($F(8,224) = 2.720$, $p \leq 0.05$) (see Table 10, lower panel).

One effect that was unexpected revealed significance in TW1 in a condition main effect at lateral sites ($F(1,28) = 4.459$, $p \leq 0.05$).

To summarize, a fronto-central negativity between 300-600 ms and a positivity between 1200-1400 ms and 1500-1600 ms relative to NP2 onset was proven for 4;6-year-olds processing the double nominative violation in comparison to the correct sentence. The additional effect in TW1 will be discussed below.

Table 10. Condition Main Effects of 4;6-year-olds' ERPs in Different TWs, double nominative compared to subject-initial sentences; the upper panel reflects the distribution of the negativity and the lower panel the distribution of the positivity (separated by the dotted line).

TW (ms)	F(1,28)	Electrode Site
03: 300-400	6.335-15.653	FC4**, F4*, F8***, C4*
04: 400-500	8.292	F8**
05: 500-600	4.291	F8*
15: 1500-1600	5.338	F8*

*p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001

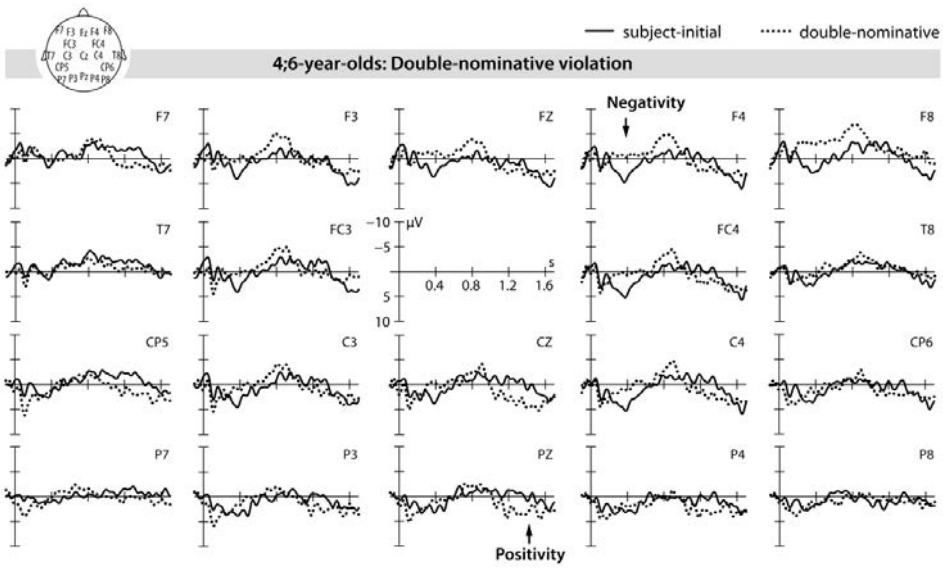


Figure 20. Grand average ERPs relative to NP2 onset for subject-initial (solid line) sentences versus double-nominative (dotted line) constructions for 4;6-year-olds. ERPs to the double- nominative violation show a frontal negative shift and a parietal positive shift.

Experiment 2: Double-Accusative Violation

Visual inspection of the ERPs in 4;6-year-olds indicated a focal negativity in left-lateralized centro-parietal brain regions for the processing of double accusative compared to object-initial constructions (see Figure 21). Accordingly, statistical analysis attested marginal significance for the interaction of *Condition* and *Hemisphere* in TW9 and 10 ($F(1,28) = 3.907$, $p = 0.058$, $F(1,28) = 4.034$, $p = 0.054$). Analysis of single site electrodes in these two TWs confirmed significant results at P3 in TW9 ($F(1,28) = 4.265$, $p \leq 0.05$), in TW10 at P3 ($F(1,28) = 8.270$, $p \leq 0.01$), and at P7 ($F(1,28) = 4.806$, $p \leq 0.05$). In TW12, the analysis resulted in a significant outcome also for the interaction of *Condition* and *Hemisphere* ($F(1,28) = 5.472$, $p \leq 0.05$), which was found in subsequent analysis significant at single electrodes P3 ($F(1,28) = 8.111$, $p \leq 0.01$) and P7 ($F(1,28) = 5.472$, $p \leq 0.05$). In sum, the processing of the double accusative violation compared to the object-initial sentence is reflected as a left-lateralized parietal negativity from 900-1300 ms in 4;6-year-olds.

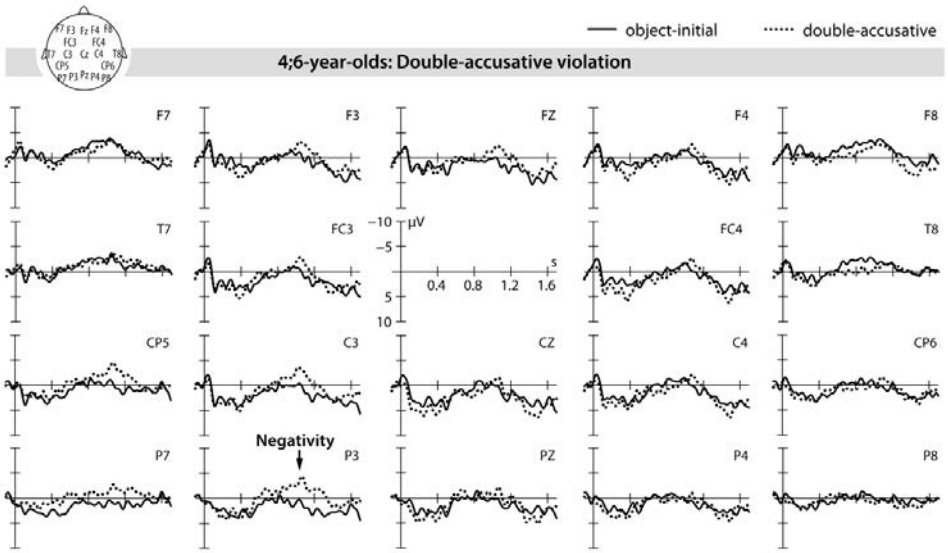


Figure 21. Grand average ERPs relative to NP2 onset for object-initial (solid line) sentences versus double-accusative (dotted line) constructions for 4;6-year-olds. ERPs to the double accusative violation reveal a negative shift starting at 900ms.

7.2.4.3 Interim Summary: ERP-data II

In the double nominative condition compared to the subject-initial structures in ERP-Study II, 4;6-year-olds showed, as already seen in adults and also in three-year-olds, an early negativity and a late positivity indicating correct argument expectations for the subject-initial structure. In addition, an early positivity occurred that will be addressed later. In the double accusative condition compared to the object-initial structures, a negativity between 900-1300 ms resulted suggesting thematic violation detection in children at the age of 4;6.

7.2.5 Summary and Interim Discussion

The study concerning 4;6-year-olds served the aim to investigate the development of the sensitivity to linguistic cues regarding syntactic-thematic interpretations in preschoolers. While much research being conducted with behavioral paradigms (Lindner, 2003; Mills, 1977; Schaner-Wolles, 1989) point into the direction that children start to use the case-marking cue for the interpretation of topicalized objects shortly before their fifth birthday, even these finding are still under discussion. Dittmar et al. (2008a) stated, based on a behavioral acting-out paradigm, that children do not use the case-marking cue until their seventh birthday.

The current behavioral sentence-picture matching task was to function as further evidence on the debate outlined above. More important, the eye tracker and ERP-Experiment I provide first

results using these methods to this end as to this point only behavioral methods have been employed. Concerning the interpretation of object-first structures, saccades recorded in the eye tracker experiment offer attaining a deeper understanding of the interaction between physiological processes and the behavioral results observed. Furthermore, the ERP-Experiment I that examines the neurophysiological aspects of the processing of object-first sentences seeks to reveal underlying mechanisms in the brain leading to the behavior detected in children at 4;6 years. It is reasonable to hypothesize that ERP-effects indicating the sensitivity to case-marking cues precede the behavioral interpretational competence of object-initial structures.
Beyond that, ERP- Experiment II scrutinizes argument expectations in 4;6-year-olds drawing on a paradigm that violates case-markings of noun phrases in a systematic manner. This study makes it possible to integrate the results of the behavioral, eye tracking, and ERP-Experiment I into the broader context of established argument structures and expectations in preschoolers. Given that three-year-old toddlers demonstrated stable argument expectations only for the SVO sentence structures, 4;6-year-olds might already have specific expectations regarding an OVS structure if they indeed have started to be sensitive to the case-marking cue.

In the behavioral study, children at the age of 4;6 performed at chance level in the object-initial condition while they performed above chance in the subject-initial condition. Given the behavioral result in the object-first, concluding a word-order strategy as in three-year-olds is not possible. From these findings, it is only feasible to deduct neither a strong reliance on the word-order cue nor on the case-marking cue in 4;6-year-olds since in the former case performance would result in a below-chance outcome while in an above chance outcome in the latter.
More sensitivity to the word-order cue than visible in the behavioral test was revealed in the eye tracker study in 4;6-year-old preschoolers; generally speaking, they performed below chance in the object-first condition while above chance in the subject-first condition. More specifically, fixation durations demonstrated results on chance-level relative to NP1 onset; in relation to NP2 onset, however, summed gaze duration revealed above-chance outcome in the subject-first condition while responses to the object-first condition remained at chance-level. The more detailed trial course analysis made more facets of 4;6-year-olds' fixations visible and exposed results below chance in the object-first condition at an early time window right after NP2 onset and results above chance in the subject-first condition at two later time windows right after NP2 offset (5200-6800 ms and 7600-8600 ms relative to trial onset). Thus, reflecting automatic processes, children relied on the word-order cue in the eye tracker study.

However, the behavioral test, mirroring more controlled processes, did not account for the same pattern (see above).

As a consequence of the behavioral and eye tracking study, evidence alludes to a word-order strategy in 4;6-year-olds regarding the interpretation of object-first structures, no evidence was found for sensitivity to the case-marking cue in these experiments.

Concerning children's responses in the ERP-Experiment I, no differences in the processing of the two conditions at NP1 but a slight P600 at NP2 were found. Since preschoolers at the age of 4;6 do not show differences in ERP-waves at NP1, it is plausible to conclude that they employ a word order strategy, taking the first noun phrase in both sentence structures as the agent regardless of the case-marking (as shown in Chan et al. (2009)). However, children at this age start to detect case-marking differences at NP2 and moreover try to functionally interpret these, as suggested by the emergence of a late positivity in response to the object-initial compared to the subject-initial sentences. This positivity is interpreted as a P600, which was previously reported in two-year-olds (Oberecker et al., 2005). In adults, a P600 is elicited by non-preferred syntactic structures like by garden-path sentences reflecting increased processing demands (Hagoort et al., 1993; Osterhout & Holcomb, 1993). In addition, the P600, as a response to well-formed sentences, was often interpreted as a syntactic reanalysis cost (Schlesewsky & Bornkessel, 2006), a reanalysis of phrase structure (Bornkessel, McElree, et al., 2004), or local integration processes in syntactic complex structures (Fiebach et al., 2002). More specifically, in a study regarding ambiguous sentences that were disambiguated towards an object-initial structure, Frisch et al. (2002) found a P600 in adults. Hence, although the P600 component is only weakly pronounced in 4;6-year-olds, it may be interpreted as a beginning of a clear case-marking sensitivity and a reflection of syntactic integration processes.

In ERP-Experiment II, 4;6-year-olds displayed an early negativity and a late positivity in response to the double-nominative violation compared to the subject-initial condition. The negativity, distributed over frontal brain regions, appeared between 300-600 ms. The ERP component of the LAN, distributed over left frontal brain regions, is usually found at this time-window (between 300-500 ms) as a reaction to morphosyntactic violations (Fiebach et al., 2002; Friederici, 2002). Although the negativity in the present study is not as focal but more broadly distributed over frontal brain regions than the LAN usually is, this effect nevertheless emerges at the exact time-window of the LAN and is also functionally consistent with the test material because it occurs in relation to a morphosyntactic violation. Hence, for the SVO argument order, established argument expectancies exist in 4;6-year-olds as well as in three-

year-olds, as can be learned from the attempt to repair the second nominative (indicated by the P600) and the notion of a morphological violation (as indicated by the LAN).

In addition to the LAN-P600 pattern, ERPs in 4;6-year-olds showed an early positivity (100-200 ms) for the double nominative compared to the subject-initial condition. A similar early positivity was found in different contexts as phonological processing, phrase-structure violations, and syntactic violations in several studies dealing with language processing (Mills & Sheehan, 2007; Oberecker et al., 2005; Silva-Pereyra, Klarman, et al., 2005) pointing towards additional and increased attention mechanisms that might be involved in children's language processing (Mills & Sheehan, 2007).

In contrast to the double nominative condition, the double accusative condition compared to the object-initial structures elicited different ERP results for 4;6-year-olds. A negativity between 900-1300 ms was observed.

While children at the age of three detect a morphosyntactic violation in the double accusative condition but do neither thematically or syntactically repair it, children at the age of 4;6 start to be able to establish thematic dependencies given the structures investigated. The left-lateralized posterior negativity can be, considered its distribution, interpreted as an N400 as Holcomb et al. (1992) convincingly demonstrated that the N400 has delayed latencies in childhood decreasing with age. 4;6-year-olds have thus begun to acquire the functional characteristics of the accusative case marking and repair processes regarding thematic dependencies come into play at that age. A clear argument expectation regarding the OVS order cannot be stated since no P600 was evident. Hence, the preschoolers possess a thematic expectancy and interpretation of these structures and do not yet have the resources to repair the sentence syntactically or to detect the syntactic ill-formedness.

7.2.6 Interim Conclusion

In sum, children 4;6 years of age are in a transitory state between the sensitivity to the word-order cue and the case-marking cue for the interpretation of object-first structures. While they clearly shift their attention to the word-order cue in the eye tracker experiment, the ERP-Study I points towards the beginning of syntactic integration and thus the sensitivity to the case-marking cue at NP2. A development beyond an exclusive SVO expectation became visible in ERP-Study II. Here, results of the double-accusative violation demonstrated not only violation detection, but also thematic processes to be involved.

7.3 Six-Year-Olds

The main steps in German language and grammar acquisition are accomplished in normally developed six-year-olds (Szagun, 2006). Thus, the hypothesis follows that six-year-old children are able to correctly interpret object-initial sentences and have established argument expectancies regarding simple transitive structures. More specifically, the use of the case-marking cue for correct thematic role assignment is surmised to be acquired.

In an acting out task, Dittmar et al. (2008a) tested German children at the age of two, five, and seven. Five-year-olds were able to use the word order cue alone, but not case-marking. Seven-year-olds were eventually able to assign correct thematic roles to constituents in a transitive sentence based on the case-marking cue alone.

However, starting at the age of five, there seems to be more attention to the case-marking cue (Lindner, 2003; Mills, 1977; Schaner-Wolles, 1989) as Mills (1977) found a blocking of the word order strategy for unambiguous accusative markers in initial position at this age. These findings contradict the study by Dittmar et al. (2008a) as it was not until children were seven years of age that they were able to correctly use the case-marking cue. Hence, the present study of six-year-olds aims to clarify the question whether these children already make use of the case-marking cue and under which conditions they are sensitive to which cues for sentence interpretation.

7.3.1 Behavioral Data

7.3.1.1 Methods

7.3.1.1.1 Subjects

In the behavioral experiment, 33 children (16 female) at the age of six were tested. Three of them were excluded because they did not display age-appropriate language development in the TROG-D (Fox, 2008). The final sample of the behavioral experiment consisted of 30 six-year-olds (14 female).

7.3.1.1.2 Stimuli

Six-year-olds were presented with subject-first and object-first sentences that they had to match to corresponding pictures (see Section 5.1 Experimental Design and Material). In each trial, two pictures were shown one of which depicting the correct agent and patient roles and the other one reversed thematic roles.

7.3.1.1.3 Data analysis

As explained in detail in Section 5.7 Data Processing and Analysis, correct identifications of the corresponding picture in each trial per condition were averaged and afterwards statistically analyzed against chance level (50%). Comparisons between 4.5-year-olds' behavioral data and six-year-olds' data were calculated with a t-test for independent samples.

7.3.1.2 Results

Six-year-old children performed above chance in the subject-initial condition (96.39%, $t(29) = 32.600$, $p \leq 0.001$). In the object-initial condition, however, the data of the same age group did still not result in a significant outcome above chance (55.28%, $t(29) = 1.139$, $p > 0.1$) (see Figure 22).

From a developmental perspective, correct responses to the subject-initial condition increased significantly between 4.5- and six-year-olds, which was confirmed by a t-test for independent samples (4.5 vs. six: $t(63.640) = -3.293$, $p \leq 0.01$). Significant improvement between these two age groups in the object-initial condition was not evident. However, in this condition, there was a significant difference in performance between three-year-olds and six-year-olds (three vs. six: $t(43.087) = -2.019$, $p \leq 0.05$).

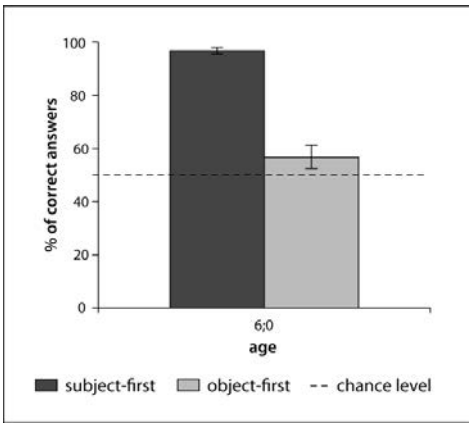


Figure 22. Six-year-olds: Results of the behavioral task to identify which picture corresponded to each sentence.

7.3.1.3 Interim Summary: Behavioral data

In the behavioral experiment, six-year-olds identified the corresponding picture in the subject-initial condition systematically correct and close to perfect. In the object-initial condition,

however, they neither pointed systematically to the correct nor incorrect picture, as also seen for 4;6-year-olds.

7.3.2 Eye-Tracking Data

7.3.2.1 Methods

7.3.2.1.1 Subjects

At the age of six years, 32 (13 female) children were tested. Due to not age-appropriate performance in the language test (TROG-D, (Fox, 2008)), an insufficient trial number or a clear looking preference for one side of the screen (see 5.7 Data Processing and Analysis), the data of seven children had to be excluded from the analysis of gaze duration from NP1/NP2 onset and from the trial course analysis, respectively, resulting in 25 (12 female) six-year-olds for all three samples.

7.3.2.1.2 Stimuli

Two pictures per trial were presented on a screen. At the same time, children listened to sentences constructed in the subject-first and object-first structure. One picture depicted the corresponding thematic roles of the auditory stimuli and the other one showed reversed actor and patient roles (see Section 5.1 Experimental Design and Material).

