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The role of proficiency in syntactic second language processing: Evidence from event-related brain potentials in German and Italian

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dedicated to my parents

gewidmet an meine Eltern

dedicato ai miei genitori

Hominis mens discendo alitur et cogitando. [Cicero]

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Abstract

In the present study a series of experiments were conducted in order to investigate the role of proficiency while processing different syntactic features in late second language (L2) learners of German and Italian. Two equivalent materials in German and Italian were realized as simple active sentences including a correct sentence, a word category violation (created by the omission of a noun in the prepositional phrase), a morphosyntactic agreement violation (created by an inflexion error on the verb), and a combination of the two. The methodology of event-related brain potentials (ERPs) was used to investigate the exact timing of online processing mechanisms of the brain while the sentences were presented acoustically.

Experiment 1 investigated Italian native speakers and aimed to investigate whether the same brain processing mechanisms are also observable for an Italian material as previously found for other languages. The ERP results showed for the word category violation an early anterior negativity (ELAN) reflecting initial phrase structure building processes, an additional negativity reflecting reference-related processes, and a late P600 evidencing processes of reanalysis. Agreement violations, on the other hand, gave rise to an anterior negativity (LAN) reflecting the detection of the morphosyntactic error and a P600 as reanalysis. Combined violations displayed the same ERP components as in the pure word category violation, suggesting primacy of word category information over other linguistic information types, in this case over morphosyntax. Thus, Experiment 1 successfully replicated the same brain processing steps for these different syntactic information types in Italian. In particular, the findings represent the first ERP evidence in the Italian language concerning word category violations and a combined violation including a word category and a morphosyntactic error.

Subsequently, four experiments were conducted in order to study high (*Experiment 2*) and low proficient (*Experiment 3*) late L2 learners of German as well as high (*Experiment 4*) and low proficient (*Experiment 5*) L2 learners of Italian. High proficient L2 learners in both languages showed the same brain processing steps for all syntactic violations as native speakers. For the word category violation they displayed an early anterior negativity, an additional negativity, and a late P600. Note that no ERP study investigating natural languages had shown an early anterior negativity in late second language learners, so far. These findings suggest that a high L2 proficiency can even lead to early (automatic) brain processing mechanisms in late learners. For the processing of the morphosyntactic error an anterior negativity and a P600 was observed. For the combined violation the same ERP components were found as in the pure category violation.

Low proficient L2 learners of German and Italian displayed some differences in contrast to high proficient L2 learners. In word category violations they showed an early anterior negativity, an additional negativity, and a P600. However, the additional negativity displayed a longer extension and the P600 was delayed and reduced in amplitude suggesting more uncertainty while processing reference-related information and initiating reanalysis. The surprising presence of an early anterior negativity even in low proficient L2 learners might be explained by the fact that the sentences were simple and created in the active voice. As active is easier to be learned and acquired prior to passive during first language acquisition, it might be possible that even low proficient L2 learners display phrase structure building processes under these circumstances, in contrast to L2 studies using passive constructions. Morphosyntactic violations failed to show an anterior negativity but they showed a delayed and reduced P600. Also the absence of an anterior negativity might be explained in analogy to first language development. At the beginning of children's language development no morphosyntactic features are used. They start using morphosyntax at about 2 to 5 years of age. Similarly, in L2 acquisition even though they learn the most important rules for forming correct morphosyntactic features quite early it takes much more time until they internalise and use them correctly. Combined violations gave rise to the same ERP pattern with the same latencies and amplitudes as the pure word category violation in both low proficient L2 learners except for the absence of an early anterior negativity in low proficient L2 learners of Italian.

In sum, these findings emphasize that with a high proficiency in late second language learners native-like neural responses can be achieved challenging the notion of a principled difference of language processes in the brain between native and late second language learners.

Zusammenfassung

In der folgenden Studie wurden eine Reihe von Experimenten mit dem Ziel durchgeführt, die Rolle des Zweitsprachniveaus bezüglich der Verarbeitung verschiedener syntaktischer Eigenschaften bei Personen, welche Deutsch oder Italienisch als Zweitsprache (L2) spät erlernt haben, zu untersuchen. Dazu wurden zwei äquivalente Materialien, ein deutsches und ein italienisches, verwendet. Diese beinhalteten einen korrekten Satz, eine Wortkategorieverletzung (erzeugt durch die Absenz eines Nomens in der Präpositionalphrase), eine morphosyntaktische Kongruenzverletzung (erzeugt durch einen Flexionsfehler am Verb) und eine Kombination aus beiden Verletzungen. Alle Sätze waren einfach und in der aktiven Form erzeugt. Um die exakten zeitlichen online Verarbeitungsmechanismen des Gehirns während der akustischen Satzpräsentation zu untersuchen, wurde die Methodologie der ereigniskorrelierten Hirnpotentiale (EKPs) verwendet.

In *Experiment 1* wurden italienische Muttersprachler untersucht wobei der Frage nachgegangen wurde, ob auch für die italienische Sprache dieselben neuronalen Verarbeitungsmechanismen wie in anderen Sprachen vorhanden sind. Die EKP-Ergebnisse zeigten für die Wortkategorieverletzung eine frühe anteriore Negativierung (ELAN), welche Prozesse des initialen Phrasenstrukturaufbaus reflektiert, gefolgt von einer zusätzlichen Negativierung, welche Referenz-bezogene Prozesse widerspiegelt, und eine späte P600, welche für einen Reanalyseprozess steht. Morphosyntaktische Kongruenzverletzungen elizitierten eine anteriore Negativierung (LAN), welche die Detektion des morphosyntaktischen Fehlers reflektiert, und eine P600 als Reanalyse. Kombinierte Verletzungen zeigten dieselben EKP-Komponenten wie in der reinen Wortkategorieverletzung und weisen somit auf eine Vorrangstellung der Wortkategorieinformation vor anderen linguistischen Informationsarten, in diesem Fall vor der Morphosyntax, hin. Mit Experiment 1 konnten somit erfolgreich dieselben neuronalen syntaktischen Verarbeitungsschritte auch für das Italienische repliziert werden. Insbesondere stellen diese Ergebnisse die erste EKP-Evidenz in der italienischen Sprache bezüglich der Wortkategorieverletzung und bezüglich einer Kombination aus einem Wortkategorie- und einem morphosyntaktischen Fehler dar.

In der Folge wurden vier weitere Experimente durchgeführt, mit dem Ziel, späte Zweitsprachlerner des Deutschen mit einem hohen (*Experiment 2*) und einem niedrigen (*Experiment 3*) Zweitsprachniveau und Zweitsprachlerner des Italienischen mit einem hohen (*Experiment 4*) und einem niedrigen (*Experiment 5*) Zweitsprachniveau zu untersuchen. L2 Lerner beider Sprachgruppen mit einem hohen Niveau zeigten bezüglich aller syntaktischen Verletzungen dieselben neuronalen Verarbeitungsschritte wie bei Muttersprachlern. Bezüglich der Wortkategorieverletzung zeigten sie eine frühe anteriore Negativierung, eine zusätzliche Negativierung und eine späte P600. Die Ergebnisse der vorliegenden Studie sprechen dafür, dass ein hohes L2 Niveau auch zu frühen (automatischen) neuronalen Verarbeitungsmechanismen bei Spätlernern führen kann. Dies wurde bis dato in keiner EKP-Studie, welche Zweitsprachlerner in natürlichen Sprachen untersuchte, gefunden. Bezüglich der morphosyntaktischen Verletzung wurde eine anteriore Negativierung und eine P600 beobachtet. Für die kombinierte Verletzung wurden wiederum dieselben EKP-Komponenten wie bei der reinen Wortkategorieverletzung gefunden.