7.3.2.1.3 Data Analysis

The analysis of both time windows, beginning at NP1 and NP2, respectively, included a mean number of 11.3 trials. These numbers did not differ significantly between conditions. The averaged mean number of trials across all time windows included in the trial course analysis resulted in 10.8.

Corresponding fixation durations to the matching picture with the auditory stimulus presented were averaged and analyzed according to NP1 onset (until verb offset, 1.5s of length), to NP2 onset (2s of length) and in sliding windows of 200 ms across the whole trial (trial course analysis) (see Section 5.7 Data Processing and Analysis). Every condition (subject-first/object-first) was statistically analyzed in relation to chance-level (50%) for all three analyses. In addition, trial-course statistics were computed employing two-way ANOVAs with condition (subject-first/object-first) and time window (44 time windows, each 200 ms of length) as factors. T-tests for independent samples were used to compute differences between the eye tracker data of the 4;6-year-olds already presented and six-year-olds.

7.3.2.2 Results

NP1

Six-year-olds correct fixation duration to the corresponding picture in relation to NP1 onset until verb offset (1.5s) amounted to 47.61% in the subject-first condition and 47.62% in the object-first condition. One-sample t-tests against 50% did not reveal any significant difference from chance in the subject-first condition ($t(24) = -1.021$, $p > 0.10$), however, for the object-first condition significant difference below chance was found ($t(24) = -2.206$, $p \leq 0.05$). T-tests for independent samples revealed no differences between 4.5- and six-year-olds for fixation durations from NP1 onset (subject-first condition: $t(50) = 0.896$, $p > 0.10$; object-first condition, $t(37.364) = 0.280$, $p > 0.10$).

NP2

The results of six-year-olds' summed gaze duration to the corresponding picture in relation to NP2 (2s time window) amounted to 66.15% in the subject-first condition and for 55.06% in the object-first condition (see Figure 23). Statistical analysis revealed significant findings above chance in both conditions ($t(24) = 6.285$, $p \leq 0.001$ for the subject-first condition; $t(24) = 2.338$, $p \leq 0.05$ for the object-first condition). In addition, the two conditions differed significantly in six-year-olds as revealed by a paired t-test ($t(24) = 3.994$, $p \leq 0.001$). Statistical comparison between preschoolers at the age of 4;6- and six-year-olds delivered, in turn, significant differences in both conditions ($t(50) = -2.649$, $p \leq 0.05$ for the subject-first condition; $t(50) = -2.432$, $p \leq 0.05$ for the object-first condition).

In sum, six-year-old children's fixation duration after NP2 onset revealed above-chance results in the subject-first as well as in the object-first condition, which both increased significantly in comparison to 4;6-year-olds.

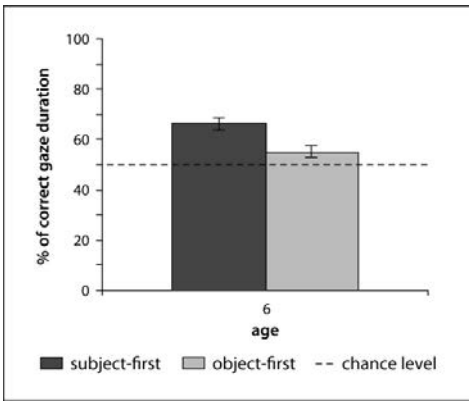


Figure 23. Six-year-olds: Averages of the correct fixation duration per condition in a two seconds time window beginning at NP2.

Trial Course Analysis

Statistical analysis of fixation durations to the corresponding pictures over the trial course within TWs of 200 ms (see Figure 24) delivered a time window main effect ($F(44,1056) = 8.018$, $p \leq 0.001$) and an interaction condition x time window ($F(44, 1056) = 3.269$, $p \leq 0.001$). Subsequent one-way ANOVAs revealed a condition main effect for the continuous time windows between 4600-5800 ms relative to trial onset (see Table 11).

Table 11. Significant condition main effects in six-year-olds' trial course analysis calculated for 200 ms time windows.

TW (ms)	F(1,24)	p-value
4600-4800	9.049	≤ 0.01
4800-5000	14.464	≤ 0.001
5000-5200	32.457	≤ 0.001
5200-5400	47.836	≤ 0.001
5400-5600	31.166	≤ 0.001
5600-5800	6.856	≤ 0.05

One-sample t-tests, calculated separately for every TW, revealed significant outcome above chance in the subject-first condition between 4600-7800 ms, and between 8400-8800 ms relative to trial onset (see Table 12). In the object-first condition, significant fixation durations above chance were found also in the statistical analysis between 5800-8400 ms, relative to trial onset (see Table 13).

Table 12. Significant t-values (one-sample t-test calculated against chance-level) of six-year-olds' fixation durations in different TWs of the trial course analysis in the subject-first condition

TW (ms)	t(24)	p-value
4600-4800	2,335	≤ 0.05
4800-5000	4,403	≤ 0.001
5000-5200	6,468	≤ 0.001
5200-5400	6,872	≤ 0.001
5400-5600	6,443	≤ 0.001
5600-5800	4,297	≤ 0.001
5800-6000	3,335	≤ 0.01
6000-6200	4,342	≤ 0.001
6200-6400	4,139	≤ 0.001
6400-6600	4,608	≤ 0.001
6600-6800	4,407	≤ 0.001
6800-7000	3,263	≤ 0.01
7000-7200	2,603	≤ 0.05
7200-7400	2,242	≤ 0.05
7400-7600	2,376	≤ 0.05
7600-7800	2,192	≤ 0.05
8400-8600	3,157	≤ 0.01
8600-8800	2,851	≤ 0.01

Table 13. Significant t-values (one-sample t-test calculated against chance-level of 50%) of six-year-olds' fixation durations in different TWs of the trial course analysis in the object-first condition

TW (ms)	t(24)	p-value
5800-6000	3,776	≤ 0.001
6000-6200	5,652	≤ 0.001
6200-6400	5,606	≤ 0.001
6400-6600	5,461	≤ 0.001
6600-6800	5,354	≤ 0.001
6800-7000	5,366	≤ 0.001
7000-7200	4,228	≤ 0.001
7200-7400	4,668	≤ 0.001
7400-7600	4,877	≤ 0.001
7600-7800	4,447	≤ 0.001
7800-8000	2,715	≤ 0.05
8000-8200	3,248	≤ 0.01
8200-8400	3,797	≤ 0.01

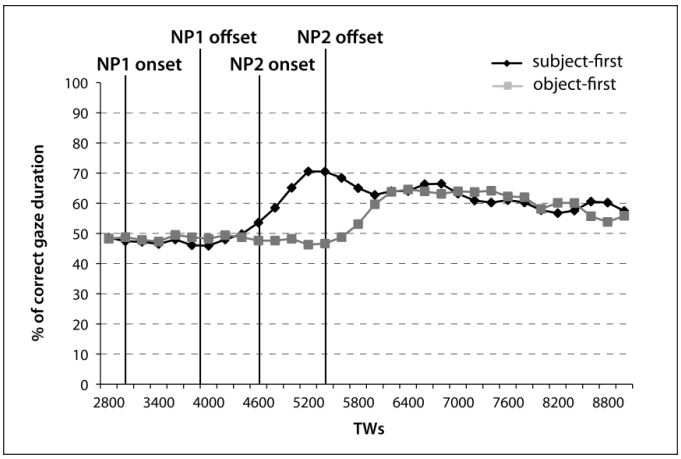


Figure 24. Six-year-olds: Averages of the correct fixation duration per condition over the course of a trial in 200 ms windows.

7.3.2.3 Interim Summary: Eye-tracking data

For six-year-olds, the analysis of fixation durations in the 1.5 s time window at NP1 showed results at chance level in both conditions as in all younger age groups as well. On the contrary, at NP2, analysis revealed outcomes above chance in the subject-initial and in the object-initial

condition. In the trial course analysis, results exposed above chance gaze durations starting shortly after NP2 onset (at 4600 ms relative to trial onset) in the subject-initial condition, while this effect only started one second after sentence offset in the object-initial condition, namely at 5600 ms relative to trial onset.

In sum, 6-year-olds are sensitive to the case-marking and interpret the object-initial sentences correctly but still need a significantly longer processing time compared to the subject-initial structures.

7.3.3 ERP-Data I: Processing of Object-First Structures

7.3.3.1. Methods

7.3.3.1.1 Subjects

The data of approximately one-quarter of all children tested in the EEG experiment (31 six-year-olds, 15 female) were excluded because they contained disproportionate numbers of artifacts caused by exaggerated movement and/or perspiration (skin potentials) or the subject did not display age-appropriate language development in the test for reception of grammar (TROG-D; (Fox, 2008) (see Section 5.6 Language Testing: TROG-D). The final sample of the EEG experiment consisted (for NP1/NP2, respectively) of 21/24 six-year-olds (8/10 female). Subject numbers differed for NP1/NP2 because processing procedures concerning rejection of trials were kept constant across all analyses (see Section 5.7 Data Processing and Analysis).

7.3.3.1.2 Stimuli

Six-year-olds were presented with auditory stimulus material containing subject-first and object-first sentences (see Section 5.1 Experimental Design and Material).

7.3.3.1.3 Data Analysis

The resulting mean number of averaged trials across six-year-old participants was 14/15 for NP1 and NP2, respectively. These numbers did not differ between conditions.

Statistical analyses were performed separately for mean amplitudes on midline and lateral electrode sites. For midline sites (FZ, CZ, and PZ), a two-way ANOVA was calculated with the factors *Condition* (subject-initial and object-initial) and *Region* (anterior, central, and posterior). For lateral sites, a three-way ANOVA was computed with the factors *Condition*, *Site* (F7, F3, F4, F8, FC3, FC4, T7, C3, C4, P7, CP5, CP6, T8, P3, P4, P8, O1, O2), and

Hemisphere (left and right). Significant interactions involving the factor *Condition* were further analyzed for each *Site*/*Region* using a one-way ANOVA with *Condition* as factor.

7.3.3.2 Results

NP1

A similar negativity as in the adults' response to the object-initial condition compared to the subject-initial condition was observed in six-year-olds over fronto-central brain regions (Figure 25, left panel). Statistical analysis showed a main effect for condition in TW3 both for lateral sites ($F(1,20) = 5.372$, $p \leq 0.05$) and for midline ($F(1,20) = 4.460$, $p \leq 0.05$).

NP2

In the oldest age group tested, ERP responses to object-initial structures in comparison to subject-initial structures showed a very broadly distributed positive wave, which was apparent both at an early starting point and then again at later time windows (Figure 25, right panel). Accordingly, ANOVAs showed a significant effect for the factor *Condition* at lateral sites (TW1: $F(1,23) = 10.415$, $p \leq 0.01$;TW2: $F(1,23) = 5.798$, $p \leq 0.05$; TW7: $F(1,23) = 6.463$, $p \leq 0.05$; TW8: $F(1,23) = 4.392$, $p \leq 0.05$; TW9: $F(1,23) = 10.944$, $p \leq 0.01$; TW10: $F(1,23) = 13.263$, $p \leq 0.001$; TW11: $F(1,23) = 12.642$, $p \leq 0.01$; TW12: $F(1,23) = 11.739$, $p \leq 0.01$; TW13: $F(1,23) = 11.003$, $p \leq 0.01$; TW14: $F(1,23) = 8.464$, $p \leq 0.01$; TW15: $F(1,23) = 12.911$, $p \leq 0.01$; TW16: $F(1,23) = 8.855$, $p \leq 0.01$). A significant effect for the factor condition at midline was also found (TW1: $F(1,23) = 5.069$, $p \leq 0.05$; TW10: $F(1,23) = 5.343$, $p \leq 0.05$; TW11: $F(1,23) = 5.643$, $p \leq 0.05$; TW13: $F(1,23) = 4.709$, $p \leq 0.05$; TW14: $F(1,23) = 4.883$, $p \leq 0.05$; TW15: $F(1,23) = 6.245$, $p \leq 0.05$; TW16: $F(1,23) = 11.391$, $p \leq 0.01$). An interaction of *Condition*, *Hemisphere* and electrode *Site* occurred in TW5, although no significant differences at single electrode sites could be detected. An interaction between *Condition* and *Region* at midline was also found in TW9 ($F(2,46) = 4.834$, $p \leq 0.05$), which was significant in an analysis of single central electrodes at FZ ($F(1,23) = 8.380$, $p \leq 0.01$). In addition, an interaction of *Condition* and electrode *Sites* was also present in TW12 ($F(8,184) = 2.857$, $p \leq 0.05$), TW13 ($F(8,184) = 4.227$, $p \leq 0.05$), and TW14 ($F(8,184) = 3.503$, $p \leq 0.001$). Separate analyses of single electrode sites revealed significant condition effects for the positivity, broadly distributed over frontal, central and temporal brain regions (Table 14). In sum, the statistical analyses demonstrated processing differences between object-initial structures and subject-initial structures in six-year-olds that were evident in a long-lasting and broadly distributed positive shift in response to object-initial sentences.

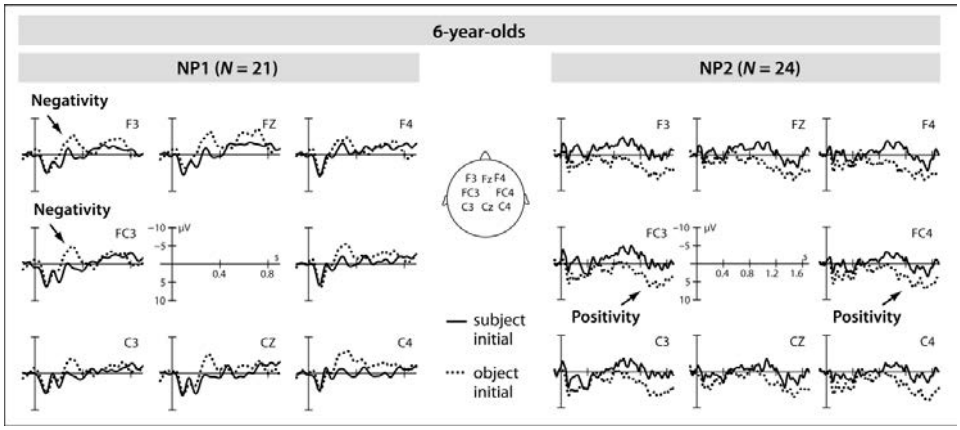


Figure 25. Grand-average ERPs of six-year-olds for selected electrodes, object-initial versus subject-initial, relative to the onset of NP1 (left panel) / NP2 (right panel). The subject-initial condition (solid line) is plotted against the object-initial condition (dotted line). Negative voltage is plotted upwards.

Table 14. Condition Main Effects of 6-year-olds' ERPs in Different TWs Relative to NP2 Onset

TW (ms)	F(1,23)	Electrode Site
12: 1200-1300	5.853-19.481	F7***, F3***, FC3***, FC4**, F4**, F8*** T7***, C3**, CP5*, C4**, T8**
13: 1300-1400	5.200-20.775	F7***, F3***, FC3***, FC4**, F4**, F8*, T7** C3***, CP5*, C4**, T8**
14: 1400-1500	4.529-16.865	F7***, F3**, FC3**, FC4**, F4*, F8*, T7*, C3**, CP5*, C4**, T8*

*p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001

7.3.3.3 Interim Summary: ERP-data I

ERP-data of the six-year-olds revealed the same processing differences as in adults at NP1 for the object-initial compared to the subject-initial condition, namely an early fronto-central negativity. However, the rest of the sentence is not equally effortlessly processed as in adults revealing a broadly distributed positivity at NP2 onset for the object-initial condition.

7.3.4 ERP-Data II: Processing of Argument Violations

7.3.4.1 Methods

7.3.4.1.1 Subjects

The data of approximately one quarter of all children tested (31 six-year-olds, 15 female) in the EEG experiment were excluded because they contained disproportionate numbers of artifacts caused by exaggerated movement and/or perspiration (skin potentials) or the subject did not display age-appropriate language development in the test for reception of grammar (TROG-D; (Fox, 2008) (see Section 5.6 Language Testing: TROG-D). The final sample of the EEG experiment consisted of 21 six-year-olds (12 female).

7.3.4.1.2 Stimuli

In the ERP-Experiment II, six-year-olds listened to auditory stimulus material containing subject-first, object-first, double-nominative, and double-accusative structures (see Section 5.1 Experimental Design and Material).

7.3.4.1.3 Data Analysis

The resulting mean number of averaged trials across participants accounted for 15 in six-year-olds. These numbers did not differ between conditions.

Statistical analyses for mean amplitudes on midline and lateral electrode sites were computed separately. For midline sites (FZ, CZ, and PZ), a two-way ANOVA was calculated with the factors *Condition* (subject-initial and double nominative in experiment 1 and object-initial and double accusative in experiment 2) and *Region* (anterior, central, and posterior). For lateral sites, a three-way ANOVA was performed with the factors *Condition*, *Site* (F7, F3, F4, F8, FC3, FC4, T7, C3, C4, P7, CP5, CP6, T8, P3, P4, P8, O1, O2), and *Hemisphere* (left and right). Significant interactions involving the factor *Condition* were further analyzed for each *Site*/*Region* employing a one-way ANOVA with *Condition* as factor.

As already explained in Section 7.1.4.1.3 Data Analysis, regarding the analysis of the three-year-olds' data, ERP responses to the subject-initial and double-nominative condition and also to the object-initial and double-accusative condition were only compared at NP2.

7.3.4.2 Results

Experiment 1: Double-Nominative Violation

Very similar to the two younger age groups, six-year-olds' ERPs indicated an early negativity and a late positivity as the brain response to the double nominative constructions compared to the subject-initial sentences (see Figure 26). The negativity was proven only marginally significant in TW3 as a main effect of condition at midline ($F(1,20) = 4.298$, $p = 0.051$). The positivity was statistically confirmed by a condition main effect at lateral sites in TW12 ($F(1,20) = 7.482$, $p \leq 0.05$), and by a significant condition x region interaction at midline in TW13 ($F(2,40) = 3.561$, $p \leq 0.05$) that reached significance at PZ in a single electrode analysis ($F(1,20) = 6.644$, $p \leq 0.05$). Moreover, in TW16, an interaction of condition and hemisphere revealed significance ($F(1,20) = 4.733$, $p \leq 0.05$), which was further observed significant at F4 in a subsequent one-way ANOVA ($F(1,20) = 5.119$, $p \leq 0.05$).

Hence, six-year-olds showed an early negativity (300-400 ms) and a late positivity (1200-1300 ms/1600-1700 ms) for the processing of the double nominative that was most pronounced at a parietal and a frontal electrode.

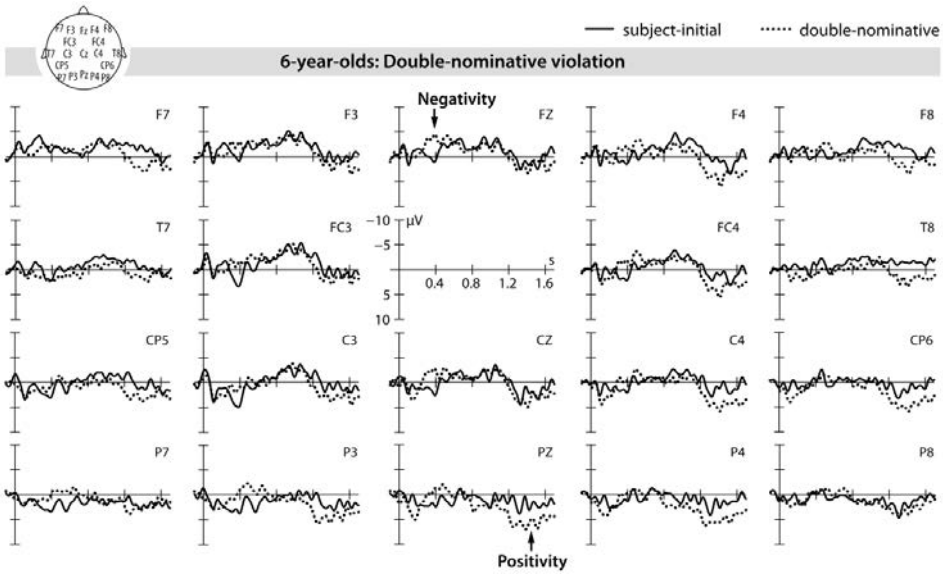


Figure 26. Grand average ERPs relative to NP2 onset for subject-initial (solid line) sentences versus double-nominative (dotted line) constructions 6-year-olds. ERPs to the double-nominative violation show a frontal negative shift and a parietal positive shift.

Experiment 2: Double-Accusative Violation

Six-year-olds' ERPs suggested two negativities to reflect the processing of the double accusative construction compared to the object-initial one (see Figure 27). In TW6, condition main effects, both at lateral sites as well as at midline were found to be significant ($F(1,20) = 5.986$, $p \leq 0.05$, and $F(1,20) = 4.783$, $p \leq 0.05$, respectively). In the subsequent TW7, a condition main effect was also attested significant at lateral sites ($F(1,20) = 7.129$, $p \leq 0.05$). Then again, in TW13 and TW15, a condition main effect also resulted at lateral sites reflecting the second negativity ($F(1,20) = 4.416$, $p \leq 0.05$, and $F(1,20) = 4.756$, $p \leq 0.05$, respectively).
In sum, six-year-olds process the double accusative with a negativity between 600-800 ms and a second negativity between 1300-1400 ms/1500-1600 ms.

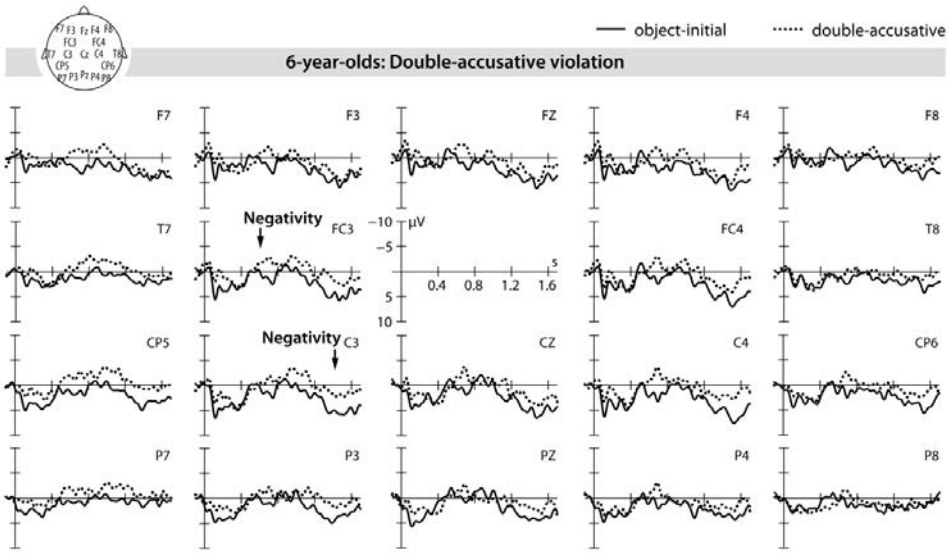


Figure 27. Grand average ERPs relative to NP2 onset for object-initial (solid line) sentences versus double-accusative (dotted line) constructions for 6-year-olds. ERPs display two negative shifts peaking at 700ms and around 1400ms.

7.3.4.3 Interim Summary: ERP-data II

As both younger age groups, six-year-olds show correct argument expectation for the subject-initial structures by also revealing an early negativity and a late positivity in their ERP response to the double-nominative violation compared to the subject-initial condition. In the double-accusative compared to the object-initial condition, however, six-year-olds do not demonstrate an adult-like pattern. Instead, two negativities (600-800 ms and 1300-1600 ms after NP2 onset) occurred suggesting thematic/syntactic repair strategies.

7.3.5 Summary and Interim Discussion

Following insights into grammar acquisition (Klann-Delius, 1999; Szagun, 2006), main acquisition steps should in general be accomplished in normally developed German six-year-olds. Hence, the initial hypothesis for the study in six-year-olds states that children at this age are able to correctly interpret object-initial sentences and have established adult-like argument expectancies regarding simple transitive structures. In specific, functional characteristics of the nominative and accusative should be acquired. Not only should the children be sensitive to the case-marking cue for the interpretation of topicalized objects but should also be able to correctly assign thematic roles and integrate both arguments into the transitive sentence structure regardless of their word order.

However, Dittmar et al. (2008a) reported in a behavioral study that only children at the age of seven were eventually able to assign correct thematic roles to constituents in a transitive sentence based on the case-marking cue alone. This finding stands in contrast to other behavioral studies which found more attendance to the case-marking cue starting at the age of five (Lindner, 2003; Mills, 1977; Schaner-Wolles, 1989). The present study of six-year-olds aims to clarify the question whether these children already make use of the case-marking cue and under which conditions they are attentive to which cues for sentence interpretation. Employing not only a behavioral sentence-picture matching paradigm but also the eye tracker and the ERP method will provide more insights into the processing mechanisms that come into play at this age. Since six-year-old preschoolers are already very aware of tests and assessments, the eye tracking experiment attempts to reveal physiological processes that mirror more automatic behavior without meta-linguistic mechanisms involved. In addition, ERP-Experiment I aims to reveal the neurophysiologic processing underpinnings of object-initial sentences while ERP-Experiment II seeks to uncover the hypothesized established argument expectancies in six-year-olds using a violation paradigm.

In the behavioral test, the hypothesis that children at the age of six will be able to use the case-marking cue for sentence interpretation could not be affirmed. The preschoolers did not perform above chance in the object-initial condition although they improved significantly compared to three-year-olds. In the subject-initial condition the outcome was above chance-level and significantly increased compared to 4;6-year-olds. Considering the chance-level performance in the object-initial condition, it is not possible to conclude which cues or if any six-year-olds utilize for thematic role assignment in this case.

However, in the eye tracker study, the same age group performed, generally speaking, above chance in the object-first condition. Nevertheless, the analysis at NP1 showed results at chance

level in both conditions as in all younger age groups as well. On the contrary, at NP2, analysis revealed outcomes above chance in the subject-initial and in the object-initial condition which is in line with the hypothesis that six-year-olds are sensitive to the case-marking cue although gaze duration to the corresponding pictures still differ significantly between conditions. The trial course analysis provides more detailed insights into the timely sequence the fixation durations in the experiment. While in the subject-initial condition, results exposed above chance gaze durations starting shortly after NP2 onset (at 4600 ms relative to trial onset), in the object-initial condition, this effect only starts one second after sentence offset, namely at 5600 ms relative to trial onset. Hence, differences in the gaze duration analysis at NP2 in a 2s time window between the two conditions results from differing onsets of the above-chance-performance, respectively. These different onsets, early for subject-first sentences and late for object-first sentences, in turn, reveal vast divergent processing timings between the two conditions.

ERP patterns to the object-initial sentences at NP1 exhibited a 'topicalization negativity' over fronto-central brain regions similar to adults, which, however, was not as prolonged as in adults but peaked at the same latency, namely at 300 ms. Thus, at sentence onset, six-year-olds process object-initial structures in the same manner as adults. In contrast, the rest of the sentence does not seem to be as equally effortlessly processed as in adults since six-year-olds display a long-lasting and broadly distributed positivity at the onset of NP2. As in 4;6-year-olds, this positivity is interpreted as a P600, which is much more pronounced than in the younger age group. As shown in several studies regarding syntactic processing in adults (Hagoort et al., 1993; Osterhout & Holcomb, 1993), the P600 points to increased processing demands, syntactic reanalysis costs or local integration processes in syntactic complex structures (Fiebach et al., 2002). More specifically, in a study regarding ambiguous sentences that were disambiguated towards an object-initial structure, Frisch et al. (2002) found a P600 in adults. Hence, six-year-olds are able to process the initial case marking at sentence onset in an adult-like manner but show difficulties in the process of syntactically integrating the second noun phrase and ultimately assigning correct thematic roles for the object-initial construction even in unambiguous sentences. Thus, six-year-olds are sensitive to the case-marking cue as reflected in the ERP and eye tracker results, but still have difficulties in (controlled) thematic role assignment as visible in the behavioral results and the relatively late eye tracker response. These specific integration problems at NP2 might very well be the reason for poor performance in interpreting topicalized objects behaviorally in which extra meta-linguistic processes might be additionally involved. Moreover, the eye tracker response to the object-first condition is later than the subject-first, which is in line with the enhanced effort (P600) shown

at NP2 in the ERPs. However, the negativity at NP1 is not reflected in a respective effect in the eye tracker results. Consequently, six-year-olds seem to not be able to take advantage of these automatic-processing mechanisms shown in the ERP-Experiment I at sentence onset.

In ERP-Experiment II, six-year-olds processed the double nominative in the same way as all the younger age groups revealing a negativity-positivity pattern, which, in turn, is interpreted as a LAN-P600 pattern. It reflects established argument expectancies for the SVO word order in six-year-olds and the notion of morphological violations *(*see Sections 7.1.5 and 7.2.5 for a discussion of three- and 4;6-year-olds*)*.

Six-year-olds reveal a more complex ERP pattern when processing the double accusative violation suggesting structural thematic/syntactic processes to be involved. They showed two negativities, one between 600-800 ms and one between 1300-1600 ms in response to the accusative violation compared to the correct transitive construction. The first can be clearly interpreted as an N400; it appears in the exact time-window as found for six-year-olds (Hahne et al., 2004). The N400 in response to the double-accusative violation demonstrates thematic integration difficulties similar to the processing of the 4;6-year-olds in this experiment. The second effect, a late negativity (1300-1600 ms), was also evident in response to the double accusative compared to the object initial condition, which, in line with Silva-Pereyra et al. (2005), can be seen as an immature 'sentence closure' processing step. Consequently, a repair process regarding the overall syntactic wellformedness signaled by a P600 is still missing in six-year-olds. The late negativity could be reluctantly interpreted as a precursor to that. Hence, although preschoolers at the age of six still do not show a clearly established argument expectation for OVS structures, a development from only thematic expectations to also syntactic expectations is visible.

7.3.6 Interim Conclusion

In sum, six-year-olds show sensitivity to the case-marking cue for the interpretation of object-initial structures as evident in the eye tracker and ERP-Experiment I. Yet, they still display difficulties in thematic role assignment. The present ERP results indicate that although they react to object-initial noun phrases in a similar way to adults, unlike adults, they still have problems when it comes to integrating the second noun phrases for interpretation. The ERP data thus build on the behavioral data from the study by Dittmar et al. (2008a) and are also complemented by the behavioral data from the present study. An argument expectation for

OVS structures becomes visible that goes beyond thematic expectations but represents, although still immature, a development towards syntactic expectations.

III Discussion and Conclusion

The main objective of the present work is a contribution to the understanding of the development of thematic role assignment mechanisms and argument expectations in preschool children. Experiments were conducted with children at the age of 3;0, 4;6, and 6;0 years. In particular, by presenting unambiguously case-marked object-initial structures compared to subject-initial structures, the ability in children to assign participant roles on basis of case-marking cues was investigated. Based on the competition model (Bates & MacWhinney, 1987, 1989), it was hypothesized that children proceed from the usage of the word-order cue (subject-first strategy) to only later using the most reliable German cue for masculine NPs, namely case marking.

The acquisition of case marking and the developmental steps taken in interpreting hierarchical ordered structures, in particular topicalized objects, are studied on different behavioral and processing levels by means of different methods. The paradigm of sentence-picture matching examines the behavioral competence of children to interpret these structures by identifying a corresponding picture to a test sentence. Thus, children had not only to process and understand a certain linguistic input but also translate their comprehension into an action metalinguistically by pointing to a matching picture. The second method, the eye tracker method, employed the paradigm of looking-while-listening (preferential looking). Here, the online comprehension of topicalized objects is measured with a time-sensitive method that excludes metalinguistic factors. Last, the neural correlates of the online processing of object-initial versus subject-initial sentences are analyzed in the ERP study I.

Moreover, the repair mechanisms for thematic hierarchizing and argument expectations present in children at the respective ages are investigated in ERP study II which employed a violation paradigm. The processing of double-nominative constructions compared to subject-initial structures and double-accusative constructions compared to object-initial structures are evaluated to gain further insights regarding the development of the ability to abide to the theta criterion in preschool children.

For an exact comparison of adult behavior, gaze behavior and neural correlates in the respective experiments described above, the same studies are likewise conducted with adults.

8 General discussion: Investigations of the Development of Syntactic Processing

The following discussion first describes and discusses the adults' results as a model for the interpretation of the children's data. The results are interpreted on basis of the Neurocognitive Model of Auditory Sentence Comprehension (Friederici, 2002) and the eADM (Bornkessel, 2002). Second, it illustrates the developmental picture that becomes evident in the three age groups regarding the interpretation and processing of object-initial structures. The sensitivity to different morphosyntactic cues in the different groups is discussed. Third, the development of repair mechanism for thematic hierarchizing as apparent from the present study is summarized and interpreted. For an overview of the main findings and conclusions for all experiments, please see Table 15. In subchapter 8.3, conclusions possible drawn when contrasting the three different methods employed in the present work are explained. Last, future perspectives are provided to specify open questions and aspects regarding the development of the processing and interpretation of the studied linguistic structures in children.

Table 15. Overview of main findings and conclusions for all age-groups and experiments of the present work

	3-year-olds	4;6-year-olds	6-year-olds	Adults
Behavioral experiment Performance in correct interpretation of object-initial structures	below chance level	on chance level	on chance level	above chance level, close to perfect
	→sensitivity to word-order cue			*→correct thematic role assignment*
Eye-tracker experiment Fixation durations in the object-initial condition across the course of a trial	on chance level	below chance level	above chance level	above chance level, close to perfect
		→sensitivity to *word-order cue*	*→sensitivity to case-marking cue*	*→correct thematic role assignment*
ERP study I **NP1** Object-initial vs. subject-initial	Early and late positivity	None	Topicalization negativity	Topicalization negativity
NP2 Object-initial vs. subject-initial	Negativity	P600	P600	None
	→sensitivity to the two different structures	*→transition between sensitivity to word-order and case-marking cue*	*→sensitivity to case-marking cue*	*→processing effort at NP1, effortless thematic role assignment*
ERP study II **Double nominative violation**	LAN-P600	LAN-P600	LAN-P600	LAN-P600
	→ Correct argument expectations for subject-initial structures, theta criterion is established in all age-groups			
Double accusative violation	Early positivity	N400	N400-Late negativity	LAN-P600
	→error detection	*→thematic repair strategies*	*→thematic / syntactic repair strategies*	*→correct argument expectations*

8.1 Discussion of Adults' Syntactic Processing

Several studies on language processing in adults show the merely effortless ability to assign thematic roles to unambiguously case-marked arguments in simple transitive main clauses regardless the given word order (Frisch & Schlesewsky, 2005; Frisch et al., 2002; Schlesewsky et al., 1999). However, when it comes to the processing of more complex non-canonical structures, as for instance scrambled German clauses, electrophysiological studies found a LAN (Rösler et al., 1998; Schlesewsky, Bornkessel, et al., 2003) or a scrambling negativity in response to object-initial arguments (Bornkessel & Schlesewsky, 2006b; Bornkessel et al., 2003). It is argued that adults expect a prototypical argument structure, in particular a prototypical word order that leads to a subject-first preference in German speakers (Bornkessel et al., 2002b; Ferreira, 2003). These expectancies cause the LAN or scrambling negativity in non-canonical complex structures. In the neurocognitive model of auditory sentence comprehension, these processes are assigned to phase 2 of language comprehension in which morphosyntactic as well as thematic roles assignment are computed (Friederici, 2002). In a similar manner, the eADM positions the scrambling negativity in phase 2b of the COMPUTE PROMINENCE step in which thematic roles are assigned to the arguments on basis of morphosyntactic information (Bornkessel & Schlesewsky, 2006a).

Confronted with case-marking violations, especially with identically case-marked arguments in a transitive constructions, German adults displayed a biphasic N400-P600 pattern at NP2 processing in ERPs (Frisch & Schlesewsky, 2005). In accordance with the eADM, the N400 is interpreted as signaling problems of thematic hierarchizing as a consequence of the COMPUTE PROMINENCE step that elicits a prominence mismatch based on the previous prominence information by the case marking at NP1. The P600, or named 'late positivity' within the eADM, is a response to the overall well-formedness of the sentence in step 3 of the model. In English (Coulson et al., 1998) and Finnish (Frisch, Schlesewsky, & Wegener, 2005), the same violations elicited a LAN-P600 pattern instead. In the eADM, Bornkessel and Schlesewsky (2006a) assigned the LAN in these studies to a structural mismatch for the language parser in the step of ASSIGN +/- AGRT for the arguments. Since in English, as opposed to German, morphological case carries little meaning, only the position of a nominative at NP2 elicits the mismatch.