Zweitsprachlerner beider Sprachgruppen mit einem niedrigen Niveau zeigten einige Unterschiede im Vergleich zu L2 Lernern mit einem hohen Niveau. Bezüglich Wortkategorieverletzungen zeigten sie eine frühe anteriore Negativierung, eine zusätzliche Negativierung und eine P600. Dennoch wies die zusätzliche Negativierung eine längere Extension auf und die Amplitude der P600 war verspätet und reduziert. Dies weist auf mehr Unsicherheit bei der Verarbeitung Referenz-bezogener Information und bei der Initiierung von Reanalyseprozessen hin. Das unerwartete Vorhandensein einer ELAN auch bei L2 Lernern mit einem niedrigen Niveau könnte durch die Tatsache erklärt werden, dass die Sätze einfach und in der aktiven Form erzeugt wurden. Da die aktive Form beim Erstspracherwerb früher und leichter erlernt wird als die passive Form, könnte angenommen werden, dass auch L2 Lerner mit einem niedrigen Niveau unter diesen Umständen Phrasenstrukturaufbauprozesse zeigen, im Unterschied zu L2 Studien, welche Passivsätze verwendeten. Morphosyntaktische Verletzungen wiesen keine anteriore Negativierung auf, zeigten jedoch eine verspätete P600 mit einer reduzierten Amplitude. Die Abwesenheit der anterioren Negativierung wird analog zur Erstsprachentwicklung erklärt. Am Anfang des Erstspracherwerbs verwenden Kinder keine morphosyntaktischen Eigenschaften. Sie beginnen mit dem Gebrauch von Morphosyntax mit ungefähr 2 bis 5 Jahren.

Obwohl bei der Zweitsprachverarbeitung die wichtigsten Regeln für das Bilden von morphosyntaktischen Eigenschaften ziemlich früh erlernt werden, wird relativ viel Zeit benötigt bis diese internalisiert sind und auf korrekte Weise verwendet werden. Kombinierte Verletzungen zeigten dasselbe EKP-Muster mit denselben Latenzen und Amplituden für beide L2 Gruppen mit einem niedrigen Niveau. Die einzige Ausnahme bildeten die L2 Lerner des Italienischen, welche keine frühe anteriore Negativierung aufwiesen.
Zusammenfassend unterstreichen diese Ergebnisse die Tatsache, dass späte Zweitsprachlerner mit einem hohen Niveau muttersprachenähnliche neuronale Prozesse zeigen können. Dies fordert wiederum die Auffassung einer prinzipiell unterschiedlichen neuronalen Sprachverarbeitung zwischen Muttersprachlern und späten Zweitsprachlernern heraus.

Riepilogo

Nel presente studio è stata condotta una serie di esperimenti con lo scopo di analizzare il ruolo del livello linguistico durante l'elaborazione di varie caratteristiche sintattiche in persone, le quali hanno imparato il tedesco o l'italiano come seconda lingua (L2) in età giovanile. Due materiali equivalenti, uno tedesco ed uno italiano, sono stati realizzati con frasi semplici nella forma attiva includendo una violazione della categoria delle parole (creata attraverso l'omissione di un sostantivo in una frase preposizionale), una violazione della congruenza morfosintattica (creata attraverso un errore della flessione del verbo) ed una combinazione di entrambe le violazioni. È stata usata la metodologia dei potenziali evento-correlati (ERPs) per studiare l'esatta coordinazione temporale dei meccanismi d'elaborazione online del cervello durante la presentazione acustica delle frasi.
Nell' *Esperimento 1* sono state esaminate persone di madrelingua italiana e lo scopo era di analizzare se gli stessi meccanismi d'elaborazione del cervello, come precedentemente trovati in altre lingue, sono osservabili anche per il materiale italiano. I risultati dei potenziali evento-correlati riguardanti la violazione della categoria delle parole hanno mostrato un primo potenziale negativo anteriore (ELAN), il quale riflette processi iniziali di costruzione della struttura della frase, seguito da un aggiuntivo potenziale negativo, il quale riflette processi relativi ad una referenza, ed un potenziale positivo (P600), il quale riflette processi di rianalisi. Le violazioni della congruenza morfosintattica, d'altra parte, ha rivelato un potenziale negativo anteriore (LAN), il quale riflette la scoperta dell'errore morfosintattico, seguito dal potenziale P600 come reanalisi. Le violazioni combinate hanno causato gli stessi componenti evento-correlati come la sola violazione della categoria delle parole, indicando una priorità dell'informazione sulla categoria delle parole su altre informazioni linguistiche, in questo caso sulla morfosintassi. Di conseguenza, l' Esperimento 1 ha replicato con successo gli stessi processi d'elaborazione nel cervello riguardanti i vari tipi d'informazioni sintattiche in italiano. In particolare, i risultati rappresentano la prima evidenza con potenziali evento-correlati nella lingua italiana riguardante le violazioni della categoria delle parole e le violazioni combinate includendo un errore di categoria e uno di morfosintassi.
In seguito sono stati condotti ulteriori quattro esperimenti con lo scopo di studiare persone, le quali hanno imparato il tedesco come seconda lingua e hanno acquisito un livello alto (*Esperimento 2*) o basso (*Esperimento 3*), e persone, le quali hanno imparato l'italiano come L2 e hanno un livello alto (*Esperimento 4*) o basso (*Esperimento 5*). Persone con un alto livello hanno mostrato gli stessi stadi d'elaborazione del cervello come persone di madrelingua per tutte le violazioni sintattiche. Per quanto riguarda la violazione della categoria hanno rivelato un primo potenziale negativo anteriore, un potenziale negativo aggiuntivo ed una P600. Fino ad ora nessuno studio con potenziali evento-correlati e usando una lingua naturale ha verificato il primo potenziale negativo anteriore in persone, le quali hanno imparato la seconda lingua in età giovanile. I presenti risultati quindi indicano che un livello alto nella L2 può portare a meccanismi d'elaborazione neuronali molto rapidi (e automatici) in persone che hanno imparato la seconda lingua in età giovanile. In riguardo agli errori morfosintattici sono stati trovati un potenziale negativo anteriore e una P600. Relativo alla violazione combinata sono stati rilevati gli stessi componenti come nella singola violazione della categoria.
In persone con un livello linguistico basso sono state rilevate alcune differenze in confronto a persone con un livello linguistico alto. Le violazioni della categoria hanno mostrato un primo potenziale negativo anteriore, seguito da un potenziale negativo aggiuntivo ed una P600. Il potenziale negativo aggiuntivo, però, ha mostrato un'estensione più lunga e la P600 si è presentata con ritardo e con un'ampiezza ridotta.

Questi risultati indicano che i partecipanti sono insicuri nell'elaborare informazioni relative ad una referenza e nell'iniziare la reanalisi. L'inaspettata presenza del primo potenziale negativo anteriore anche in persone con un basso livello può essere spiegato dal fatto che le frasi erano semplici e creati nella forma attiva. Siccome durante l'acquisizione della madrelingua nel periodo infantile la forma attiva viene imparata prima e più facilmente che la forma passiva, sembra plausibile che anche persone con un basso livello nella L2 mostrino processi di costruzione della struttura della frase in queste circostanze, in confronto a studi analizzando la seconda lingua con strutture passive. Le violazioni morfosintattiche non hanno rivelato il potenziale negativo anteriore, ma una P600 ritardata e ridotta. Anche l'assenza del potenziale negativo può essere spiegato in analogia con lo sviluppo del linguaggio nei bambini. All'inizio dello sviluppo linguistico i bambini non usano caratteristiche morfosintattiche. Iniziano ad usare la morfosintassi a circa 2 anni e terminano lo sviluppo della stessa verso i 5 anni. In modo simile, durante l'acquisizione della L2, anche se le regole più importanti per creare caratteristiche morfosintattiche vengono imparate abbastanza presto, la scioltezza e l'uso corretto di esse necessita ancora più tempo. Le violazioni combinate hanno mostrato gli stessi potenziali evento-correlati con le stesse latenze e ampiezze come la singola violazione della categoria. L'unica eccezione era l'assenza del primo potenziale negativo anteriore in persone con un basso livello della lingua italiana.

Riassumendo, i risultati del presente studio sottolineano il ruolo di un livello linguistico alto in persone che hanno imparato la seconda lingua in età giovanile per l'elaborazione neuronale simile a persone di madrelingua. I risultati sfidano l'ipotesi di una differenza principale nei processi linguistici nel cervello tra persone di madrelingua e persone che hanno imparato la seconda lingua in età giovanile.

Theoretical Part

Chapter 1

Introduction to Psycholinguistics

1.1 The language components

The linguistic system can be subdivided into different language components, which interact with each other and have specific functions in order to allow language comprehension and production. These components comprise *syntax*, which contains rules allowing different word combinations to form an acceptable sentence, *morphosyntax*, which contains rules defining the structure within single words, *phonology*, which deals with the sounds of language and their physical attributes, *semantics*, which defines the meaning of words, sentences, text passages, and discourses, and *pragmatics*, which deal with the question how utterances have to be formulated to achieve a specific effect in the listener (Yule, 1985).

1.1.1 Word category information

Because the present study concentrates on syntactic and morphosyntactic processing a brief description of different syntactic rules and anomalies will be provided at this point. Syntax contains different word categories, which are positioned in a language specific order to create a well-formed sentence. Word categories comprise nouns, verbs, adjectives, adverbs, prepositions, articles etc. The American linguist Noam Chomsky (1957, 1965) postulated that the linguistic system of each language consists of a finite amount of rules, which organize sentences in various ways and allow an indefinite number of possible combinations.

Such combinations are put together according to different parsing principles (Frazier & Rayner, 1982), e.g. only one syntactical structure is initially considered, the meaning is not involved in the initial selection of a syntactic structure, the simplest structure with the fewest nodes (principle of minimal attachment) is selected and every new word is attached to the current phrase if this is grammatically permissible (principle of late closure). Thus, each language has a more or less rigid word order, which allows some combinations and denies others. For example, the German and Italian sentences a) and b) do not allow a verb following directly a preposition and are therefore incorrect. They contain a word category error, because a wrong category occurs after the preposition. This syntactic anomaly creates a phrase structure violation due to the missing noun in the prepositional phrase.

a) Der Junge im Ø singt ein Lied. (The boy in-the Ø sings a song.)
b) Il signore nel Ø beve un caffé. (The man in-the Ø drinks a coffee.)

1.1.2 Morphosyntactic information

Morphosyntactic rules comprise a variety of word-formation parameters, such as gender (masculine, feminine, and in some languages neuter), number (singular, plural), case (nominative, genitive, dative, accusative, etc.), tense (present, past, etc.), person agreement (1^{st}, 2^{nd}, 3^{rd}), etc. In many Indoeuropean languages morphological markers are distinguishable in the suffix, e.g. the person agreement *ich sing-e* (1^{st} person sing.), *du sing-st* (2^{nd} person sing.), *er sing-t* (3^{rd} person sing.). When altering the morphosyntactic marker of a verb, which does not agree with the subject of the sentence anymore, a subject-verb-agreement violation realized by an inflectional error results as in sentences c) and d). In the German sentence c) the inflection error is created by the 2^{nd} person singular and in the Italian sentence d) by the 1^{st} person singular instead of the correct 3^{rd} person singular.

c) Der Junge im Kindergarten sing*st* ein Lied.
(The boy in-the kindergarden sing a song.)

d) Il signore nel bar bev*o* un caffé.
(The man in-the bar drink a coffee.)

1.2 Crosslinguistic comparison between German and Italian

Although German and Italian belong to the Indo-European Languages they developed historically from two different linguistic origins, namely Germanic and Romance languages (Comrie, 1990).
Germanic and Romance languages display some major differences concerning phonology, morphology, and syntax. A brief overview about the main similarities and distinction characteristics shall be given here.

Concerning the phonology, German displays 21 consonant and 19 vowel phonemes. Although Italian has less uniformity of phoneme usage because of various regional differences, the conventional phonological system, which was predominantly influenced by the Florentine language, consists of 21 consonant and 7 vowel phonemes (Comrie, 1990).

Morphological characteristics of German *nouns* can be subdivided in three genders (masculine, feminine, neuter), two numbers (singular, plural), and four cases (nominative, genitive, dative, accusative). All these characteristics are marked by the determiner in German. Italian has two genders (masculine, feminine), and two numbers (singular, plural). Plural forms are realized by adding suffixes or by no addition in German, whereas a vowel alteration of the last phoneme takes place in Italian plural marking. The *verb* morphology in German distinguishes between “strong” and “weak” verbs. The former suffer from a vowel alteration and take inflectional affixes for person and agreement, whereas the latter undergo no vowel alteration and take (partially different) inflectional affixes for person and agreement.

German verbs can be categorized according to several parameters: 3 persons (1^{st}, 2^{nd}, 3^{rd}), 2 numbers (singular, plural), 6 tenses (present, past, perfect, pluperfect, future I and II), 3 moods (indicative, subjunctive, imperative), and 2 voices (active, passive). Italian, on the other hand, can primarily be subdivided into three regular conjugation categories according to the ending of the verbs (-are, -ere, -ire). They display 3 persons (1^{st}, 2^{nd}, 3^{rd}), 2 numbers (singular, plural), 8 tenses (present, present perfect, imperfect, pluperfect, simple past, past anterior, future present, future perfect), 4 moods (indicative, subjunctive, imperative, conditional), and 2 voices (active, passive) (Comrie, 1990).

Concerning the syntax both languages have a relatively free word order. However, Italian is freer than German. The basic word order in German can be defined as SOV (subject – object – verb), but finite verbs appear after the subject in main clauses. Thus, German belongs to the so-called *V2 (verb second) languages* because the verb is placed at the second position in a sentence. Italian, on the other hand, has an SVO (subject – verb – object) word order (Guasti, 2004). Additionally, Italian can omit the subject in a sentence, so that it represents a *null subject language* in contrast to German, which does not allow the omission of the subject (De Vincenzi, 1991).

1.3 Language processing models

In the last decades language processing models tried to describe the mechanisms of language comprehension by combining the different language components and by explaining how they are processed. Two main classes of models have been proposed in order to explain language comprehension: serial (modular) and parallel (interactive) models.

1.3.1 Serial (modular) models

Serial (modular) models assume that the different language components are independent from each other, i.e. autonomous, and are processed one after another. Frazier and Fodor (1978) and Frazier (1987) postulate a two-stage parsing model. In a first-pass parsing stage (Preliminary Phrase Packager – PPP) syntactic information e.g. word category or phrase structure information is processed autonomously and phrasal/clausal packages are formed.

During the second-pass parsing stage (Sentence Structure Supervisor – SSS) semantic and pragmatic information are processed and the system has to decide how to connect the various information types together.

1.3.2 Parallel (interactive) models

Parallel (interactive) models assume that different information types interact with each other. In this regard we can distinguish models, which do not take into consideration temporal aspects and others, which do. The former (McClelland & Rumelhart, 1981, cited in Friederici, 1987) assume that information can interact at any time. The latter define the time at which certain information types are allowed to interact with each other. Marslen-Wilson and Tyler (1975, 1980) could show that after the sensory input first all possible words with the same initial letter are activated. This process is independent of the presented context (correct, semantically or syntactically anomalous, or scrambled), i.e. it does not consider context information. As the acoustic input proceeds, the amount of possible words decreases since only one possible word remains. Apart from the acoustic-phonetic analysis the lexical, structural, and interpretative aspects are assumed to be simultaneously analyzed from an early stage on as soon as information is available and to allow a free communication and interaction during the comprehension process.

Although these models were mainly based on empirical findings from English they make the claim to hold for language processing in general, i.e. across different language types.

Chapter 2

Bilingualism and second language processing models

2.1 Definitions of Bilingualism

There are several types of definitions of bilingualism, which rely on different factors such as age of acquisition, proficiency, organization of two linguistic codes, or the influence of L2 on L1. We can distinguish *early* and *late bilinguals* due to the age of acquisition of the second language. Early bilinguals can be further subdivided into simultaneous and sequential learners referring to whether two languages were learned simultaneously at an early age, e.g. in the family, or whether one language was learned after the other but both were acquired during childhood (von Hapsburg & Peña, 2002). Peal and Lambert (1962, cited in Bhatia & Ritchie, 2004) focused on the degree of competence in the two languages and distinguished *balanced/ambilinguals* (von Hapsburg & Peña, 2002) and *dominant bilinguals*. Balanced bilinguals master both languages equally well, whereas dominant (or unbalanced) bilinguals perform better in one than in the other language. Weinrich (1952, cited in Bhatia & Ritchie, 2004) distinguishes different dimensions of how two linguistic codes are organized by individuals. *Compound bilinguals* have learned two languages concurrently before their sixth year (Fabbro, 1999) and thus, they possess two linguistic codes stored in one meaning unit. *Coordinate bilinguals* have learned the second language before puberty, within or without the family (Fabbro, 1999). These bilinguals, therefore, have two linguistic codes, which are organized within two separate meaning units. *Subordinate bilinguals* have one language as the native language and use the second language as mediator of the first language (Fabbro, 1999). This subtype is assumed to interpret its linguistic L2 code through the L1.