In the present adult study, the behavioral results by Knoll (2011) as well as the eye tracker results confirm the effortless and accurate processing of unambiguously case-marked object-initial sentences. Correct identification of the corresponding picture is almost perfect in adults and does not differ between the conditions subject-initial and object-initial sentences. The

same is true for the fixation duration to the matching picture in the two conditions. Moreover, given that gaze shift to the corresponding pictures takes place right after NP1 offset as visible in the trial course eye tracking data for the subject-initial condition as well as the object-initial condition, it is evident that thematic role assignment is accomplished already after computing NP1 in adults and does not undergo any revision processes at NP2. However, the neurophysiological underpinnings of these results reveal an additional effort at NP1 in form of a topicalization negativity for the object-initial condition (see chapter 6.5 for discussion on these results). This indicates a reflection of the often stated subject-first preference in adults (Beim Graben et al., 2000; Friederici & Mecklinger, 1996; Mecklinger et al., 1995). At the subsequent NP2, no additional effort is visible when comparing the ERP responses of object-initial and subject-initial processing. Hence, the processing effort at NP1 for object-initial clauses is due to the subject-first preference in adults and can be accounted to the COMPUTE PROMINENCE step in Phase 2b of the eADM (Bornkessel & Schlesewsky, 2006a) leads to neither any additional processing efforts at NP2 nor to delayed or revisional gaze shifts in the eye tracking experiment. In other words, adults have to revise their assumed default expectation of a prototypical transitive sentence already when encountering the first word, the determiner 'den', which is reflected by a topicalization negativity. As a consequence, the processing of the rest of the sentence is undemanding for the system and additional effort is not even reflected in online gaze measurements.

Surprisingly, the double-nominative violation compared to the subject-initial condition and also the double-accusative violation compared to the object-initial condition in ERP-study II elicited a biphasic LAN-P600 pattern instead of a N400-P600 pattern as in Frisch and Schlesewsky (2005). The P600 is interpreted as a response to the overall syntactic well-formedness of the sentence and as a process positioned in Phase 3 of the eADM. The LAN in the present study is crosslinguistically in line with results from English (Coulson et al., 1998) and Finnish (Frisch et al., 2005) and is located at the step of ASSIGN +/- AGRT in Phase 2b of the eADM. As evident from ERP-study I and the eye tracking experiment on the processing of object-initial sentences, the computation of prominence is already completed at NP1 in the tested stimuli. Hence, syntactic integration of NP1, regardless of an accusative or nominative marked argument, is accomplished already at the point of the verb. Therefore, at NP2 in the present violation paradigm, only the position of the identical case-marked argument induces a mismatch at the step ASSIGN +/- AGRT signalled by a LAN as in English and Finnish (compare for a similar argumentation on the semantic level, Kim & Sikos, 2011). The question remains why this mechanism is not present for similar stimuli, although containing wh-questions instead of declarative main clauses, in the study by Frisch and Schlesewsky (2005).

An important reason can be attributed to the difference in tasks between the two experiments. Frisch and Schlesewsky performed both, an acceptability judgement task as well as an additional probe detection task. The latter sought to make certain that participants not only processed the interrogative words' and definite determiners' inflections but also the lexical words in the sentences. Given that in the present study no task is introduced for the reasons of comparability with the children's studies, it is a likely assumption that adults only process the case marking on the determiner in the presented stimuli without paying attention to the semantics which led to the computing steps surmised above. Additionally in a different semantic violation paradigm, Isel and Shen (2011) demonstrated also the alteration of ERP responses caused by particular task demands (also compare Bornkessel-Schlesewsky & Schlesewsky, 2008; Mueller, Oberecker, & Friederici, 2009).

8.2 Discussion of Children's Syntactic Processing

Chapter 8.2.1 illustrates the developmental picture that becomes evident in the three age groups regarding the interpretation and processing of object-initial structures. The sensitivity to different morphosyntactic cues in the different groups is discussed. Next, in Chapter 8.2.2, the development of repair mechanism for thematic hierarchizing as apparent from the present study is summarized and interpreted. Table 15 illustrates the main findings and conclusions for all age-groups and experiments of the present work.

8.2.1 Processing and Interpreting Object-Initial Sentences

The present study investigates for the first time the neurophysiological underpinnings of processing topicalized object noun phrases by measuring the associated ERPs in children at the age of 3;0, 4;6, and 6;0. In addition, the online comprehension by a looking-while-listening paradigm in the eye tracker is tested as well as the behavioral ability to correctly interpret these sentences by a sentence-picture matching task. Crucially, the cues to sentence understanding in the object-initial structures compete in the tested stimuli as put forward by Bates and MacWhinney (1989). Therefore, these present experiments constitute an excellent tool to disentangle the sensitivity to the word-order cue and the case-marking cue in language development.

From a developmental perspective, in the behavioral study, the ability to correctly interpret subject-initial sentences increased over all three age-groups with 6-year-olds reaching adult-level accuracy. Already 3-year-olds performed above chance in this condition which once more confirms the coalitions-as-prototypes model by Bates and MacWhinney (1987) which

suggests that if all cues for thematic role assignment are available in coalition, this is the easiest interpretational situation for children. Therefore, above-chance outcome could be already found in the youngest age-group in the present study.

Although behavioral performance in the object-initial condition also increases over age, 4;6- and not even 6-year-olds showed above-chance outcome. The 3-year-olds display significant below-chance accuracy in the behavioral task which points towards a subject-first strategy and the usage of the word-order cue also discussed in chapter 7.1.5. At least the tendency to the word-order cue becomes evident in this result even when it is not applied in a consistent manner in the sentence-picture matching task in 3-year-olds as the difference between the subject-initial and object-initial would be even greater in this case. The behavioral results of the 4;6- and 6-year-olds are not as easy to interpret, but will become more comprehensible in the context of the additional measure, eye tracking and ERPs.

The development between 3- and 6-year-olds in the fixation durations to the corresponding picture in the eye-tracker experiment made, to some extent, different processes in online comprehension visible. The 3-year-olds' results, in contrast to the behavioral experiment, stay over the whole course of a trial in both conditions on chance level and do not reveal any tendency to the word-order cue. Children at the age of 4;6 years, however, do display sensitivity to the word-order cue by fixating the corresponding object-initial picture significantly below chance in a 800ms long time window right after NP2 onset and the subject-initial picture significantly above chance right after NP2 offset. Puzzlingly, the consistent gaze shift to the correct picture occurred much later (approximately one second) in the subject-initial than to the incorrect picture in the object-initial condition although the latter is surmised more difficult to interpret than the former. One possible explanation lies in the assumption that the nominative might be more salient to this age-group than the accusative case marking. Hence, children encounter a nominative case-marked determiner at NP2 onset in the object-initial condition and automatically process it faster than the accusative-marked determiner in the subject-initial sentence at NP2.

Further development in fixation durations become evident in 6-year-olds' results who are clearly sensitive to the case-marking cue. Trial course analysis revealed above-chance performance in the subject-initial condition right after NP2 onset and one second after sentence offset in the object-initial condition. Here, it becomes obvious that the pattern of the order of consistent gaze shift of the two conditions dramatically changes between 4;6 and 6;0 years of age which leads towards different interpretational strategies in online comprehension in these two age-groups. While 4;6-year-olds interpret the object-initial sentences on basis of the

determiner at NP2 onset in the majority of cases incorrect, i.e. apply a subject-first strategy and do not pay attention to the case-marking at that point, 6-year-olds are sensitive to the case-marking and interpret the object-initial sentences correctly but still need a significantly longer processing time compared to the subject-initial structures. Interestingly, neither age-group shows increase in correct fixations after NP1, as evident in comparative adult's results. Hence, 6-year-olds have not yet reached adult online comprehension abilities in being sensitive to the case-marking at NP1 to assign thematic roles to the arguments and being already able to fixate the correct corresponding picture at that point of the sentence. Moreover, at NP2, they still differ in their reactions to the two conditions which is not even evident at NP1 in adults.

The development in the ERP patterns in response to the object-initial compared to the subject-initial condition confirms the hypothesis of neurophysiological sensitivity to certain linguistic cues is evidenced earlier than the behavioral competence to interpret these structures. In 3-year-olds, an early and a late positivity are shown for the processing of the object-initial sentences compared to the subject-initial sentences at NP1. According to Silva-Pereyra and colleagues (2005), who found the same pattern, it was previously discussed that this age-group might process the accusative marking as a morphosyntactic violation in sentence initial position. Even more tentatively, the negativity that occurred 400-700ms post NP2 onset might reflect underlying semantic interpretational difficulties as the N400 was often shown at this time window in young children (Friedrich & Friederici, 2005; Silva-Pereyra, Klarman, et al., 2005; Silva-Pereyra, Rivera-Gaxiola, et al., 2005). Speculatively, 3-year-olds might expect an inanimate noun since the prototypical transitive structure sets an inanimate accusative-marked argument at the position of NP2 (Dowty, 1991).

In further development, 4;6-year-olds process both conditions in the same manner at NP1. The absence of any processing differences at sentence initial position suggests a subject-first strategy for the object-initial sentences also shown in the eye-tracking experiment but not in the behavioral experiment. At NP2, however, 4;6-year-olds reflect the processing of the object-initial compared to the subject-initial condition by a weakly pronounced P600 indicating syntactic integration difficulties, and hence, the beginning of the sensitivity to the case-marking cue. The analysis of the ERPs in this age-group suggests high variance in the data (chapter 7.3.2.3). Therefore, additional analyses were conducted and the data was divided into two groups based on a median split according to individual performances in the TROG-D (Fox, 2008). Good performers show a significantly longer-lasting and pronounced P600 at NP2 than poor performers in which a P600 could hardly be proven (see Appendix E). This pattern stresses the impression that children at the age of 4;6 are in a transitory state in cue-sensitivity

for sentence interpretation and, depending on individual language development, a subgroup is already sensitive to the case-marking cue at that age.
Consequently, 6-year-olds' ERPs clearly make the sensitivity to the case-marking cue evident at that age. The same topicalization negativity as in adults occurs at NP1 when processing the object-initial compared to the subject-initial sentences. However, in contrast to adults, additional processing costs appear at NP2 in form of a long-lasting and pronounced P600, which reflects syntactic integration difficulties. These integration difficulties explain very well the delay in the consistent gaze shift to the corresponding object-initial picture in the eye tracker experiment.

Taken together, a developmental continuum in interpretational strategies, sensitivity to and functional use of word order and case-marking information emerges in the present data comparing object-initial and subject-initial sentences in a behavioral paradigm, an eye-tracking paradigm, and an ERP study. First, 3-year-olds merely detect differences between the structures and begin to use a word-order strategy as proposed in the competition model by Bates and MacWhinney (1987, 1989). Children 4;6 years of age are in a transitory state indicated by their starting sensitivity to the case-marking cue for thematic role assignment as identified by Dittmar and colleagues (2008a) in children at the age of 5;0. This observation contradicts the study by Chan and colleagues (2009) who postulate the highest usage of the word-order cue at the age of 4;6. Furthermore, 6-year-olds are sensitive to the case-marking cue (as postulated for 5-year-olds in Lindner, 2003; Schaner-Wolles, 1989) but are still not yet perfect in thematic role assignment. The present ERP results indicate that although they react to object-initial noun phrases in a similar way to adults, unlike adults, they still have problems integrating the second noun phrases for interpretation. The ERP data thus build on the behavioral data from the study by Dittmar et al. (2008a) and also complement the behavioral and eye-tracking data from the present study. The development of cue-sensitivity between 3;0- and 6;0-year-old children found in the present studies substantiates the assumption of Tracy (1986) that the disentangling of word order and case marking occurs as one of the last steps in German children's language acquisition.

8.2.2 Theta Role Assignment and Thematic Hierarchization

The second objective of this current study was to investigate argument expectations and repair mechanisms for thematic hierarchizing on a sentential level in preschool children by employing a violation paradigm to reveal processing strategies related to the existing syntactic-

thematic interpretations of arguments. ERPs of 3-, 4;6- and 6-year-olds were measured when listening to either double-nominative or double-accusative constructions compared to their correct counterparts (i.e. subject-initial or object-initial, respectively).

As previously discussed, adults displayed a biphasic LAN-P600 pattern when processing both, the double-nominative as well as the double-accusative violation. In the double nominative condition compared to the subject-initial structures in the present children's study, all three age groups showed an adult-like response by a negativity-positivity pattern. The positivity is interpreted as a P600 as in adults indicating a response to the overall well-formedness of the sentence, as well as syntactic integration difficulties and the attempt to repair the second nominative already in children at an age of 3 years. The negativity, distributed over frontal brain regions, appears between 500-800ms in 3-year-olds, between 300-600ms in 4;6-year-olds and between 300-400ms in 6-year-olds and was previously interpreted as a LAN in all age-groups. Interestingly, the LAN could be detected for the first time in children as young as 3;0 years. Two other studies testing children around that age found positivities instead of a LAN (Silva-Pereyra, Klarman, et al., 2005; Silva-Pereyra, Rivera-Gaxiola, et al., 2005). For all age-groups tested in the present study, it is thus summarized that correct argument expectancies exist for the SVO order and that the violation at NP2 is reflected by the same neurophysiological, adult-like pattern in all age-groups. The results indicate the Theta Criterion as a basic principle in thematic role assignment is already established by the age of 3 years. Moreover, as in adults and according to the eADM, in the prototypical word order, children as young as 3;0 years might have already completely syntactically integrated the NP1 and consequently at NP2 a LAN occurs indicating a mismatch in the ASSIGN +/- AGRT. step.

While this mechanism was proven for adults in both conditions, double-nominative and also double-accusative, this picture only emerges in children for the double-nominative violation. The processing of the double-accusative violation, in contrast, is reflected by different ERP effects in the different age-groups of preschool children.

The double accusative condition when compared to the object-initial structures makes a clear development visible. In 3-year-olds, an early positivity (100-500ms) occurred; in 4;6-year-olds, a negativity between 900-1300ms is observed. 6-year-olds show two negativities, a negativity between 600-800ms and one between 1000-1700ms in response to the accusative violation compared to the correct transitive construction. These results emphasize, first of all, that for the double accusative violation the processing strategies still vary to a great extent in the development throughout childhood.

Evidently, different interpretational strategies and argument expectancies emerged in all children between the nominative violation and the accusative violation. Schlesewsky and

colleagues (2003) argued that quick and early semantic interpretation might be possible in adults by means of a subject-first processing mechanism. This assertion is applicable in preschool children for the double nominative which children are able to repair already at the age of 3;0. The double accusative cannot be interpreted quickly or nor repaired on basis of the subject-first strategy. Evident is the following development: 3-year-olds process the accusative violation as a morphosyntactic violation as previously discussed (chapter 7.1.5) and display an early positivity as an immature precursor to the LAN. Since 3-year-olds' ERPs show a LAN-like effect for the double nominative condition deducing that the accusative violation causes higher processing difficulties at that age. In subsequent development, 4;6-year-olds start to repair the violation by thematic interpretations as the negativity is interpreted as an N400 (chapter 7.2.5). Furthermore, 6-year-olds reflected the double-accusative violation also by an N400 and thus also indicate thematic integration difficulties. In addition, the late negativity that was also present in 6-year-olds is interpreted as an immature 'sentence closure' processing step (Silva-Pereyra, Rivera-Gaxiola, et al., 2005) (chapter 7.3.5). In parallel to 3-year-olds' ERPs which exhibited an immature LAN in response to the double-accusative violation, 6-year-olds display also a precursor to an ERP component, namely the P600, in the same condition. This equivalence underlines once more the increased processing demands produced by the double-accusative violation in preschoolers (also compare Seidl, Hollich, & Jusczyk, 2003). These results demonstrate that processing differences of double accusative violations still exist at the age of 6;0 between children and adults indicating that the function of the accusative case is not yet fully acquired and argument expectations for OVS structures are not completely established at that age. These findings also deliver converging evidence for the reasoning deducted from the results of the processing of object-initial sentences even 6-year-olds not yet completely syntactically integrated NP1, because otherwise they would show clear argument expectations for the OVS structure. Consequently, the Theta Criterion is only established for the nominative case marking but not for the accusative case-marking in all age-groups.

In contrast to adults (Frisch & Schlesewsky, 2005), the nominative violation seems to be more salient, i.e. more prevalent, for children than the accusative violation, since the detection of the double nominative violation is much easier for them and elicits more mature ERP responses. The detection of the double accusative violation might be hindered by an even stronger subject-first hypothesis in children than in adults. The subject-initial structure seems to be understood as the default or prototype by preschool children as they exhibit great problems to interpret object-initial structures. Moreover, evidence suggests for a majority of SVO

compared to OVS structures in the input (Dittmar et al., 2008a) and for object-initial structures in general (Tabor, Juliano, & Tanenhaus, 1997).

Children might not be able to inhibit or revise their subject-first strategy, and therefore, might be not able to interpret the double accusative on syntactic grounds that is necessary for these interpretational and repair processes. Thus, they encounter an accusative at NP1 and cannot completely inhibit their subject-first strategy. Then in the next step, NP2, marked in the accusative, meets again the subject-first strategy. Consequently, the accusative violation does not stick out at NP2 as much as the double nominative. There is much evidence for the inability of inhibitory control in children correlated with an immature dorsolateral prefrontal cortex (DLPFC). Maturation of the DLPFC correlates with higher performances in numerous tasks (e.g. card sorting tasks, false belief task, go/no-go tasks) that require inhibitory control in children especially between 3-7 years of age, but still proceeds approximately until the age of 20. Hence, the general ongoing maturation of DLPFC in 3- to 7-year-olds (for more evidence, please see Moriguchi & Hiraki, in press) may be a reason for the very specific task to inhibit a subject-first strategy for argument expectancies in German (Diamond, 2002; Moriguchi & Hiraki, in press).

Besides the immature DLPFC in children, there might be more underlying neuroanatomical reasons for 6-year-old children not being completely able to process object-initial sentences or double-accusative violations in an adult-like manner. Evidence found that the dorsal pathway connecting Broca's area and the posterior superior temporal gyrus (pSTG) is not yet fully developed in 7-year-olds (Brauer, Anwander, & Friederici, 2011). The interplay between the left inferior frontal gyrus (IFG) and the left pSTG has been argued to be crucial for syntactic-semantic integration with the IFG being mainly involved in the processing of hierarchical structures and the pSTG in binding the verb and its arguments (Friederici, in press). The dorsal pathway between these two regions runs via the arcuate fasciculus and superior longitudinal fasciculus. According to Brauer and colleagues (2011) this pathway is not completely myelinated in children at the age of 7;0 which could lead to processing difficulties of the tested structures in the present work.

Results on functional connectivity in children's brains complement the picture of the underlying brain development for processing complex syntax. It is known for adults, that the language network shows strong projections between frontal and temporal regions in the left hemisphere (Lohmann et al., 2010). While this intrahemispheric functional network seems a necessary prerequisite for complex linguistic processes, children at the age of 6;0 are found to display a stronger interhemispheric functional connectivity between temporal regions instead (Friederici, Brauer, & Lohmann, 2011).

In sum, converging evidence shows that the neuroanatomical, neurophysiological and functional brain structures of the language system are still in the process of maturation at late preschool age in children which correlates with the behavioral, eye-tracking, and ERP-results on processing non-canonical structures as well as ERP-results on case violations in the present work.

8.3 Methodological Comparison of Developmental Markers: From the Brain to the Eye to Behavior

When contrasting the three different methods employed in the present work, it is obvious that different findings resulted within each age group depending on the methodological approach applied; for an overview, please see Table 16. In the present chapter, these differences will be highlighted. Given that the comparison between processing of the subject-initial and object-initial condition is scrutinized using all three methods (i.e. the behavioral method, the eye tracking method, and the ERP method), conclusions are primarily drawn from these three different experiments rather than from the ERP study investigating the processing of syntactic violations. Crucially, it is discussed which considerations and insights can be deduced from the comparison of the different results for the different methods. Which cognitive processes do the various methods depict; what may be expected from employing a certain method; and what are the advantages and disadvantages of each of them? While the conclusions that can be drawn from the present ERP results in this regard and in comparison to the other two methods are largely obvious, the relation between the behavioral and eye tracking method is more puzzling and especially interesting in light of the current findings.

Table 16. Overview of the different results depending on the methodological approach applied regarding the processing of object-initial sentences

	3-year-olds	4;6-year-olds	6-year-olds	Adults
Behavioral experiment	-	+/-	+/-	+
Eye-tracker experiment	+/-	-	+	+
ERP study I				
NP1	Early/late Pos.	ø	Topic. Neg.	Topic. Neg.
NP2	Neg.	P600	P600	ø

Below chance level (-), on chance level (+/-), or above chance level (+) performance/fixation durations are indicated for the behavioral and eye-tracker experiment concerning the object-initial condition.

For three-year-olds, the behavioral method reveals large differences between the correct interpretation of subject-initial and object-initial structures which are interpreted as exposing a subject-first strategy at that age. In contrast, they performed completely on chance-level in the eye tracker experiment in both conditions. The ERP method, in turn, showed the sensitivity to the topicalized objects in differing ERP waves between the two tested structures.

In 4;6-year-olds, the sentence-picture matching task produced findings on chance level for the object-initial condition, while the eye tracker results demonstrate below-chance outcome for the same condition. The latter, as for three-year-olds in the behavioral paradigm, suggests a sign of the sensitivity to the word-order cue. In contrast, the ERP method illustrated processing differences between the two conditions time-locked to NP2 pointing towards the sensitivity to the case-marking cue.

In six-year-olds, the behavioral method showed also, as in 4;6-year-olds, correct interpretation of the object-initial structures on chance level. On the contrary, the eye tracker results displayed above chance fixation durations for the same condition in six-year-olds, and, most importantly, large time differences between fixations in the two conditions. The correct fixations for the object-initial sentences start much later, namely one second later, than for the subject-initial sentences. Regardless these differences in timing, the eye tracker method revealed the sensitivity to the case-marking cue in six-year-olds. The same is true for the ERP results in that age group.

Adults' behavioral and eye tracking results show close to perfect ability to correctly interpret object-initial sentences and no differences to the subject-initial sentences. The ERPs in response to the former condition in comparison to the latter, however, showed extra processing costs at the sentence onset.

From the brief evaluation of the outcomes of the three methods testing the same structures in each age group, substantial differences between the respective results of these methods become evident that led to different interpretations, in turn. In particular, outcome of the behavioral and eye tracking experiments differ surprisingly within each age group to a large extent. Therefore, the question arises which underlying processes these two methods exactly depict.

For the eye tracking method, *the linking hypothesis* was formulated (cf. Allopenna, Magnuson, & Tanenhaus, 1998; Tanenhaus & Trueswell, 2006). It states for the link between eye movements and linguistic input that the activation by a certain word or proposition determines the probability for attentional and ultimately saccadic shift to fixate the corresponding picture.

Hypothetically, the same probability is true for a sentence-picture matching task. However, not only in the present study but in numerous more, asymmetries between the two methods have been found (Brandt-Kobele & Höhle, 2010; Gertner et al., 2006; Höhle, Berger, Müller, Schmitz, & Weissenborn, 2009; Sekerina, Stromsworld, & Hestvik, 2004). Especially, earlier abilities are observed in eye tracking paradigms than in picture-selection tasks. Brandt-Kobele and Höhle (2010) have put forward two explanatory arguments for this phenomenon. First, general task demands might be higher in picture selection as children have to keep linguistic and visual information in parallel in memory, make a decision and finally have to point to one picture. Preferential looking, in contrast, might mirror more automatic responses that are not as under conscious control as picture selection actions (for an overview, compare Rayner, 1998). The characteristic difference, consists in the former method not requiring a choice of the children.

The second explanation, following Trueswell and Gleitman (2007), suggests that different phases of the interpretational process are depicted by the two different methods. The off-line behavioral method might reflect a later phase than the on-line eye-tracker method. At this later stage, heuristics, guessing and interpretational strategies might come into play whereas the on-line measurement gives a picture of the merely pure structural analysis of a sentence by a participant (Brandt-Kobele & Höhle, 2010).

While the relation between eye tracking and behavioral results are debatable, it is well established that ERP results deliver measurements of the underlying neuronal mechanisms in a highly temporal resolution. In this regard, certain processing abilities can be detected in children before overt behavioral responses become apparent (for an overview, please compare Männel & Friederici, 2008).

In light of these theoretical considerations, the present disparities between the findings of the different methods sketched above are very well explainable. As explicitly formulated for three-year-olds in Brandt-Kobele and Höhle (2010), the distinction between the depiction of different processing stages in eye tracker and picture selection tasks applies also to the present results in three-year-olds. While this age group might not be able to process the structures on-line on pure syntactic grounds as shown in the eye tracker experiment, an interpretational strategy clearly is shown in the behavioral experiment, namely the subject-first strategy. However, the sensitivity to the different syntactic structures found in the ERP-experiment precedes the sensitivity observed in the on-line results of the eye-tracker experiment. Thus, as hypothesized earlier, the ERP method might detect processing differences before the eye tracking method and overt behavioral responses might be shown the latest regarding these

three methods. At least at the age of 3;0, additional interpretational strategies might emerge in the sentence-picture matching task.

In 4;6- and six-year-olds these heuristic strategies were not evident in the behavioral task. However, the general sensitivity of the different methods to different processing stages manifests also in these two age groups. For 4;6-year-olds, ERPs showed already the processing of case-marking while the eye tracking results reveal the sensitivity to the word order information for on-line syntactic interpretation. For six-year-olds, both, ERP and eye tracking findings display the processing of case marking. In addition, the time course of fixation duration to the corresponding object-initial picture shifted to above-chance level one second after sentence offset. Speculatively, these surprisingly long processing time sequences apparent in the gaze shift at the age of six, might account for the chance-level outcome in the object-initial condition of the behavioral method that shadows or shortens these processes by the pressure to point to a picture.

In adults, the eye tracker experiment reveals incremental interpretation already at NP1 in the subject-initial as well as in the object-initial condition as shown before in other eye-tracking experiments (Trueswell, Sekerina, Hill, & Logrip, 1999). Interestingly, the ERPs in this regard display extra processing costs for the object-initial condition in form of a topicalization negativity. The same negativity was present in six-year-olds' ERPs that apparently precedes the ability to use the information at NP1 for incremental interpretation.

In sum, the three different methods each depict different processing phases. While the ERP method makes underlying neuronal mechanisms visible which precede the on-line activation of gaze shifts for fixation in eye-tracker measurements. In overt behavioral responses, in turn, metalinguistic and heuristic strategies might come additionally into play, at least in toddlers.

9 Future Perspectives

Given that the present study focuses largely on the development of morphosyntactic cue-usage and cue-sensitivity for transitive sentence interpretation and processing, further studies are required to clarify the role of other cues in this respect. Semantic aspects for thematic role assignment and thematic hierarchical ordering were not taken into account in the current thesis, although it is known that adults use, for instance, animacy as a cue in this regard (Frisch & Schlesewsky, 2001, 2005; Kuperberg, 2007; Kuperberg et al., 2003; Schlesewsky & Bornkessel, 2004, 2006). Since the prototypical actor is presumed to be animate and the prototypical patient to be inanimate, especially toddlers might rely on the animacy cue or on a coalition of all prototypical cues including animacy information (Bates et al., 1984; MacWhinney et al., 1984). In previous behavioral studies, evidence was found for the main usage of the animacy in children aged between two and three years (Chan et al., 2009; Lindner, 2003). Future studies are necessary to gain more knowledge about the development about this specific cue during language acquisition and, more particularly, the underlying neural mechanisms associated with it. On another semantic note, one shortcoming of the stimuli employed in the present experiments might exist in asymmetries in the prototypicality of the Actors. Supposedly, it is possible that, for example, a beetle might not be considered as prototypical for an Actor as a tiger, because it does not meet the prototypical definition (Primus, 1999) of performing as many physical activities as a tiger. Further studies should clarify if these considerations about general world knowledge play an important role in children's sentence interpretations.

The contextual factors constitute a second aspect of topicalizations previously excluded in the present studies. The noncanonical object-initial structure rarely occurs in isolation but more often in context serving the pragmatic function of focus within the information structure of a text or discourse (Weskott, 2003). For adults, experimental and neurophysiological evidence confirmed that contextual factors facilitate sentence processing and the processing of non-canonical structures (Bornkessel et al., 2003; Haupt et al., 2008; Hendriks, Banga, van Rij, Cannizzarro, & Hoeks, in press; Kaiser & Trueswell, 2004; Traxler & Tooley, 2007). For preschoolers, context might provide an even stronger informational resource for sentence interpretation as they have not yet fully established the grammatical system of their mother tongue. First evidence points towards this direction (Brandt, Kidd, Lieven, & Tomasello, 2009). Moreover, focus information interacts highly with prosody information as, for instance, pitch accent. Recently, the facilitation effect of prosody and context could be shown for adults (Wang, Bastiaansen, Yang, & Hagoort, 2011) as well as for children (Grünloh et al., 2011).

More studies are required to articulate the informative value of prosody and context in syntactic processing during language acquisition.

10 Conclusion

The present thesis aims to provide better understanding of morphosyntactic cue-usage and cue-sensitivity for sentence interpretation and the mechanisms of syntactic repair during language acquisition in preschool children aged three to six years. For the first time, the current studies examine the neural correlates of these processes by means of ERPs and the on-line processing by means of an eye tracker.

The results provide evidence for early sensitivity to noncanonical syntactic structures and the usage of the word-order cue in 3-year-olds. Children 4;6 years of age are in a transitory state between the sensitivity to the word-order cue and the case-marking cue while 6-year-olds employ the case-marking cue systematically, though they are still not yet perfect in thematic role assignment.

The neurophysiology underlying syntactic repair strategies elucidates, furthermore, the function of the nominative and the subject-initial argument structure and the principle that a case only be assigned once in a sentence (Theta Criterion) are already established in 3-year-olds. Repair Strategies for a more complex double-accusative violation shift in three-, 4;6-, and six-year-olds from error detection, to thematic, and subsequently, to syntactic/thematic strategies. The fact that, in this case, adult-like mechanisms of syntactic repair and adequate argument expectancies do still not exist at the age of 6;0 points towards the inability to inhibit a subject-first strategy in preschool children.

References

Akhtar, N., & Tomasello, M. (1997). Young children's productivity with word order and verb morphology. *Developmental Psychology, 33*(6), 952-965.

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition: Evidence for continuous mapping models. *Journal of Memory and Language, 38*, 419-439.

Bader, M., & Meng, M. (1999). Subject-Object ambiguities in German embedded clauses: An across-the-board comparison. *Journal of Psycholinguistic Research, 28*, 121-143.

Bates, E., & MacWhinney, B. (1987). Competition, variation, and language learning. In B. MacWhinney (Ed.), *Mechanisms of language acquisition* (pp. 157-193). Hillsdale, NJ: Lawrence Erlbaum.

Bates, E., & MacWhinney, B. (1989). Functionalism and the competition model. In B. MacWhinney & E. Bates (Eds.), *The cross-linguistic study of sentence processing* (pp. 3-73). New York: Cambridge University Press.

Bates, E., MacWhinney, B., Caselli, C., Devescovi, A., Natale, F., & Venza, V. (1984). A cross-linguistic study of the development of sentence interpretation strategies. *Child Development, 55*, 341-354.

Beim Graben, P., Saddy, J. D., Schlesewsky, M., & Kurths, J. (2000). Symbolic dynamics of event-related brain potentials. *Physical Review E, 62*(4), 5518-5541.

Bornkessel-Schlesewsky, I., Kretzschmar, F., Tune, S., Wang, L., Genc, S., Philipp, M., . . . Schlesewsky, M. (2011). Think globally: Crosslinguistic variation in electrophysiological activity during sentence comprehension. *Brain and Language, 117*, 133-152.

Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2008). An alternative perspective on "semantic P600" effects in language comprehension. *Brain Research Reviews, 59*(1), 55-73.

Bornkessel, I. (2002). *The Argument Dependency Model: A neurocognitive approach to incremental interpretation*. Leipzig: MPI Series in Cognitive Neuroscience.

Bornkessel, I., Fiebach, C. J., & Friederici, A. D. (2004). On the cost of syntactic ambiguity in human language comprehension: An individual differences approach. *Cognitive Brain Research, 21*, 11-21.

Bornkessel, I., McElree, B., Schlesewsky, M., & Friederici, A. D. (2004). Multi-dimensional contributions to garden path strength: Dissociating phrase structure from case marking. *Journal of Memory and Language, 51*, 495-522.

Bornkessel, I., & Schlesewsky, M. (2006a). The extended argument dependency model: A neurocognitive approach to sentence comprehension across languages. *Psychological Review, 113*(4), 787-821.

Bornkessel, I., & Schlesewsky, M. (2006b). The role of contrast in the local licensing of scrambling in German: Evidence from online comprehension. *Journal of Germanic Linguistics, 18*, 1-43.

Bornkessel, I., Schlesewsky, M., & Friederici, A. D. (2002a). Beyond syntax: language-related positivities reflect the revision of hierarchies. *Neuroreport, 13*, 361-364.

Bornkessel, I., Schlesewsky, M., & Friederici, A. D. (2002b). Grammar overrides frequency: evidence from the online processing of flexible word order. *Cognition, 85*, B21-B30.

Bornkessel, I., Schlesewsky, M., & Friederici, A. D. (2003). Contextual information modulates initial processes of syntactic integration: the role of inter- versus intrasentential predictions. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 871-882.

Brandt-Kobele, O. C., & Höhle, B. (2010). What asymmetries within comprehension reveal about asymmetries between comprehension and production: The case of verb inflection in language acquisition. *Lingua, 120*, 1910-1925.

Brandt, S., Kidd, E., Lieven, E., & Tomasello, M. (2009). The discourse bases of relativization: An investigation of young German and English-speaking children's comprehension of relative clauses. *Cognitive Linguistics, 20*(3), 539-570.

Brauer, J., Anwander, A., & Friederici, A. D. (2011). Neuroanatomical prerequisites for language functions in the maturing brain. *Cerebral Cortex, 21*, 459-466.

Bresnan, J., & Kanerva, J. M. (1989). Locative inversion in Chichewa: A case study of factorization in grammar. *Linguistic Inquiry, 20*, 1-50.

Chan, A., Lieven, E., & Tomasello, M. (2009). Children's understanding of the agent-patient relations in the transitive construction: Cross-linguistic comparisons between Cantonese, German, and English. *Cognitive Linguistics, 20*(2), 267-300.

Chomsky, N. (1981). *Lectures on Government & Binding: The Pisa Lectures*. Dordrecht: Foris.

Clahsen, H. (1984). Der Erwerb von Kasusmarkierungen in der deutschen Kindersprache. *Linguistische Berichte, 89*, 1-31.

Clahsen, H. (1986). Verb inflections in German child language. Acquisition of agreement markings and the functions they encode. *Linguistics, 24*, 79-121.

Clark, E. V. (2003). *First language acquisition*. Cambridge, MA: Cambridge University Press.

Clifton, C., Traxler, M. J., Mohamed, M. T., Williams, R. S., Morris, R. K., & Rayner, K. (2003). The use of thematic role information in parsing: Syntactic processing autonomy revisited. *Journal of Memory and Language, 49*(3), 317-334.

Comrie, B. (1989). *Language Universals and Linguistic Typology*. Chicago: University of Chicago.

Coulson, S., King, J. W., & Kutas, M. (1998). Expect the unexpected: Event-related brain response to morphosyntactic violations. *Language and Cognitive Processes, 13*(1), 21-58.

De Vincenzi, M. (1991). *Syntactic parsing strategies in Italian. The minimal chain principle*. (Vol. 12). Dordrecht, NL: Kluwer Academic Publishers.

De Vincenzi, M. (1996). Syntactic analysis in sentence comprehension: effects of dependency types and grammatical constraints. *Journal of Psycholinguistic Research, 25*(1), 117-133.

Deutsch, A., Bentin, S., & Katz, L. (1999). Semantic Influence on Processing Gender Agreement: Evidence from Hebrew. *Journal of Psycholinguistic Research, 28*, 515-535.

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. Stuss & R. Knight (Eds.), *Principles of frontal lobe function* (pp. 466-503). New York: Oxford University Press.

Dittmar, M., Abbot-Smith, K., Lieven, E., & Tomasello, M. (2008a). German children's comprehension of word order and case marking in causative sentences. *Child Development, 79*(4), 1152-1167.

Dittmar, M., Abbot-Smith, K., Lieven, E., & Tomasello, M. (2008b). Young German children's early syntactic competence: a preferential looking study. *Developmental Science, 11*, 575-582.

Dittmar, M., Abbot-Smith, K., Lieven, E., & Tomasello, M. (in press). Children aged 2;1 use transitive syntax to make a semantic-role interpretation in a pointing task. *Journal of Child Language*.

Dowty, D. R. (1991). Thematic Proto-Roles and Argument Selection. *Language, 67*, 547-619.

Dürscheid, C. (2000). *Syntax* (Vol. 3). Wiesbaden: Westdeutscher Verlag.

Eisenberg, P. (1999). *Grundriß der deutschen Grammatik* (Vol. 2. Der Satz). Stuttgart, Weimar: Metzler.

Fanselow, G. (2000). Optimal Exceptions. In B. Stiebels & D. Wunderlich (Eds.), *The Lexicon in Focus* (pp. 173-209). Berlin: Akademie Verlag.

Ferreira, F. (2003). The misinterpretation of noncanonical sentences. *Cognitive Psychology, 47*, 164-203.

Fiebach, C. J., Schlesewsky, M., & Friederici, A. D. (2002). Separating syntactic memory costs and syntactic integration costs during parsing: the processing of German WH-questions. *Journal of Memory and Language, 47*, 250-272.