This means that they have a representation of what they want to express in their L1 and they translate it into L2. A further distinction refers to how one's L2 affects the retention of the L1 (Lambert, 1974, cited in Bhatia & Ritchie, 2004). *Additive bilinguals* can enhance their L2 without losing L1 proficiency, whereas *subtractive bilinguals* describe persons, who have learned the L2 at the expense of losing their L1 competence. Further, bilinguals can be defined according to the reasons why they became bilingual (Valdes & Figueroa, 1994, cited in von Hapsburg & Peña, 2002). *Elective bilinguals* have chosen themselves to become bilinguals and often attend language courses or study-abroad programs. *Circumstantial bilinguals*, on the other hand, must learn second language out of necessity, e.g. immigrants.

2.2 Theories of second language processing

2.2.1 The critical period hypothesis (E. H. Lenneberg)

The concept of a critical period during life, where a greater sensitivity to certain environmental stimuli is present, arises from animal studies. Lorenz (1937), as a classical example, found the principle of filial imprinting in birds, which refers to the fact that only during a specific period, soon after hatching, graylag goslings get attached to the first moving object they see. Beyond this critical period the filial imprinting does not occur anymore or not in the same strength. Eric Lenneberg (1967) adapted the critical period concept to human language development. He postulated a critical period during which language acquisition takes place. He defined the onset of this period between the age of 2 and 3 years of life. Because Lenneberg assumed cerebral immaturity until age 2 he put the onset of language acquisition to this point in time. He further believed that "the onset of language is not simply the consequence of motor control" (p. 127). Thus, the language development does not primarily rely on articulatory skills, which, as a countermove, cannot be predicted simply on the basis of general motor development. Following this assumption Lenneberg thought that there must exist a "peculiar, language-specific maturational schedule" (Lenneberg, 1967, p. 131). He placed the end of the critical period at age 13, or puberty.

This termination is related to a decline in language acquisition capabilities, which coincide temporally with “a loss of adaptability and inability for reorganization in the brain” (p.179). Lenneberg refers to neurophysiological processes of hemisphere lateralization as he assumed the completion of lateralization of language functions to the left hemisphere to occur with puberty.

The critical period hypothesis proposed by Lenneberg raised various questions in second language acquisition research, especially concerning the end point of language acquisition (for a review on pros and contras concerning the critical period hypothesis see Birdsong, 1999). First of all, I will focus on the onset of the critical period. Research on speech perception found, contrary to Lenneberg, evidence for speech sound categorization skills in children in their first months of life (e.g. Werker & Lalonde, 1988, cited in de Groot & Kroll, 1997), indicating that language development starts prior to age 2. Furthermore, Werker and Lalonde (1988, cited in de Groot & Kroll, 1997) found that 6-month-old children were sensitive to phonetic categories in both a foreign language and in a familiar language, which provides evidence for innate phonetic discrimination skills.

Another important factor, which has to be considered about the critical period hypothesis is the maturational aspect, which is implied by this theory. Lenneberg argues that a decline of linguistic competence is visible with increasing age of acquisition. There is diverging evidence regarding this issue. Some studies show that the earlier the age of acquisition the better the performance in the second language. The most robust findings refer to pronunciation (Thompson, 1991; cited in de Groot & Kroll, 1997).

Further evidence in favor of a decline with increasing age of acquisition can be found during listening comprehension tasks as well as while performing grammaticality judgment tasks (Oyama, 1978; Johnson & Newport, 1989; both cited in de Groot & Kroll, 1997).

Birdsong (1992), on the other hand, found that persons who had learned the second language well after puberty were able to attain a native-like second language level when performing grammaticality judgments. These findings provide evidence that second language acquisition can also reach a native-like level when the second language is learned in adulthood.

Even Lenneberg's firm assumption that language acquisition terminates at age 13, with puberty, does not find convincing evidence in second language research. Apart from the fact that a native-like second language level can be achieved also during adulthood (Birdsong, 1992), other studies find AoA effects also among adults challenging the notion that puberty marks the end of language acquisition (Seright, 1985, cited in de Groot & Kroll, 1997). Thus, it seems that language acquisition and the decline of proficiency persists also after puberty.
Lenneberg did not clearly state to which aspects of language (syntax, semantics, phonology etc.) the critical period refers. He simply generalizes the hypothesis to the term language. However, some hints can be found as he placed the beginning of language acquisition at age 2. This age coincides with the upcoming of first syntactic features. Apart from syntax, he must have also considered phonology to be affected by critical period effects as he stated that foreign accents cannot be overcome after puberty. In contrast, Lenneberg seems to not have considered vocabulary learning subject to maturational constraints (de Groot & Kroll, 1997).

2.2.2 Universal Grammar (N. Chomsky)

The American linguist Noam Chomsky postulated a theory trying to describe how the linguistic system is organized. The central concept is Universal Grammar (UG). This concept refers to the fact that the human language system consists of different aspects, rules, and elements, which are universal to all languages (Chomsky, 1976). With this definite amount of elements an indefinite number of utterances can be produced or understood (Chomsky, 1957, 1965, 1981). The theory developed over the years and is composed of different subtheories, which try to capture the essential linguistic features of human language. One of the most powerful subtheories is the *Principle and Parameter Theory* (1981). This theory assumes that language consists of principles that apply to all languages and thus are universal, and of parameters that vary across languages within clearly defined limits. This means that language knowledge does not consist of rules as such but that rules are derived from underlying principles. The Universal Grammar establishes single principles that apply to all rules in one language, and further, are applicable to other languages as well.

Universality of a principle does not mean that it must occur in all languages without exceptions but the principle must be ascribed to language faculty itself rather than to experience of learning a particular language (Cook & Newson, 1996). Thus, principles of universal grammar are innate and present in any newborn before concrete language experience. One of the principles of UG is *structure-dependency*, which refers to the fact that all sentences consist of phrases (and not only single words). As a consequence, language knowledge is related to this structural relationship. This means that, for example, the transformation from an active sentence (The manager fires Barnes) into a passive one (Barnes was fired by the manager), requires not only the movement of single words but the movement of whole phrases, i.e. the object noun phrase has to be moved to subject position. Thus, the right element in the right phrase has to be moved. In order to know which element has to be moved, one must know the underlying sentence structure (Cook & Newson, 1996). Because this principle is common to all languages it is defined as universal principle. Parameters, on the other hand, are not universal but represent the variations across different languages. One of the parameters of language is the *head parameter*, which refers to the position of the head of a phrase. A head of a noun phrase is the noun, a head of a prepositional phrase the preposition, the head of a verb phrase the verb and so on. There are two possibilities in which the position of the head of a phrase can occur, namely either in head-first (i.e. at the beginning of a phrase) or in head-last position (i.e. at the end of a phrase). English is a head-first language as e.g. the head (in) of the prepositional phrase “in the bank” is positioned at the beginning of the phrase. Japanese, in contrast, is a head-last language (Cook & Newson, 1996). Apart from principles and parameters the theory of universal grammar comprises different modules such as the *X-bar Theory*, which describes the structure of phrases, the *Theta Theory*, which assigns semantic relations or roles (agent, patient, goal etc.) between parts of the sentence, the concept of *Government*, which refers to the syntactic relationship between a governor and an element that is governed, the *Case Theory*, which describes morphosyntactic aspects of inflection and agreement within a sentence, and the *Binding Theory*, which describes whether referential aspects such as pronominals, anaphors, or referring expressions are integrated in a sentence (Cook & Newson, 1996).

Chomsky further distinguishes between Externalized (E-) language and Internalized (I-) language. *E-language* refers to the language properties that can be described from external facts. E-language assumes language as a social phenomenon and thus analyzes the discourse, the relationship between listener and speaker, the situation in which the communication occurs and so on. Chomsky's first goal was, however, to understand *I-language*. This concept refers to what a speaker knows about language and where this knowledge comes from. This distinction partly corresponds to an early distinction between competence and performance, first mentioned in Chomsky's book "Aspects of the Theory of Syntax" in 1965. *Competence* (corresponding to I-language) was defined as "the speaker-hearer's knowledge of his language" (Chomsky, 1965, p.4) and *performance* (corresponding to E-language) as "the actual use of language in concrete situations" (Chomsky, 1965, p.4). Competence is, thus, independent of the situation, and reflects the knowledge of, for example, an English speaker that rules must be structure-dependent and English is a head-initial language.

Principles and parameters of UG were not only studied in adult native speakers but also the question how language acquisition functions was of strong interest. Chomsky (1995) assumes that a newborn baby has no language knowledge and thus has an *initial zero state* S_o. The adult native speaker, at the other end of the continuum, has full knowledge of the language, the competence is essentially complete and static. This stage is referred to as *steady state* S_s. Chomsky compares this process from S_o to S_s with a black box, something comes in and something comes out. *Primary linguistic data* (input children get from their parents and other caretakers) comes into the black box, where it is processed and the output is the linguistic competence. Chomsky calls the black box *language acquisition device (LAD)*, which can be seen as the language faculty, i.e. Universal Grammar (Cook & Newson, 1996). Thus, UG is present in the child's mind as a system of principles and parameters and leads to linguistic competence in the adulthood. The principles as such are innate, what the child has to learn are the values of the parameters together with the vocabulary incorporating the pronunciation, meaning, and syntactic restrictions.

In order to learn adequately, a child must be provided with specific evidence requirements (Cook & Newson, 1996):

- *Positive evidence requirement*: children learn language from correct examples spoken by others, without correction, explanation etc. (negative evidence).
- *Occurrence requirement*: any type of evidence needed by the child occurs in normal language situations.
- *Uniformity requirement*: type of evidence is available to all children regardless of variations in culture, class etc. (since all children acquire L1).
- *Take-up requirement*: children actually use this type of evidence.

The Universal Grammar theory and its acquisition were also adapted for second language acquisition. The acquisition concept for native speakers could in principle be extended for L2 acquisition by adding a second language input, which is processed by the language acquisition device through UG and leads to an L2 grammar output. However, some problems arise. First, an L2 learner usually already has a grammar containing UG principles and parameters of the L1. Thus, the initial state of an L2 learner differs from that of a child and is therefore called S_i. Second, the final state of an L2 learner is hard to define, and can be defined as S_t. There are several different stages of competence, some L2 learners are more competent whereas others do not reach high competence (Cook & Newson, 1996). Chomsky (1986) assumes that the final stage of an L2 must be considered equal to that of L1, namely it should contain the complete knowledge of language. He does not accept intermediate stages, but says that an L2 learner can be described according to the level of knowledge he or she has already reached. But only when full knowledge is acquired, they will then know the language.
The central question in second language research incorporating the UG theory is whether principles and parameters of UG are accessible also during second language acquisition. Several different approaches have emerged. Some researchers postulate that second language learners have *direct access to UG*. This means that they possess the principles of UG and set the parameters without relying on the already established L1 grammar. This approach is mainly based on the observation that some L2 learners are able to achieve an ultimate attainment very similar to that of native speakers and thus may rely on UG also in the second language.

The direct access to UG hypothesis may be acceptable at least for some principles, e.g. structure-dependency, as studies (Otsu & Naoi, 1986; cited in Gass & Selinker, 2001) showed that Japanese native speakers, who do not possess such a principle for question formation in Japanese, display structure-dependency in their L2 (English). A second approach is based on the assumption that there is only an *indirect access to UG* in second language acquisition. This hypothesis argues that L2 learning uses the L1 instantiation of UG principles and parameters to acquire the L2 and to apply them to L2. Thus, L2 competence will only reflect those UG elements that are present in the L1. A third approach postulates that there is *no access to UG* at all. This means that the second language learner has to acquire L2 through other cognitive strategies than UG. Thus, L2 competence is distinct from L1 competence. As most second language learners do not reach a native-like level several studies tested whether UG principles can be accessed and came to the results that these are not directly accessed (Clahsen & Muysken, 1986; Johnson & Newport, 1991; both cited in Cook & Newson, 1996).

Some variations to these approaches further assume that second language learners may have access to some UG aspects but their grammar is not the same as the L2 grammar itself. This so-called *interlanguage* may show properties of the L1 or it may contain elements, which do neither belong to the L1 nor to the L2 grammar (White, 1996; cited in Ritchie & Bhatia, 1996).

2.2.3 Bilingual Language Mode (F. Grosjean)

Grosjean (2001) proposes a model, which aims to elucidate how bilinguals process their two languages separately or together. It accounts for both the bilingual speaker and the bilingual listener involved in a conversation. The language mode, according to Grosjean, reflects the state of activation of the languages of a bilingual person and the related language processing mechanisms at a given point in time (Figure 2.1).

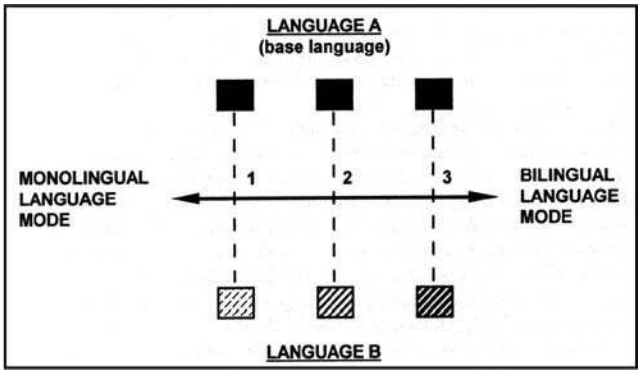

Figure 2.1: Bilingual Language Mode

Language A represents the native language and Language B is the second language. The squares indicate the degree of activation: black squares indicate a high activation, as this is the case for the native language, and white squares indicate no activation. In position 1, the language B is only less activated and thus reflects a *monolingual mode*. This state refers, for example, to a situation in which a bilingual person is involved in a conversation with a monolingual person. In this case the bilingual person deactivates the language, which the other person does not understand, because the conversation does only take place in one language, the one of the monolingual person. In position 2, the bilingual is in an *intermediate mode*, as language B is somewhat more activated. In such a situation the bilingual person might, for example, speak with another person, who knows language B, but for some reasons does not have the same proficiency level as the bilingual person or does not like to mix languages. In this case language B is only partially activated in the bilingual person. In position 3, language B is highly activated, but it still differs in activation from the base language A. This state is called the *bilingual mode* and describes a situation in which the bilingual person is speaking with other bilinguals, who also mix languages. Both languages are activated but B is somewhat less active than the base language because B as it is not currently the main language of processing.

There are a number of factors, which influence language mode and define at which point of the continuum the bilingual is positioned at a given point in time (Grosjean, 2001). These factors include:

- the bilingual himself (language proficiency, language mixing habits and attitudes, usual mode of interaction, kinship relation, socioeconomic status, etc.)
- the situation (physical location, presence of monolinguals, degree of formality and of intimacy)
- the form and content of the message being uttered or listened to (language used, topic, type of vocabulary needed, amount of mixed language)
- the function of the language act (to communicate information, to request something, to create a social distance between the speakers, to exclude someone, to take part in an experiment, etc.)
- the specific research factors (the aims of the study taking place, the type and organization of the stimuli, the task used, etc.)

Additionally, Grosjean (2001) draws the attention toward several points that should be considered concerning language mode. First, bilinguals differ among themselves and can, therefore, be found at very different positions along the continuum. Second, one bilingual can change its place along the continuum at any time when the factors determining a language mode change. These changes in movement usually occur unconsciously and can be quite extensive. Third, a detailed definition of the two extreme poles of activation of the continuum is still unclear, so far. It is proposed that language B is never totally deactivated in the monolingual mode, whereas language B very rarely reaches the same level of activation as the base language in the bilingual mode. However, further research is needed in order to capture this issue in more detail.

2.2.4 Neurocognitive approaches of second language processing

2.2.4.1 The Neurolinguistic Theory of Bilingualism (M. Paradis)

Paradis proposes a neurolinguistic theory of bilingualism, which incorporates a series of hypotheses together with aspects, which affect the second language acquisition and processing (Paradis, 2004).

The *Three-Store Hypothesis* refers to the neurofunctional separation of a nonlinguistic cognitive store from two language stores in bilinguals. The two language stores contain the grammar and the lexical meanings for words of each of the language of the bilingual person. Both languages are thus organized in two different language systems. The cognitive store interacts with these two language systems and is represented by a conceptual system, which contains the mental representations of things put together by combining different characteristic features. A concept can therefore be acquired through experience, by organizing perceptual features into coherent wholes.

The *Subsystems Hypothesis* postulates that the two (or more) languages of a bilingual (or multilingual) person are represented as subsystems of the language store. These subsystems contain the grammar of the respective languages. At a neuroanatomical level these subsystems belong to the same area in the brain, they just differ at a micro-anatomical level.