Foley, W. A., & Van Valin, R. D., Jr. (1984). *Functional syntax and universal grammar*. Cambridge: Cambridge University Press.

Fox, A. V. (2008). *TROG-D. Test zur Überprüfung des Grammatikverständnisses*. Idstein: Schulz-Kirchner Verlag.

Frazier, L. (1987). Syntactic processing: Evidence from Dutch. *Natural Language and Linguistic Theory, 5*, 519-559.

Frenzel, S., Schlesewsky, M., & Bornkessel-Schlesewsky, I. (2010). Conflicts in language processing: A new perspective on the N400–P600 distinction. *Neuropsychologia*.

Friederici, A., & Frisch, S. (2000). Verb Argument Structure Processing: The Role of Verb-Specific and Argument-Specific Information. *Journal of Memory and Language, 43*(3), 476-507.

Friederici, A. D. (1995). The time course of syntactic activation during language processing: A model based on neuropsychological and neurophysiological data. *Brain and Language, 50*, 259-281.

Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *TRENDS in Cognitive Sciences, 6*(2), 78-84.

Friederici, A. D. (2006). The neural basis of sentence processing: Inferior frontal and temporal contributions. In Y. Grodzinsky & K. Amunts (Eds.), *Broca's region* (pp. 196-217). Oxford: Oxford University Press.

Friederici, A. D. (in press). The brain basis of language processing: From structure to function. *Physiological Reviews*.

Friederici, A. D., & Alter, K. (2004). Lateralization of auditory language functions: A dynamic dual pathway model. *Brain and Language, 89*, 267-276.

Friederici, A. D., Brauer, J., & Lohmann, G. (2011). Maturation of the language network: Fron inter- to intrahemispheric connectivities. *PLoS ONE, 6*(6).

Friederici, A. D., Hahne, A., & Mecklinger, A. (1996). Temporal structure of syntactic parsing: Early and late event-related brain potential effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*, 1219-1248.

Friederici, A. D., Hahne, A., & Saddy, D. (2002). Distinct neurophysiological patterns reflecting aspects of syntactic complexity and syntactic repair. *Journal of Psycholinguistic Research, 31*, 45-63.

Friederici, A. D., & Kotz, S. A. (2003). The brain basis of syntactic processes: functional imaging and lesion studies. *Neuroimage, 20*, S8-S17.

Friederici, A. D., & Mecklinger, A. (1996). Syntactic parsing as revealed by brain responses: First-pass and second-pass parsing processes. *Journal of Psycholinguistic Research, 25*, 157-176.

Friederici, A. D., & Oberecker, R. (2008). The development of syntactic brain correlates during the first years of life. In A. D. Friederici & G. Thierry (Eds.), *Early Language Development* (pp. 215-231). Amsterdam: John Benjamins.

Friederici, A. D., Pfeifer, E., & Hahne, A. (1993). Event-related potentials during natural speech processing - effects of semantic, morphological and syntactic violations. *Cognitive Brain Research, 1*, 183-192.

Friederici, A. D., & Weissenborn, J. (2007). Mapping sentence form onto meaning: The syntax–semantic interface. *Brain Research, 1146*, 50-58.

Friedrich, M., & Friederici, A. D. (2005). Semantic sentence processing reflected in the event-related potentials of one- and two year-old children. *Neuroreport, 16*, 1801-1804.

Frisch, S., Hahne, A., & Friederici, A. D. (2004). Word category and verb-argument structure information in the dynamics of parsing. *Cognition, 91*, 191-219.

Frisch, S., & Schlesewsky, M. (2001). The N400 indicates problems of thematic hierarchising. *Neuroreport, 12*, 3391-3394.

Frisch, S., & Schlesewsky, M. (2005). The resolution of case conflicts from a neurophysiological perspective. *Cognitive Brain Research, 25*(2), 484-498.

Frisch, S., Schlesewsky, M., Saddy, D., & Alpermann, A. (2002). The P600 as an indicator of syntactic ambiguity. *Cognition, 85*(3), B83-92.

Frisch, S., Schlesewsky, M., & Wegener, H. (2005). The interaction of morphological case and word order constraints: Cross-linguistic ERP evidence from German, Russian and Finnish. *Journal of Cognitive Neuroscience, (Supplement) 26*.

Gertner, Y., Fisher, C., & Eisengart, J. (2006). Learning words and rules. Abstract knowledge of word order in early sentence comprehension. *Psychological Science, 17*, 684-691.

Givón, T. (1984). *Syntax: A functional-typological introduction*. Amsterdam: John Benjamins.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*, 95-112.

Grimshaw, J. (1990). *Argument structure*. Cambridge, MA: MIT Press.

Grünloh, T., Lieven, E., & Tomasello, M. (2011). German children use prosody to identify participant roles in transitive sentences. *Cognitive Linguistics, 22*, 393-419.

Gunter, T. C., Friederici, A. D., & Schriefers, H. (2000). Syntactic Gender and Semantic Expectancy: ERPs Reveal Early Autonomy and Late Interaction. *Journal of Cognitive Neuroscience, 12*, 556-568.

Gunter, T. C., Stowe, L. A., & Mulder, G. (1997). When syntax meets semantics. *Psychophysiology, 34*, 660-676.

Haegemann, L. (1994). *Introduction to Government and Binding Theory*. Oxford: Blackwell.

Hagoort, P., Brown, C., & Groothusen, J. (1993). The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes, 8*, 439-483.

Hahne, A., Eckstein, K., & Friederici, A. D. (2004). Brain signatures of syntactic and semantic processes during children's language development. *Journal of Cognitive Neuroscience, 16*(7), 1302-1328.

Hahne, A., & Friederici, A. D. (1999). Electrophysiological evidence for two steps in syntactic analysis. Early automatic and late controlled processes. *Journal of Cognitive Neuroscience, 11*, 194-205.

Hahne, A., & Friederici, A. D. (2002). Differential task effects on semantic and syntactic processes as revealed by ERPs. *Cognitive Brain Research, 13*, 339-356.

Hanne, S., Sekerina, I., Vasishth, S., Burchert, F., & de Bleser, R. (2009). Online Satzverarbeitung kanonischer und nicht-kanonischer Sätze bei Agrammatismus - eine Blickbewegungsstudie. In J. Heide, S. Hanne, O.-C. Brandt, T. Fritzsche & M. Wahl (Eds.), *Spektrum Patholinguistik 2. Ein Kopf - zwei Sprachen. Mehrsprachigkeit in Forschung und Therapie* (pp. 161-170). Potsdam: Universitätsverlag Potsdam.

Haupt, F., Schlesewsky, M., Roehm, D., Friederici, A. D., & Bornkessel, I. (2008). The status of subject-object reanalyses in the language comprehension architecture. *Journal of Memory and Language, 59*, 54-96.

Hemforth, B. (1993). *Kognitives Parsing: Repräsentation und Verarbeitung grammatischen Wissens*. Sankt Augustin: Infix Verlag.

Hendriks, P., Banga, A., van Rij, J., Cannizzarro, G., & Hoeks, J. (in press). Adults' on-line comprehension of object pronouns in discourse. In A. Grimm, A. Müller, C. Hamann & E. Ruigendijk (Eds.), *Production-comprehension asymmetries in child language*. Berlin: De Gruyter.

Hoeks, J. C., Stowe, L. A., & Doedens, G. (2004). Seeing words in context: the interaction of lexical and sentence level information during reading. *Cognitive Brain Research, 19*, 59-73.

Höhle, B., Berger, F., Müller, A., Schmitz, M., & Weissenborn, J. (2009). Focus particles in children's language. Production and comprehension of auch 'also' in German learners from 1 year to 4 years of age. *Language Acquisition, 16*, 36-66.

Holcomb, P. J. (1993). Semantic priming and stimulus degradation: Implication for the role of the N400 in language processing. *Psychophysiology, 30*, 47-61.

Holcomb, P. J., Coffey, S. A., & Neville, H. J. (1992). Visual and auditory sentence processing: A developmental analysis using event-related brain potentials. *Developmental Neuropsychology, 8*, 203-241.

Holcomb, P. J., & Neville, H. J. (1990). Auditory and visual semantic priming in lexical decision: A comparison using event-related brain potentials. *Language and Cognitive Processes, 5*, 281-312.

Hopper, P. J., & Thompson, S. A. (1980). Transitivity in Grammar and Discourse. *Language, 56*, 251-299.

Hyönä, J., & Hujanen, H. (1997). Effects of Case Marking and Word Order on Sentence Parsing in Finnish: An Eye Fixation Analysis. *The Quarterly Journal of Experimental Psychology, 50A*(4), 841-858.

Isel, F., & Shen, W. (2011). Modulation of semantic integration as a function of syntactic expectations: event-related brain potential evidence. *Neuroreport, 22*, 195-199.

Jackendoff, R. S. (1972). *Semantic interpretation in generative grammar*. Cambridge, MA: MIT Press.

Kaan, E. (1996). *Processing subject-object-ambiguities in Dutch* (Vol. 20). Rijksuniversiteit Groningen: Groningen Dissertations in Linguistics.

Kaan, E. (1998). Sensitivity to NP-type: Processing subject-object-ambiguities in Dutch. *Journal of Semantics, 15*, 335-354.

Kaan, E., Harris, A., Gibson, E., & Holcomb, P. J. (2000). The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes, 15*, 159-201.

Kaiser, E., & Trueswell, J. C. (2004). The role of discourse context in the processing of a flexible word-order language. *Cognition, 94*, 113-147.

Keenan, E. (1976). Towards a Universal Definition of "Subject". In C. N. Li (Ed.), *Subject and Topic* (pp. 303-333). New York: Academic Press.

Kibrik, A. E. (1985). Toward a Typology of Ergativity. In J. Nichols & A. Woodbury (Eds.), *Grammar Inside and Outside the Clause* (pp. 268-323). Cambridge: Cambridge University Press.

Kim, A., & Osterhout, L. (2005). The independence of combinatory semantic processing: Evidence from event-related potentials. *Journal of Memory and Language, 52*, 205-225.

Kim, A., & Sikos, L. (2011). Conflict and surrender during sentence processing: An ERP study of syntax-semantics interaction. *Brain and Language, 118*, 15-22.

Klann-Delius, G. (1999). *Spracherwerb*. Stuttgart, Weimar: Metzler.

Kluender, R., & Kutas, M. (1993). Bridging the gap: Evidence from ERPs on the processing of unbounded dependencies. *Journal of Cognitive Neuroscience, 2*, 196-214.

Knoll, L., Brauer, J., & Friederici, A. D. (2011). *Die Verarbeitung von Kasusinformationen beim Erstspracherwerb*. Paper presented at the 53rd Annual German Experimental Psychology Meeting (TeaP), Halle.

Knoll, L. J., Obleser, J., Schipke, C. S., Friederici, A. D., & Brauer, J. (in press). Left prefrontal cortex activation during sentence comprehension covaries with grammatical knowledge in children. *NeuroImage*.

Kolk, H. H. J., Chwilla, D. J., van Herten, M., & Oor, P. J. (2003). Structure and limited capacity in verbal working memory: a study with event-related potentials. *Brain and Language, 85*, 1-36.

Kos, M., Vosse, T., van den Brink, D., & Hagoort, P. (2010). About edible restaurants: conflicts between syntax an semantics as revealed by ERPs. *Frontiers in Psychology, 1*, 1-11.

Krott, A., Baayen, R. H., & Hagoort, P. (2006). The Nature of Anterior Negativities Caused by Misapplication of Morphological Rules. *Journal of Cognitive Neuroscience, 18*, 1616-1630.

Kuperberg, G., Kreher, D., Sitnikova, T., Caplan, D., & Holcomb, P. (2007). The role of animacy and thematic relationships in processing active English sentences: Evidence from event-related potentials. *Brain and Language, 100*(3), 223-237.

Kuperberg, G. R. (2007). Neural mechanisms of language comprehension: Challenges to syntax. *Brain Research, 1146*, 23-49.

Kuperberg, G. R., Caplan, D., Sitnikova, T., Eddy, M., & Holcomb, P. J. (2006). Neural correlates of processing syntactic, semantic, and thematic relationships in sentences. *Language and Cognitive Processes, 21*, 489-530.

Kuperberg, G. R., Sitnikova, T., Caplan, D., & Holcomb, P. J. (2003). Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Cognitive Brain Research, 17*, 117-129.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207*, 203-205.

Kutas, M., & Hillyard, S. A. (1983). Event-related brain potentials to grammatical errors and semantic anomalies. *Memory and Cognition, 11*, 539-500.

Langacker, R. (1991). *Foundations of Cognitive Grammar*. (Vol. 2). Stanford: Stanford University Press.

Lau, E., Stroud, C., Plesch, S., & Phillips, C. (2006). The role of structural prediction in rapid syntactic analysis. *Brain and Language, 98*, 74-88.

Leuckefeld, K. (2005). *The Development of Argument Processing Mechanisms in German: An Electrophysiological Investigation with School-Aged Children and Adults*. Leipzig: MPI Series in Cognitive Neuroscience.

Lindner, K. (2003). The development of sentence-interpretation strategies in monolingual German-learning children with and without specific language impairment. *Linguistics, 41*, 213-254.

Lohmann, G., Hoehl, S., Brauer, J., Danielmeier, C., Bornkessel-Schlesewsky, I., Bahlmann, J., . . . Friederici, A. D. (2010). Setting the frame: The human brain activates a basic low-frequency network for language processing. *Cerebral Cortex, 20*, 1286-1292.

Lück, M., Hahne, A., & Clahsen, H. (2001). *How the processing of German plural nouns develops - auditory ERP studies with adults and children*. Paper presented at the AMLAP.

Lühr, R. (2000). *Neuhochdeutsch: eine Einführung in die Sprachwissenschaft*. München: Fink.

MacWhinney, B., Bates, E., & Kliegl, R. (1984). Cue validity and sentence interpretation in English, German, and Italian. *Journal of Verbal Learning and Behavior, 23*, 127-150.

MacWhinney, B., Leinbach, J., Taraban, R., & McDonald, J. (1989). Language learning: Cues or rules? *Journal of Memory and Language, 28*, 255-277.

Mahlstedt, A. (2008). *The Acquisition of Case marking Information as a Cue to Argument Interpretation in German: An Electrophysiological Investigation with Pre-school Children*. Leipzig: MPI Series in Cognitive Neuroscience.

Männel, C., & Friederici, A. D. (2008). Event-related brain potentials as a window to children's language processing: From syllables to sentences. In I. A. Sekerina, E. M. Fernandez & H. Clahsen (Eds.), *Developmental psycholinguistics: On-line methods in children's language processing* (pp. 29-72). Amsterdam: John Benjamins Publishing Company.

Matzke, M., Mai, H., Nager, W., Rüsseler, J., & Münte, T. (2002). The costs of freedom: an ERP-study of non-canonical sentences. *Clinical Neurophysiology, 113*, 844-852.

Mecklinger, A., Schriefers, H., Steinhauer, K., & Friederici, A. D. (1995). Processing relative clauses varying on syntactic and semantic dimensions: an analysis with event-related potentials. *Memory and Cognition, 23*(4), 477-494.

Mills, A. S. (1977). *First and second language acquisition in German. A parallel study*. Ludwigsburg, Germany: Ludwigsburg Studies in Language and Linguistics.

Mills, D. L., & Sheehan, E. A. (2007). Experience and developmental changes in the organization of language-related brain activity. In D. Coch, K. W. Fischer & G. Dawson (Eds.), *Human behavior, learning, and the developing brain. Typical development*. (pp. 183-218). New York: The Guiolford Press.

Moriguchi, Y., & Hiraki, K. (in press). Longitudinal development of prefrontal function during early childhood. *Developmental Cognitive Neuroscience*.

Mueller, J. L., Hirotani, M., & Friederici, A. D. (2007). ERP evidence for different strategies in the processing of case markers in native speakers and non-native learners. *BMC Neuroscience, 8*(1), 18.

Mueller, J. L., Oberecker, R., & Friederici, A. D. (2009). Syntactic learning by mere exposure - An ERP study in adult learners. *BMC Neuroscience, 10*(89).

Neville, H. J., Nicol, J., Brass, A., Forster, K. I., & Garrett, M. F. (1991). Syntactically based sentence processing classes: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience, 3*, 151-165.

Noble, C. H., Rowland, C. F., & Pine, J. M. (2011). Comprehension of argument structure and semantic roles: Evidence from English-Learning children and the forced-choice pointing paradigm. *Cognitive Science, 35*, 963-982.

O'Rourke, P. L., & Van Petten, C. (2011). Morphological agreement at a distance: Dissociation between early and late components of the event-related brain potential. *Brain Research, 1392*, 62-79.

Oberecker, R., & Friederici, A. D. (2006). Syntactic event-related potential components in 24-month-olds' sentence comprehension. *Neuroreport, 17*(10), 1017-1021.

Oberecker, R., Friedrich, M., & Friederici, A. D. (2005). Neural Correlates of Syntactic Processing in Two-Year-Olds. *Journal of Cognitive Neuroscience, 17*(10), 1667-1678.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9*, 97-113.

Osterhout, L., & Holcomb, P. J. (1992). Event-related potentials and syntactic anomaly. *Journal of Memory and Language, 31*, 785-804.

Osterhout, L., & Holcomb, P. J. (1993). Event-related potentials and syntactic anomaly: Evidence of anomaly detection during the perception of continuous speech. *Language and Cognitive Processes, 8*, 413-437.

Osterhout, L., Holcomb, P. J., & Swinney, D. (1994). Brain potentials elicited by gardenpath sentences: Evidence of the application of verb information during parsing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*, 786-803.

Osterhout, L., & Mobley, L. A. (1995). Event-Related Brain Potentials Elicited by Failure to Agree. *Journal of Memory and Language, 34*, 739-773.

Osterhout, L., & Nicol, J. (1999). On the distinctiveness, independence, and time course of the brain responses to syntactic and semantic anomalies. *Language and Cognitive Processes, 14*(3), 283-317.

Primus, B. (1999). *Cases and Thematic Roles*. Tübingen: Niemeyer.

Rayner, K. (1998). Eye Movements in Reading and Information Processing. *Psychological Bulletin, 124*, 372-422.

Regan, D. (1989). *Human brain electrophysiology: Evoked potentials and evoked magnetic fields in science and medicine*. . New York: Elsevier.

Reis, M. (1982). Zum Subjektbegriff im Deutschen. In W. Abraham (Ed.), *Satzglieder im Deutschen. Vorschläge zu ihrer syntaktischen, semantischen und pragmatischen Fundierung*. (pp. 171-211). Tübingen: Narr.