The *Activation Threshold Hypothesis* assumes that an item is activated whenever a sufficient activation threshold is reached. The activation threshold itself is represented by a certain amount of neural impulses. When an item is activated the threshold is lowered or fewer impulses are required to reactivate it. On the other hand, is an item not stimulated, it becomes more and more difficult to activate over time. Thus, as an item is targeted for activation and as a consequence its activation threshold is lowered (e.g. if a bilingual person uses more often language A), then its competitors are simultaneously inhibited, i.e. the activation threshold of language B is raised.

The *Direct Access Hypothesis* postulates that each word, irrespective of whether it emerges from a unilingual or a bilingual mode, is directly perceived as a word with its meaning. This means that to a specific sound or phonological sequence a meaning is immediately attributed and only after the understanding of the word is the language identified to which it belongs (e.g. English or French). Paradis provides a clear example: "The French word *dogue* and the English *dog* are distinguished by subtle phonetic features (*dogue* = 'bulldog'), but each corresponds to a different lexical representation, in the same way as two similar-sounding words in the same language (such as *five* and *fife*)" (Paradis, 2004, p. 204). The degree of (in this case phonological) similarity between two languages or between two sounds of one language leads to more or less ambiguities during the comprehension process.

Apart from these different hypotheses Paradis considered other neurofunctional mechanisms to be involved in the language use, namely implicit language competence, metalinguistic knowledge, pragmatics, and motivation and affect. *Implicit language competence* contains phonology, morphology, semantics, and syntax. It is acquired incidentally, stored implicitly, and used automatically. It is subserved by procedural memory. In contrast, *metalingustic knowledge* represents the world knowledge. It is learned and stores explicitly, and recalled consciously. It is subserved by declarative memory. Paradis assumes that second language learners may gradually shift from the exclusive use of metalinguistic knowledge to more extensive use of implicit linguistic competence as they gain more and more L2 proficiency. *Pragmatics* contains features, which provide the interlocutor's intention from the various contexts of an utterance. Pragmatic features are, for example, idiomatic expressions, proverbial phrases, plain indirect speech, but also aspects such as body language, facial expressions and prosody. *Motivation* is an important factor influencing the ability to appropriately process a second language. "It is the motor that drives the acquisition, learning and use of both first and second language" (Paradis, 2004, p. 223). Motivation, thus can encourage practice, and positively affect L2 acquisition. Emotional inputs (*affect*) consolidate the learned aspects as it strengthens the memory trace.

2.2.4.2 The Declarative / Procedural Model (M. T. Ullman)

Michael Ullman (2001a, 2001b, 2004) proposes a neurocognitve model in which he distinguished between the declarative and the procedural memory system.

The *declarative memory system* is implicated in the learning, representation, and the use of knowledge about facts and events ("semantic and episodic knowledge") in native speakers. It contains stored knowledge about words, including their sounds, meanings, and other memorized information. All these information types are consciously ("explicit") accessible. The brain regions, which subserve the declarative system, comprise the medial temporal lobe regions including the hippocampus and related structures and connections to temporal and parietal neocortical regions (Figure 2.2). More specifically, temporal lobe regions are assumed to be important for the storage of word meaning, whereas temporal-parietal areas subserve the storage of word sounds including phonological sequence information.

The *procedural memory system*, on the other hand, underlies the learning of new and the control of long-established motor and cognitive skills and habits in native speakers (e.g. the automation of motor acts such as driving a car). Regarding language, the system involves the learning and use of linguistic aspects such as syntax, non-lexical semantics, morphology, and phonology. The information is not consciously accessible, and is thus considered to be implicit. The cortical regions, which are assumed to subserve the procedural memory contains frontal/basal ganglia structures (Figure 2.2). In detail, the basal ganglia are assumed to be involved in the learning of rules, whereas projections from the basal ganglia to frontal regions may subserve grammatical processing.

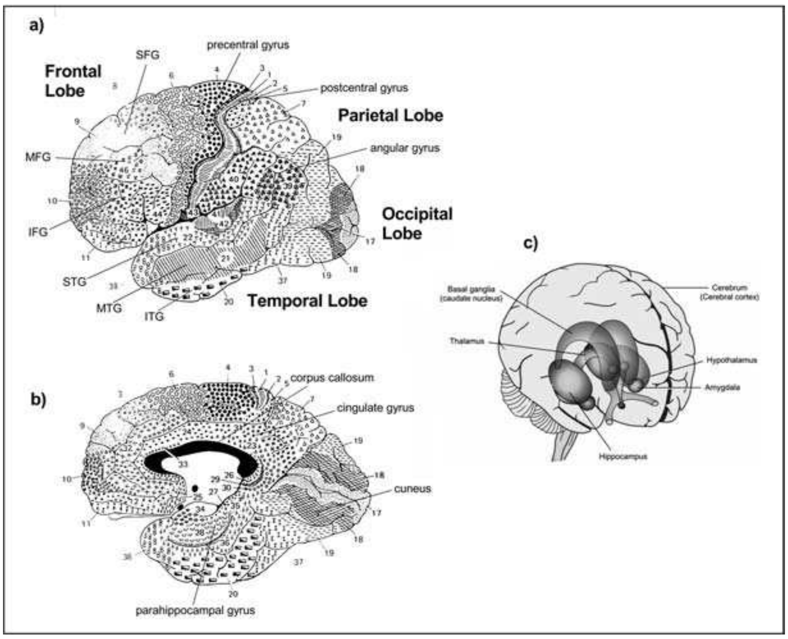

Figure 2.2: a) and b) Brodmann's cytoarchitectural map of the human cerebral cortex (both adapted from Burt, 1993); a) lateral view b) medial view; SFG = superior frontal gyrus; MFG = medial frontal gyrus; IFG = inferior frontal gyrus; STG = superior temporal gyrus; MTG = medial temporal gyrus; ITG = inferior temporal gyrus. c) view of the internal structure of the human brain (from www.oecd.org)

Ullman argues that the processing of semantics and grammar in a second language are differentially organized with respect to the two memory systems. In contrast to native speakers, who use procedural memory for learning and use grammar, second language learners rely on the declarative memory system. Grammatical rules (e.g. linguistic forms) that are compositionally computed in L1 (e.g. morphology) are simply stored in and retrieved from the lexicon, like words or idioms, in their entirety in L2. Thus, they are learned explicitly, for example in a pedagogical environment, and applied consciously, in contrast to L1, who learn and use them implicitly.

The shift of dependence from declarative to procedural memory in L2 correlates with the age of acquisition and the practice of the second language. The later the age of exposure to L2 the more learners rely on declarative memory and the more experienced L2 learners become the more they use procedural memory for grammatical computations.

With regard to the underlying brain structures, second language learners use temporal and temporo-parietal structures for both lexicon and grammar. Medial temporal lobe structures including the hippocampus and related structures are assumed to subserve the learning of both types of information. Neocortical temporal and temporo-parietal regions, on the other hand, underlie the use of already-learned forms concerning both lexicon and grammar.

Because the procedural memory system is more left-lateralized than the declarative system less left-lateralization is expected in second language learners, in contrast to native speakers.

Chapter 3
Electroencephalography

One of the most well established methods used to study the neural basis of cognitive processes is – apart from neuroimaging techniques such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and transcranial magnetic stimulation (rTMS) – the electroencephalography (EEG). This is a non-invasive neurophysiological method that measures the electric brain activity via electrodes placed onto the scalp. The EEG recordings, thus, reflect the difference in voltage between signals at two electrodes. The EEG is not only used for scientific purposes but it also represents a diagnostic instrument in clinical practice. The advantage of the EEG, in contrast to neuroimaging techniques, is the high temporal resolution in milliseconds, whereas a disadvantage constitutes the relatively low spatial resolution. For this reason this method represents a highly sensitive instrument for detecting and studying cognitive processes of the brain that occur very fast.

The psychiatrist *Hans Berger* was the first who measured voltage fluctuations not only in animals (dogs and cats) but also in human cerebral cortices in 1902 at the University clinic in Jena (Stern, Ray & Quigley, 2001).

3.1 Measuring the EEG

The instruments used to measure the EEG consist of electrodes made of AgAgCl, tin, silver etc. placed onto the scalp. Most multi-channel systems today incorporate the electrodes in a cap of different sizes that can be easily positioned on the person's head. The signal recorded from the scalp is amplified by an amplifier that must be able to show all the frequencies from 0 to 100 Hz. It should have an incoming impedance of several millions of Ohm and should reject interferences due to the ground.

Apart from this it should include filtering possibilities (Stern, Ray & Quigley, 2001). In the following experiments a 32 channel EEG amplifier (REFA) was used.

The recording of the EEG can occur monopolarly or bipolarly. When *monopolar recording* is used, each electrode is referenced against another electrode. In this regard a “common reference” refers to the case when each electrode is referenced against the same common electrode. It is important to note that the reference electrode should always be placed where no (or very less) electric activity is present. In monopolar recordings the voltage of the reference electrode is subtracted from the active electrode. The *bipolar recording* refers to the case where the recordings take place between two active electrodes (Rugg & Coles, 1996; Stern, Ray & Quigley, 2001). In the following experiments a common reference was used.

3.2 The electrode placement

The placement of the electrodes is carried out according to the 10-20 placement system (Jasper, 1958; Sharbrough, Chatrian, Lesser, Lüders, Nuwer & Picton, 1991). First of all, the distance between the nasion (the bridge of the nose) and the inion (the bump at the back of the head) and from left to right between the two preauricular points (depressions in front of the ears above the cheekbone) is measured. At 50% of both measures lies the vertex. Here the electrode CZ is placed. Then, further anatomical marks are placed at 10% from the nasion and the inion and from the preauricular points, respectively, and 20% in between. At the landmarks 20% in front of the CZ the electrode FZ and 20% behind the CZ the electrode PZ are placed. According to the same principle the electrodes C3/C4 and T3/T4 are placed to the left and right from the vertex (Figure 3.1).

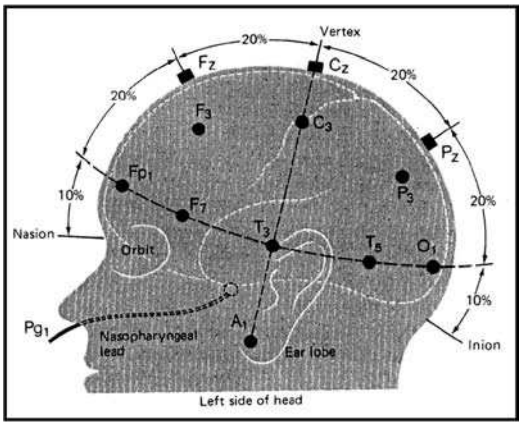

Figure 3.1: The international 10-20 electrode system (adaptation from Stern, Ray & Quigley, 2001).

Jasper (1958) named the electrodes with different letters, which are related to the different brain regions: F = frontal, C = central, T = temporal, P = parietal, O = occipital. The numbers refer to the distance from the vertex and are odd on the left and even on the right. Electrodes at the midline between nasion and inion are referred to with an additional Z. Because the number of electrodes arose in the course of the years, the 10-20 system was enlarged by the American Electrographic Society in 1991 (Sharbrough, Chatrian, Lesser, Lüders, Nuwer & Picton, 1991). The following electrode configuration was used in the following experiments (Figure 3.2). The electrode AFZ served as ground electrode and the left mastoid (A1) was the reference electrode during online recording.

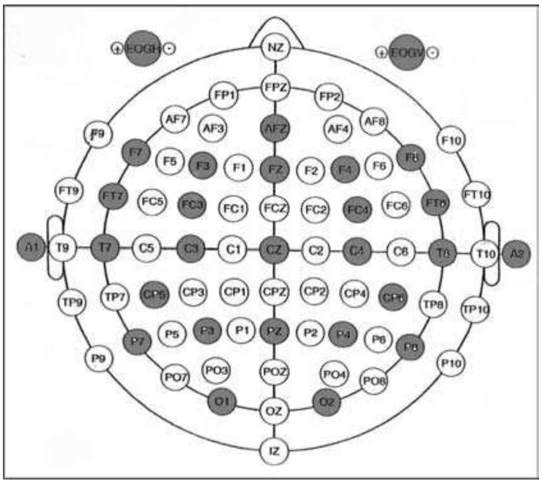

Figure 3.2: Electrode positions according to Sharbrough et al. (1991). Marked electrodes were used in the following experiments.

3.3 EEG frequency bands

The EEG signal represents the sum of oscillations that consist of different frequency bands depending on the biological, pathological and psychological status (Stern, Ray & Quigley, 2001):

- The *Alpha rhythm* (8-13 Hz): Alpha activity can be observed when persons are awake and relaxed (e.g. awake with closed eyes). It is related to relaxation and lack of cognitive processes. Its anatomical distribution is mostly pronounced at occipito-parietal regions. The Alpha rhythm can be further subdivided in upper and lower alpha (Klimesch, Schimke & Schwaiger, 1994). The former was seen in correlation with semantic memory processing, whereas the latter was observed in relation to selective attention.
- The *Beta rhythm* (13-30 Hz): Beta activity occurs when one is alert, e.g. when a person is required to perform a cognitive task, which involves attention.

- The *Gamma rhythm* (30-70 Hz): Gamma activity is characterized by very small amplitudes and high local specificity. The functionality is still unclear, but recent work observed gamma activity in relation to the brain's ability to integrate different features into a coherent whole.
- The *Theta rhythm* (4-8 Hz): Theta activity was observed in association with low level of alertness, during REM sleep, problem solving, attention, and hypnosis.
- The *Delta rhythm* (0.5-4 Hz): Delta activity was observed in healthy subjects during sleep and in correlation with pathological conditions such as tumors. This is also the predominant frequency during the first two years of human infants.

3.4 Event-related brain potentials (ERPs)

ERPs are the time-locked brain responses to a specific stimulus (event). If we present an acoustic, visual, tactile etc. stimulus we can measure the potential fluctuations that arise before, during and after the presentation. In psychophysiological literature we sometimes encounter the term "evoked potential". This refers to the same brain response after a stimulus presentation but was originally used because of the belief that the brain response was directly evoked by the stimulus. Today we know that also psychological factors of the experimental situation can contribute to the generation of a brain potential, so the term "event-related brain potentials" was introduced (Rugg & Coles, 1996).

The amplitude of ERPs is smaller than that of spontaneous EEG, which is superimposed with noise. In order to extract the ERPs from the spontaneous EEG we have to use the so-called *averaging technique*. The idea is that when the same stimulus is repeated several times a similar electrocortical activity occurs, whereas the noise is distributed randomly (Birbaumer & Schmidt, 1996; Bösel, 1996).

Glaser and Ruchkin (1976, cited in Picton, Lins & Scherg, 1995) postulate three rules about the relation between signal and noise. First, the signal and the noise are added linearly. Second, the waveform of a signal is the same for every repeated signal. Third, the noise waves are different from event to event, so that they can be assumed to represent a statistically independent group of randomly occurring processes.

Figure 3.3 illustrates such an averaging procedure. At the beginning there are 16 events. In a first step always two events were averaged together in order to reduce the noise and to get the real signal. The signal-to-noise ratio increases with the number of averaging steps. The result is a noise free event-related brain potential. The more events are averaged the better the ERP signal becomes (Birbaumer & Schmidt, 1996; Picton, Lins & Scherg, 1995).

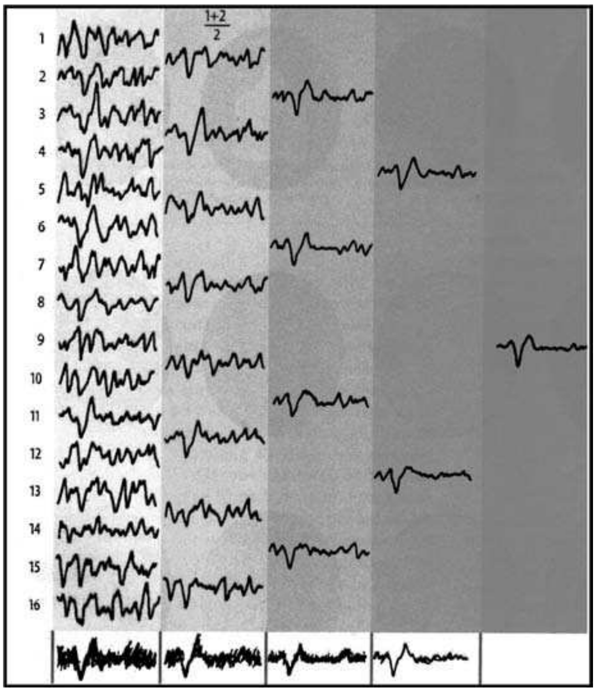

Figure 3.3: Averaging procedure in order to get event-related brain potentials (adapted from Birbaumer & Schmidt, 1996).