Rietveld, A. C. M., & Gussenhoven, C. (1985). On the relation between pitch excursion size and prominence. *Journal of phonetics, 13*, 299-308.

Röder, B., Schicke, T., Stock, O., Heberer, G., Neville, H. J., & Rösler, F. (2000). Word order effects in German sentences and german pseudo-word sentences. *Zeitschrift für Sprache und Kognition, 19*, 31-37.

Roehm, D., Bornkessel, I., Haider, H., & Schlesewsky, M. (2005). When case meets agreement: event-related potential effects for morphology-based conflict resolution in human language comprehension. *Neuroreport, 16*(8), 875-878.

Rösler, F., Friederici, A. D., Pütz, P., & Hahne, A. (1993). Event-related brain potentials while encountering semantic and syntactic violations. *Journal of Cognitive Neuroscience, 5*, 345-362.

Rösler, F., Pechmann, T., Streb, J., Röder, B., & Hennighausen, E. (1998). Parsing of sentences in a language with varying word order: Word-by-word variations of processing demands are revealed by event-related brain potentials. *Journal of Memory and Language, 38*, 150-176.

Rugg, M. D., & Coles, M. G. H. (Eds.). (1996). *Electrophysiology of mind. Event-related brain potentials and cognition*. Oxford: Oxford University Press.

Schaner-Wolles, C. (1989). Strategies in acquiring grammatical relations in German: word order or case marking? *Folia Linguistica, 23*, 131-156.

Scheepers, C., Hemforth, B., & Konieczny, L. (2000). Linking Syntactic Functions with Thematic Roles: Psych-Verbs and the Resolution of Subject-Object Ambiguity. In B. Hemforth & L. Konieczny (Eds.), *German Sentence Processing* (pp. 95-135). Dordrecht: Kluwer Academic Publishers.

Schipke, C. S., Friederici, A. D., & Oberecker, R. (2011). Brain responses to case-marking violations in German preschool children. *Neuroreport, 22*, 850-854.

Schipke, C. S., Knoll, L. J., Friederici, A. D., & Oberecker, R. (in press). Preschool children's interpretation of object-initial sentences: Neural correlates of their behavioral performance. *Developmental Science*.

Schlesewsky, M., & Bornkessel, I. (2004). On incremental interpretation: degrees of meaning accessed during sentence comprehension. *Lingua, 114*, 1213-1234.

Schlesewsky, M., & Bornkessel, I. (2006). Context-sensitive neural responses to conflict resolution: Electrophysiological evidence from subject-object ambiguities in language comprehension. *Brain Research, 1098*, 139-152.

Schlesewsky, M., Bornkessel, I., & Frisch, S. (2003). The neurophysiological basis of word order variations in German. *Brain and Language, 86*(1), 116-128.

Schlesewsky, M., Fanselow, G., & Frisch, S. (Eds.). (2003). *Case as a trigger for reanalysis - Some arguments from the processing of double case ungrammaticalities in German* (Vol. 21). Potsdam: Univ.-Bibliothek.

Schlesewsky, M., Fanselow, G., Kliegl, R., & Krems, J. (1999). Preferences for grammatical functions in the processing of locally ambiguous wh-questions in German. In B. Hemforth & L. Konieczny (Eds.), *Cognitive Parsing in German*. Dordrecht: Kluwer.

Seidl, A., Hollich, G., & Jusczyk, P. W. (2003). Early Understanding of Subject and Object Wh-Questions. *Infancy, 4*, 423-436.

Sekerina, I. A., Stromsworld, K., & Hestvik, A. (2004). How do adults and children process referentially ambiguous pronouns. *Journal of Child Language, 31*, 123-152.

Silva-Pereyra, J., Klarman, C. L., Lin, L. J., & Kuhl, P. K. (2005). Sentence processing in 30-month-old children: an event-related potential study. *Neuroreport, 16*(6), 645-648.

Silva-Pereyra, J., Rivera-Gaxiola, M., & Kuhl, P. K. (2005). An event-related brain potential study of sentence comprehension in preschoolers: semantic and morphosyntactic processing. *Cognitive Brain Research, 23*(2-3), 247-258.

Siwierska, A. (1988). *Word Order Rules*. London: Croom Helm.

Slobin, D., & Bever, T. (1982). Children use canonical sentence schemas: A crosslinguistic study of word order and inflections. *Cognition, 12*, 229-265.

Stern, C., & Stern, W. (1928). *Die Kindersprache*. *(Repographic reprint)*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Szagun, G. (2004). Learning by ear: on the acquisition of case and gender marking by German-speaking children with normal hearing and with cochlear implants. *Journal of Child Language, 31*, 1-30.

Szagun, G. (2006). *Sprachentwicklung beim Kind*. Basel: Beltz.

t'Hart, J., Collier, R., & Cohen, A. (1990). *A perceptual study of intonation*. Cambridge: Cambridge University Press.

Tabor, W., Juliano, C., & Tanenhaus, M. (1997). Parsin in a dynamical system: An attractor-based account of the interaction of lexical and structural constraints in sentence processing. *Language and Cognitive Processes, 4*, 139-175.

Tanenhaus, M. K., & Trueswell, J. C. (2006). Eye movements and spoken language comprehension. In M. J. Traxler & M. Gernsbacher (Eds.), *Handbook of Psycholinguistics: second edition* (pp. 863-900). New York: Academic Press, Elesevier.

Tomasello, M. (2005). Beyond formalities: The case of language acquisition. *The Linguistic Review, 22*, 183-197.

Tracy, R. (1986). The acquisition of case morphology in German. *Linguistics, 24*, 47-78.

Traxler, M. J., & Tooley, K. M. (2007). Lexical mediation and context effects in sentence processing. *Brain Research, 1146*, 59-74.

Trueswell, J. C., & Gleitman, L. (2007). Learning to parse and its implications for language acquisition. In G. Gaskell (Ed.), *Oxford Handbook of Psycholinguistics* (pp. 635-656). Oxford: Oxford University Press.

Trueswell, J. C., Sekerina, I., Hill, N. M., & Logrip, M. L. (1999). The kindergarten-path effect: studying on-line sentence processing in young children. *Cognition, 73*, 89-134.

Van Valin, R. D., Jr. (1999). Generalized semantic roles and the syntax-semantics interface. In f. Corbin, C. Dobrovie-Sorin & J.-M. Marandin (Eds.), *Empirical issues in formal syntax and semantics* (pp. 373-389). The Hague: Thesus.

Van Valin, R. D., Jr., & La Polla, R. J. (1997). *Syntax*. Cambridge: Cambridge University Press.

Wang, L., Bastiaansen, M., Yang, Y., & Hagoort, P. (2011). The influence of information structure on the depth of semantic processing: How focus and pitch accent determine the size of the N400 effect. *Neuropsychologia, 49*, 813-820.

Wartenburger, I., Heekeren, H. R., Burchert, F., De Bleser, R., & Villringer, A. (2003). Grammaticality judgments on sentences with and without movement of phrasal constituents - an event-related fMRI study. *2003, 16*, 301-314.

Wartenburger, I., Heekeren, H. R., Burchert, F., Heinemann, S., De Bleser, R., & Villringer, A. (2004). Neural Correlates of Syntactic Transformations. *Human Brain Mapping, 22*, 72-81.

Wartenburger, I., Steinbrink, J., Telkemeyer, S., Friedrich, M., Friederici, A., & Obrig, H. (2007). The processing of prosody: Evidence of interhemispheric specialization at the age of four. *Neuroimage, 34*, 416-425.

Watermeyer, M. (2010). *Ausagieren von Sätzen versus Satz-Bild-Zuordnung. Vergleich zweier Methoden zur Untersuchung des Sprachverständnisses anhand von semantisch reversiblen Sätzen mit Objektvoranstellung bei drei- und fünfjährigen Kindern*. Potsdam: Diploma thesis.

Weskott, T. (2003). *Information structure as a processing guide: The left periphery of German verb-second sentences and its interpretation in context*. Leipzig: University of Leipzig.

Wunderlich, D. (1997). Cause and the Structure of Verbs. *Linguistic Inquiry, 28*, 27-68.

Zawiszewski, A., & Friederici, A. D. (2009). Processing canonical and non-canonical sentences in Basque: The case of object–verb agreement as revealed by event-related brain potentials. *Brain Research, 1284*, 161-179.

Zhang, Y., Jiang, X., Saalbach, H., & Zhou, X. (2011). Multiple constraints on semantic integration in a hierarchical structure: ERP evidence from German. *Brain Research, 1410*, 89-100.

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Appendices

a) Pretest of the stimulus material

Introduction

In order to create the stimulus material of the behavioral experiment, clearness and non-ambiguity of the pictures for children in the relevant age-groups had to be assured. For this purpose, a material pretest was conducted.

Method

Participants. 10 3-year-olds, 10 4;6-year-olds, and 10 6-year-olds were tested. The age-range was kept within +/- 2 months. Of these 30 participants (14 female), 3 had to be excluded due to fuzziness or because they did not finish the test, as a consequence 27 (13 female) children entered the final sample. All children were normally developed and monolingual German.

Material. 6 picture cards illustrating the different animals were created: Igel (hedgehog), Hund (dog), Tiger (tiger), Vogel (bird), Käfer (beetle), Frosch (frog). In addition, 20 picture cards showing these animals in 10 different interactions with other animals were generated so that each verb tested was displayed twice to the participants. The 10 verbs and their corresponding visual realization that were evaluated: ziehen (to pull), küssen (to kiss), waschen (to wash), malen (to paint), tragen (to carry), kämmen (to comb), schieben (to push), schlagen (to hit), fangen (to catch), and treten (to kick).

Procedure. The experimenter presented the 6 animal cards, one at a time, to the child and asked it to name the animal. Answers were noted down. If the response did not match the intended animal, the experimenter asked the child: "Could you also say "X" (e.g. "tiger") for this picture?" The yes/no answer of the child was also marked on a test sheet. Similarly, the verb cards were evaluated. Here, the children's task was to name the action the two animals engaged in. If the chosen verb for the description did not match the intended one, in turn, a second inquiry was posed.

Analysis. Every test item (animals and verbs) for every child was coded according to the respective answer (intended description, "yes" in second inquiry, "no" in second inquiry). In a second step, intended description as well as a "yes"-answer in the second inquiry were subsumed under the code 2 and the "no"-answer was coded by 1. Averages across all children of every item were calculated and converted into percentages.

Results

Concerning the pictures depicting the animals, all of them were clearly identified in at least 90 % of all children (see Table 17).

Table 17. Percentages of unambiguous identifications of the pictures visualizing the six animals in the pretest.

	Clear identification of the picture in percentage (N=27)	Standard error in percentage
Igel (hedgehog)	98.15 %	1.85 %
Vogel (bird)	100.00 %	0.00 %
Tiger (tiger)	98.15 %	1.85 %
Hund (dog)	90.71 %	3.81 %
Käfer (beatle)	100.00 %	0.00 %
Frosch (frog)	98.15 %	1.85 %

As a consequence, all animals were included in the final test material while the picture of the dog was slightly modified.

Regarding the clearness of the 10 different depicted actions that the animals engaged in, all verbs but one were unambiguously identified in at least 90 % of all children (see Table 18).

Table 18. Percentages of unambiguous identifications of the pictures visualizing the ten verbs in the pretest.

	Clear identification of the picture in percentage (N=27)	Standard error in percentage
schlagen (to hit)	81.48 %	3.32 %
küssen (to kiss)	92.59 %	2.44 %
waschen (to wash)	91.66 %	2.56 %
malen (to paint)	100.00 %	0.00 %
schieben (to push)	90.74 %	2.67 %
tragen (to carry)	99.07 %	0.93 %
kämmen (to comb)	100.00 %	0.00 %
ziehen (to pull)	95.37 %	1.99 %
fangen (to catch)	91.66 %	2.56 %
treten (to kick)	91.66 %	2.56 %

According to the results, the six clearest pictures illustrating 6 different verbs were chosen for the final behavioral test material (malen (to paint), kämmen (to comb), tragen (to carry), ziehen (to pull), küssen (to kiss), and waschen (to wash)), while the picture of the action “to wash” was slightly modified in agreement with comments of the tested children.

b) Stimulus material

List of the behavioral and eye-tracking test sentences

01a Der Käfer trägt den Frosch.

01b Den Frosch trägt der Käfer.

01c Der Frosch trägt den Käfer.

01d Den Käfer trägt der Frosch.

02a Der Vogel kämmt den Hund.

02b Den Hund kämmt der Vogel.

02c Der Hund kämmt den Vogel.

02d Den Vogel kämmt der Hund.

03a Der Tiger zieht den Igel.

03b Den Igel zieht der Tiger.

03c Der Igel zieht den Tiger.

03d Den Tiger zieht der Igel.

04a Der Tiger küsst den Frosch.

04b Den Frosch küsst der Tiger.

04c Der Frosch küsst den Tiger.

04d Den Tiger küsst der Frosch.

.

05a Der Käfer wäscht den Hund.

05b Den Hund wäscht der Käfer.

05c Der Hund wäscht den Käfer.

05d Den Käfer wäscht der Hund.

06a Der Igel malt den Vogel.

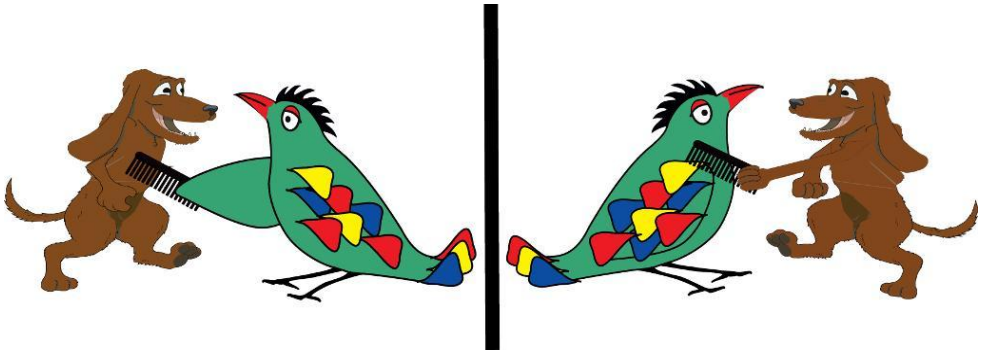
06b Den Vogel malt der Igel.

06c Der Vogel malt den Igel.

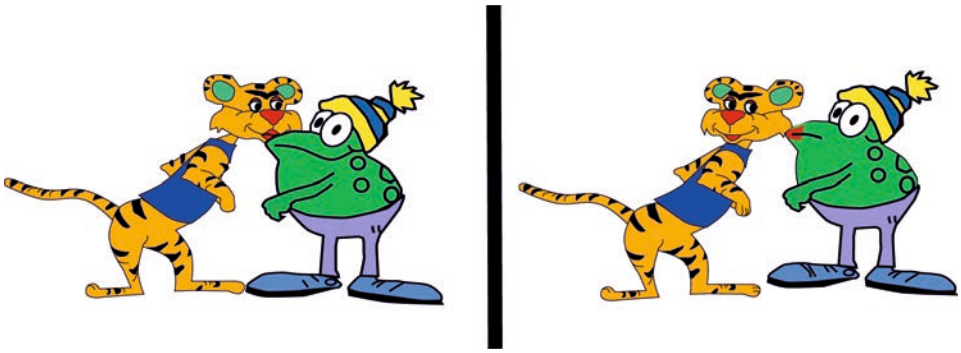
06d Den Igel malt der Vogel.

Picture examples for every depicted action in the behavioral and eye-tracking experiments as shown on the picture cards

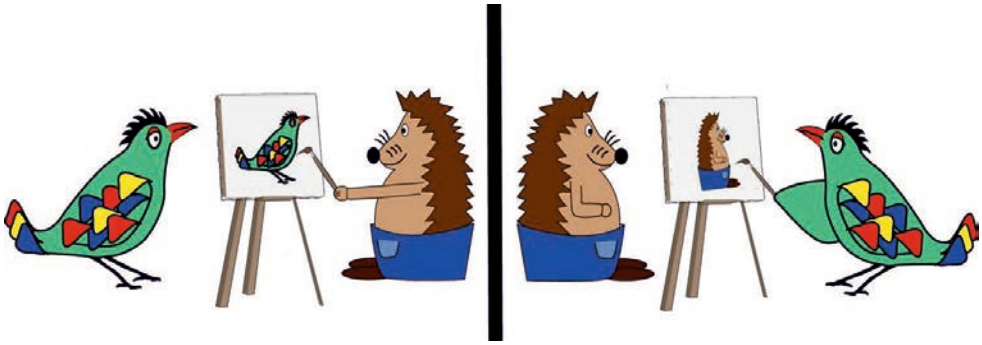
Kämmen – to comb



Küssen - to kiss

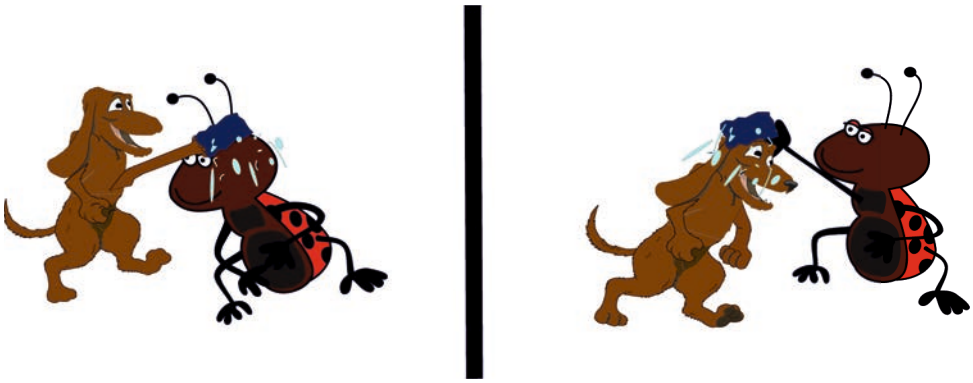


Malen - to paint

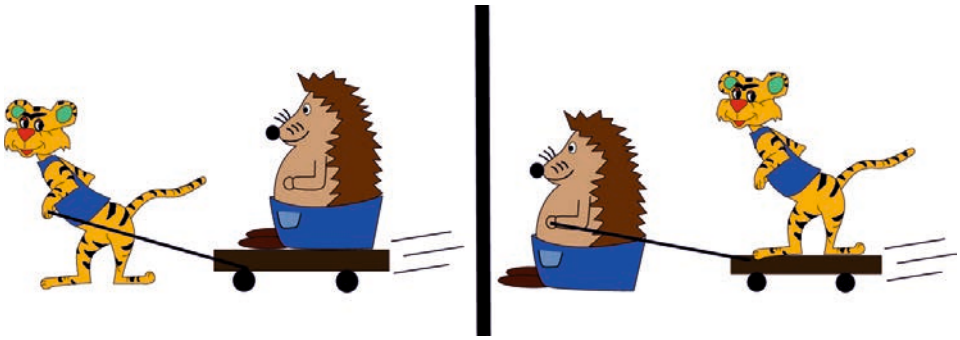


Tragen - to carry

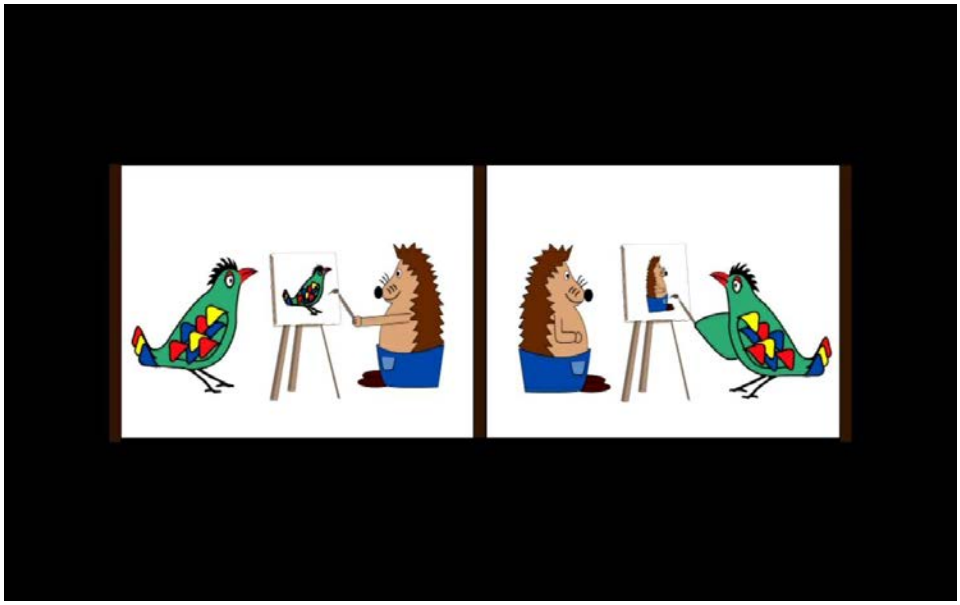
Waschen - to wash



Ziehen - to pull



Screenshot, picture example as shown on the screen in the eye-tracking experiment



List of the ERP test sentences

01a Der Käfer trägt den Frosch.

02a Der Frosch trägt den Käfer.

03a Der Vogel kämmt den Hund.

04a Der Hund kämmt den Vogel.

05a Der Tiger zieht den Igel.

06a Der Igel zieht den Tiger.

07a Der Tiger küsst den Frosch.

08a Der Frosch küsst den Tiger.

09a Der Käfer wäscht den Hund.

10a Der Hund wäscht den Käfer.

11a Der Igel malt den Vogel.

12a Der Vogel malt den Igel.

13a Der Käfer kratzt den Vogel.

14a Der Vogel kratzt den Käfer.

15a Der Igel schlägt den Käfer.

16a Der Käfer schlägt den Igel.

17a Der Frosch schiebt den Igel.

18a Der Igel schiebt den Frosch.

19a Der Hund fängt den Frosch.

20a Der Frosch fängt den Hund.

21a Der Tiger beißt den Hund.

22a Der Hund beißt den Tiger.

23a Der Vogel tritt den Tiger.

24a Der Tiger tritt den Vogel.

01b Den Frosch trägt der Käfer.

02b Den Käfer trägt der Frosch.

03b Den Hund kämmt der Vogel.

04b Den Vogel kämmt der Hund.

05b Den Igel zieht der Tiger.

06b Den Tiger zieht der Igel.

07b Den Frosch küsst der Tiger.

08b Den Tiger küsst der Frosch.

09b Den Hund wäscht der Käfer.

10b Den Käfer wäscht der Hund.

11b Den Vogel malt der Igel.

12b Den Igel malt der Vogel.

13b Den Vogel kratzt der Käfer.

14b Den Käfer kratzt der Vogel.

15b Den Käfer schlägt der Igel.

16b Den Igel schlägt der Käfer.

17b Den Igel schiebt der Frosch.

18b Den Frosch schiebt der Igel.

19b Den Frosch fängt der Hund.

20b Den Hund fängt der Frosch.

21b Den Hund beißt der Tiger.

22b Den Tiger beißt der Hund.

23b Den Tiger tritt der Vogel.

24b Den Vogel tritt der Tiger.

01c Der Käfer trägt der Frosch.

02c Der Frosch trägt der Käfer.

03c Der Vogel kämmt der Hund.

04c Der Hund kämmt der Vogel.

05c Der Tiger zieht der Igel.

06c Der Igel zieht der Tiger.

07c Der Tiger küsst der Frosch.

08c Der Frosch küsst der Tiger.

09c Der Käfer wäscht der Hund.

10c Der Hund wäscht der Käfer.

11c Der Igel malt der Vogel.

12c Der Vogel malt der Igel.

13c Der Käfer kratzt der Vogel.

14c Der Vogel kratzt der Käfer.

15c Der Igel schlägt der Käfer.

16c Der Käfer schlägt der Igel.

17c Der Frosch schiebt der Igel.

18c Der Igel schiebt der Frosch.

19c Der Hund fängt der Frosch.

20c Der Frosch fängt der Hund.

21c Der Tiger beißt der Hund.

22c Der Hund beißt der Tiger.

23c Der Vogel tritt der Tiger.

24c Der Tiger tritt der Vogel.

01d Den Frosch trägt den Käfer.

02d Den Käfer trägt den Frosch.

03d Den Hund kämmt den Vogel.

04d Den Vogel kämmt den Hund.

05d Den Igel zieht den Tiger.

06d Den Tiger zieht den Igel.

07d Den Frosch küsst den Tiger.

08d Den Tiger küsst den Frosch.

.

09d Den Hund wäscht den Käfer.

10d Den Käfer wäscht den Hund.

11d Den Vogel malt den Igel.

12d Den Igel malt den Vogel.

13d Den Vogel kratzt den Käfer.

14d Den Käfer kratzt den Vogel.

15d Den Käfer schlägt den Igel.

16d Den Igel schlägt den Käfer.

17d Den Igel schiebt den Frosch.

18d Den Frosch schiebt den Igel.

19d Den Frosch fängt den Hund.

20d Den Hund fängt den Frosch.

21d Den Hund beißt den Tiger.

22d Den Tiger beißt den Hund.

23d Den Tiger tritt den Vogel.

24d Den Vogel tritt den Tiger.

c) Acoustic analyses

The auditory stimulus material used in the ERP experiments was acoustically analyzed for the parameters duration, pitch, and intensity (Adobe Audition 1.0; Praat 4.4.18). A subset of these stimuli was also employed in the eye tracker experiments. Since the analyses throughout the whole book encompassed in particular NP1 and NP2, these sentential constituents were also focused as regions of interest in acoustic analyses (see Table 19).

Table 19. Exemplary phrases for acoustic analyses

NP1		NP2
Den Igel	zieht	der Tiger.

The mean *duration* of all sentences accounted for 2368 ms (SD = 134 ms) and did not differ between conditions. For the statistical analysis of NP1 and NP2, only the sentences of the subject-initial and object-initial conditions were included because first NPs and second NPs were identical to those in the double-nominative and double-accusative condition with the second NPs only cross-spliced. The mean duration of NP2 amounted to 800 ms (SD = 89 ms) and did not differ between conditions. However, the mean duration of NP1 (868 ms, SD = 80 ms) was significantly longer for the accusative case-marked NP1 (mean length 894 ms, SD = 87 ms) than for the nominative marked NP1 (mean length 842 ms, SD = 72 ms) as a t-test for unpaired samples revealed ($t(46) = -2.251$, $p \leq 0.05$). Exactly these articulatory differences in natural speech between accusative and nominative case-marking in initial sentence/clause position have also been found before (Leuckefeld, 2005; Mahlstedt, 2008).

For the parameter *pitch* of the f0 contour, the time onset, time minimum, time maximum, time offset, pitch onset (in Hz), pitch minimum (in Hz), pitch maximum (in Hz), and pitch offset (in Hz) were calculated separately for both noun phrases. For statistical difference evaluation between the conditions subject-initial and object-initial, unpaired t-tests were calculated. For NP2, no significant statistical differences for each value resulted. Thus, the second noun phrase did not differ in its pitch contour between conditions. As for the parameter duration, however, significant statistical differences occurred for NP1 in the time onset of pitch ($t(39.570) = -2.025$, $p \leq 0.05$), although mean time onset was only 3 ms earlier in the subject-initial (57 ms, SD = 7 ms) than in the object-initial condition (60 ms, SD = 5 ms). Also for NP1, the difference between the time minima reached significance ($t(46) = -2.173$, $p \leq 0.05$) with an

earlier time minimum in the subject-initial condition (320 ms, SD = 52 ms) than in the object-initial condition (350 ms, SD = 42 ms). The only difference for pitch revealed significance for pitch onset ($t(35.237) = 3.571$, $p \leq 0.001$) with a 13 Hz higher pitch for the nominative case-marked determiner (202 Hz, SD = 16 Hz) than for the accusative case-marked determiner (189 Hz, SD = 8 Hz). However, the assumed threshold for the perception of differences in pitch lies at approx. 10% of the mean pitch (Rietveld & Gussenhoven, 1985; t'Hart, Collier, & Cohen, 1990), hence at approx. 19 Hz in the present stimuli. Hence, the current differences in pitch onset are most likely not perceived by the participants.

For the parameter *intensity*, the time onset, time minimum, time maximum, time offset, intensity onset (in dB), intensity minimum (in dB), intensity maximum (in dB), and intensity offset (in dB) were calculated separately for both noun phrases. For NP2, in turn, no significant statistical differences for each value resulted. For NP1, significant differences resulted in the time onset ($t(46) = 2.561$, $p \leq 0.05$), although mean time onset was only 2 ms earlier in the object-initial (58 ms, SD = 3 ms) than in the subject-initial condition (60 ms, SD = 3 ms). Also, the time offset differed at NP1 significantly between conditions ($t(46) = -2.260$, $p \leq 0.05$) with an earlier time offset of intensity in the subject-initial condition (893 ms, SD = 73 ms) than in the object-initial condition (945 ms, SD = 87 ms).

d) Supplemental Statistics

Eye-tracker data in adults, trial course analysis:

Table 20. Significant t-values (one-sample t-test calculated against chance-level of 50%) of adults' fixation durations in different TWs of the trial course analysis in the subject-first condition

TW (ms)	t(20)	p-value
3800-4000	2.815	≤ .05
4000-4200	4.780	≤ .001
4200-4000	5.265	≤ .001
4400-4600	7.023	≤ .001
4600-4800	8.891	≤ .001
4800-5000	8.599	≤ .001
5000-5200	10.571	≤ .001
5200-5400	12.621	≤ .001
5400-5600	14.687	≤ .001
5600-5800	13.897	≤ .001
5800-6000	13.455	≤ .001
6000-6200	18.451	≤ .001
6200-6400	20.847	≤ .001
6400-6600	20.222	≤ .001
6600-6800	25.757	≤ .001
6800-7000	15.933	≤ .001
7000-7200	14.211	≤ .001
7200-7400	12.850	≤ .001
7400-7600	12.516	≤ .001
7600-7800	12.405	≤ .001
7800-8000	12.366	≤ .001
8000-8200	13.204	≤ .001
8200-8400	12.203	≤ .001
8400-8600	9.924	≤ .001
8600-8800	6.237	≤ .001
8800-9000	4.346	≤ .001

Table 21. Significant t-values (one-sample t-test calculated against chance-level of 50%) of adults' fixation durations in different TWs of the trial course analysis in the object-first condition

TW (ms)	t(20)	p-value
3800-4000	2.528	≤ .05
4000-4200	4.717	≤ .001
4200-4000	5.167	≤ .001
4400-4600	5.422	≤ .001
4600-4800	6.248	≤ .001
4800-5000	7.100	≤ .001
5000-5200	8.071	≤ .001
5200-5400	7.853	≤ .001
5400-5600	7.813	≤ .001
5600-5800	7.968	≤ .001
5800-6000	8.352	≤ .001
6000-6200	8.952	≤ .001
6200-6400	9.052	≤ .001
6400-6600	9.872	≤ .001
6600-6800	9.400	≤ .001
6800-7000	11.340	≤ .001
7000-7200	9.015	≤ .001
7200-7400	9.949	≤ .001
7400-7600	7.989	≤ .001
7600-7800	7.938	≤ .001
7800-8000	7.405	≤ .001
8000-8200	6.859	≤ .001
8200-8400	6.927	≤ .001
8400-8600	6.627	≤ .001
8600-8800	8.847	≤ .001
8800-9000	3.525	≤ .01

e) Analysis of 4;6-year-olds' subgroups

For further explorative analysis, the group of 4;6-year-olds was divided into two subgroups based on their individual performance in the TROG-D (Fox, 2008) employing a median split. The mean t-value in the test of poor performers accounted for 52.54, of good performers for 78.93. The analyses should be understood as explorative ones, because sample sizes are small and, consequently, data display a low signal-to-noise ratio.

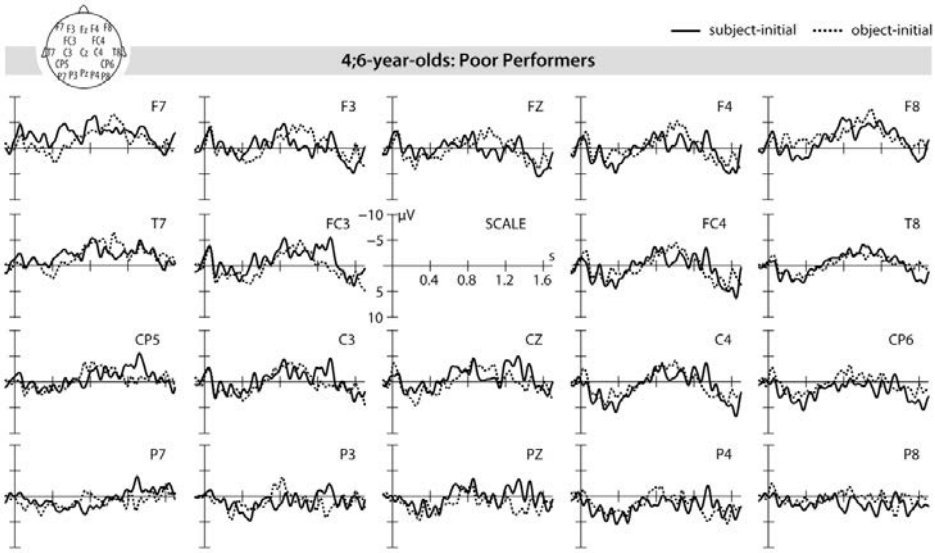


Figure 28. Grand average ERPs relative to NP2 onset for subject-initial (solid line) sentences versus object-initial (dotted line) constructions for poor language performers (as assessed by the TROG-D) in 4;6-year-olds (N = 13).

As visible in Figure 28, ERPs of the relatively poorer language performers in the group of 4;6-year-olds hardly show any processing difference between the subject-initial and object-initial condition time-locked to NP2 onset. Accordingly, statistical analysis only revealed a condition main effect at lateral sites in TW13 (1300-1400 ms), $F(1,12) = 9.524$, $p \leq 0.010$, and a tendency for a condition main effect at midline in the same TW13, $F(1,12) = 4.188$, $p = 0.063$. Hence, only the trend for a positivity in response to the object-initial compared to the subject-initial condition could be proven in the subgroup of poorer language performers in 4;6-year-olds.

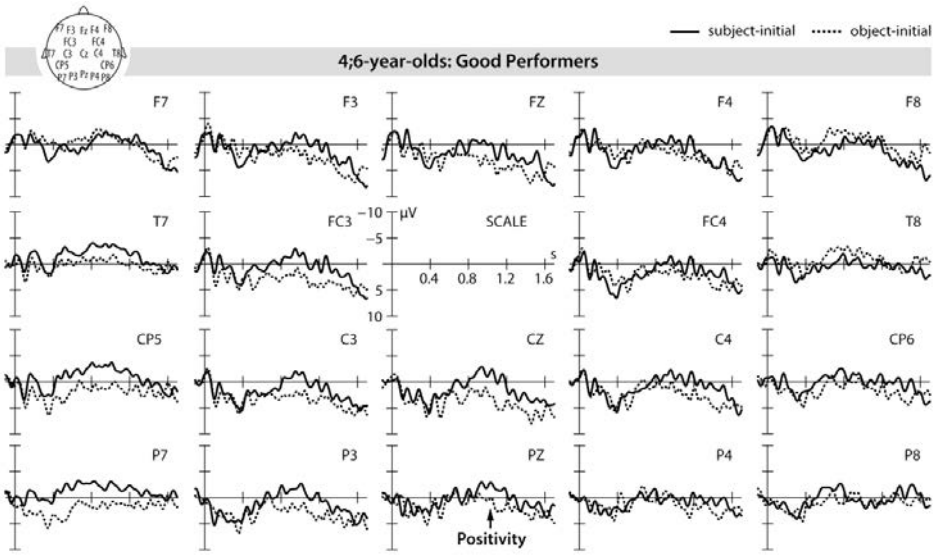


Figure 29. Grand average ERPs relative to NP2 onset for subject-initial (solid line) sentences versus object-initial (dotted line) constructions for good language performers (as assessed by the TROG-D) in 4;6-year-olds (N = 14).

In the subgroup of good language performers in 4;6-year-olds, visual inspections suggested a much more pronounced positivity for the object-initial condition compared to the subject-initial condition at NP2 onset (Figure 29). Statistical analysis confirmed this impression. In TW9, a tendency for a condition main effect at midline occurred, $F(1,13) = 3.214$, $p = 0.096$. In the subsequent TW10, the condition main effect at midline proved significance, $F(1,13) = 4.988$, $p \leq 0.05$, and the condition main effect at lateral sites was marginally significant, $F(1,13) = 3.224$, $p = 0.096$. Furthermore, in the following TW11, statistical analysis showed also a condition main effect at midline, $F(1,13) = 6.816$, $p \leq 0.05$, and marginal significance for condition at lateral sites, $F(1,13) = 3.592$, $p = 0.081$. (In addition, in TW16, a significant interaction of condition and sites occurred, $F(2,26) = 3.862$, $p \leq 0.05$, but subsequent analysis proved no main effects at single electrode sites.) In sum, good language performers in 4;6-year-olds showed a much more pronounced positivity (900-1200 ms post NP2 onset) than poor language performers comparing the processing of object-initial to subject-initial sentences.

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