3.4.1 Positive and negative ERP components

The result of the averaging procedure is an event-related potential for the averaged time window that can show positive and/or negative going waves. They are named with a P (positivity) or N (negativity), respectively, and a number. This number indicates the time in milliseconds when the potential occurred after stimulus onset, e.g. N400 refers to a negative potential, which peaked at about 400 ms.

In the neurophysiological literature it is usual to plot negative wave upwards and positive one downwards (Kutas & van Petten, 1994).

Donchin, Ritter and McCallum (1978) defined ERP-components according to four different characteristics such as *polarity* (positive or negative waveform), *latency* (time of the maximum peak of the component), *topography* (the positions on the scalp where the effect occurs) and *sensitivity* (influence of experimental manipulations).

3.4.2 ERP components related to language processing

3.4.2.1 The N400

The N400 is a language-related ERP component, which was observed in correlation with lexical-semantic processing. Kutas and Hillyard (1980a) first observed this ERP component when semantically incorrect sentences such as “He spread the warm bread with socks” were compared to correct sentences. The elicited N400 was present between 250 and 600 ms and had a centro-parietal distribution. The peak of this negativity was reached at about 400 ms after stimulus onset (“socks”). Thus, the N400 component was seen in correlation with the processing of semantic anomalies. The presence of the N400 in similar contexts has been replicated many times both in the visual and in the auditory modality (for a review see e.g. Kutas & Federmeier, 2000).

In order to test whether the N400 reflects a general effect of surprise due to a mismatch or is actually related to sentence processing, Kutas and Hillyard (1980b) presented both semantically anomalous sentences and sentences containing a physically deviating word (bold-faced printed). The physical deviation led to a P300 but not to an N400, suggesting that the N400 was indeed related to sentence processing.

The N400 was shown not only to occur in semantically anomalous sentences, but this component was also observed in single words of a correct sentence. Non-words, thus, showed a greater N400 than real words (e.g. Bentin, McCarthy & Wood, 1985).

Furthermore, several studies showed that the N400 varies with respect to the expectation of a certain word in a sentence (Kutas, Lindamood & Hillyard, 1984; Brown & Hagoort, 1993). The amplitude was shown to be larger, when the word is unexpected (“The pizza was too hot to cry.” in Kutas, Lindamood & Hillyard, 1984). Respectively, when a word is highly expected to occur in a sentence context and, thus, the cloze probability is high, the amplitude of the N400 is smaller (“The pizza was too hot to eat.”). Thus, the N400 reflects difficulty with the integration of a new word into the prior sentence context.

Finally, the N400 was shown to occur in both sentence-internal and sentence-final position (Kutas & Hillyard, 1983).

3.4.2.2 The (E)LAN

Left anterior negativities were found in relation to syntactic anomalies, especially in phrase structure violations and in morphosyntactically incorrect sentences. I will first give an overview on studies, which found an ELAN (early left anterior negativity) or LAN (left anterior negativity) in phrase structure violations.

Neville, Nicol, Barss, Forster and Garrett (1991) first described an early negativity when they compared English visually presented word category violations (realized by an inverted word order) to correct sentences. They found a negativity peaking at about 125 ms after stimulus onset with a left anterior distribution.

The ELAN component was replicated in different languages such as German (Friederici, Pfeifer & Hahne, 1993; Friederici, Hahne & Mecklinger, 1996; Hahne & Friederici, 1999, 2002; Friederici, Gunter, Hahne & Mauth, 2004 in sentences where a noun was missing in the prepositional phrase), Dutch (Hagoort, Wassenaar & Brown, 2003), French (Isel, Hahne & Friederici, 2004), and Spanish (Hinojosa, Martín-Loeches, Casado, Muñoz & Rubia, 2003). Furthermore, it was found in both the visual (e.g. Neville et al., 1991) and the auditory modality (e.g. Friederici et al., 1993).

This ERP component was interpreted to reflect phrase structure building processes triggered on the basis of word category information (for a review see e.g. Friederici, 2004). The ELAN is considered to be automatic in nature as the component neither varies with the proportion of correct and incorrect sentences presented during the experimental setting (Hahne & Friederici, 1999) nor by attentional factors (attention directed to semantically incorrect sentences in Hahne & Friederici, 2002). Thus, the ELAN seems to reflect automatic first-pass parsing strategies.

The latency of the ELAN in phrase structure violations was found to differ depending on the point of availability of word category information (the so-called word category recognition point). Whereas the ELAN occurs early in time (between 100 and 300 ms) when the category violation is encoded early, for example in the prefix of the critical item (e.g. Friederici et al., 1993; Hahne & Friederici, 1999; 2002) or at a short preposition (Neville et al., 1991), it was observed somewhat later in time (between 300 and 500 ms) when the category information was encoded in the suffix (e.g. Friederici et al., 1996; Friederici et al., 2004) or occurred at different points within the critical word (Hagoort et al., 2003; Hinojosa et al., 2003).

Further, the latency of the ELAN was shown to vary as a function of the input contrast when phrase structure violations are presented visually (Gunter, Friederici & Hahne, 1999). The ELAN occurred early when a high visual contrast was present and it occurred later (> 300 ms) when the visual contrast was low.

Although the term of this ERP component implies a left-lateralization, it was often found to be bilaterally distributed. Herrmann, Friederici, Oertel, Maess, Hahne and Alter (2003) showed that in German phrase structure violations where the pitch was flattened, the ELAN showed up a right anterior distribution, suggesting that the bilateral distribution in normally auditorily presented sentences might be due to prosodic influences.

Recent MEG studies identified a magnetic counterpart to the ELAN, the so-called magnetic early left anterior negativity (mELAN). Kubota and colleagues showed that such an mELAN was present in within phrase violations but not in across phrase violations (Kubota, Ferrari & Roberts, 2003; 2004; Kubota, Inouchi, Ferrari & Roberts, 2005).

Apart from phrase structure violations left anterior negativities were often found in correlation with morphosyntactic aspects. This ERP component typically occurs within a time range between 300 and 500 ms and reflects the detection of the morphosyntactic mismatch. A LAN was observed in both the visual and auditory modality and in correlation with subject-verb-agreement violations (Osterhout & Mobley, 1995, in English sentences, which contained a singular-plural mismatch; Gunter, Stowe & Mulder, 1997, in Dutch sentences, which contained a mismatch between infinitives and participles; Friederici et al., 1993, in German sentences, which contained an inflection error instead of the correct participle; Barber & Carreiras, 2005, in Spanish gender and number agreement violations; Angrilli, Penolazzi, Vespignani, De Vincenzi, Job, Ciccarelli, Palomba & Stegagno, 2002 and De Vincenzi, Job, Di Matteo, Angrilli, Penolazzi, Ciccarelli & Vespignani, 2003, in Italian sentences with a singular-plural mismatch), gender violations (Gunter, Friederici & Schriefers, 2000, in German article-noun agreement violations), verb tense violations (Osterhout & Nicol, 1999), and morphological violations concerning word pair mismatches (Münte, Heinze & Mangun, 1993, in English pronoun-verb and pronoun-noun incongruities), incorrect irregular participles (Penke, Weyerts, Gross, Zander, Münte & Clahsen, 1997, in German), and in misapplication of stem formation (Rodriguez-Fornells, Clahsen, Lleó, Zaake & Münte, 2001, in Catalan).

LAN effects have also been attributed to verbal working memory processes (e.g. Coulson, King & Kutas, 1998). However, some recent studies showed that there are differences between negativities related to morphosyntactic processes and working memory aspects. King and Kutas (1995), for example, found that the former occur more locally after the violated element of the sentence while the latter are visible globally over the whole sentence.

3.4.2.3 The P600

This positivity peaking at about 600 ms after stimulus onset and showing a centro-parietal distribution occurs in correlation with syntactic aspects. It was interpreted to reflect processes of structural reanalysis (Osterhout & Holcomb, 1992; 1993) as it was observed in violations of structural preferences (so-called garden-path sentences).

Furthermore, the P600 component was observed following the ELAN or LAN effects in phrase structure (Friederici et al., 1993; Friederici et al., 1996; Hahne & Friederici, 1999, 2002; Friederici et al., 2004; Hagoort et al., 2003; Isel et al., 2004; Hinojosa et al., 2003) and morphosyntactic agreement violations (Osterhout & Mobley, 1995; Gunter et al., 1997; Friederici et al., 1993; Barber & Carreiras, 2005; Angrilli et al., 2002; De Vincenzi et al., 2003), suggesting processes of syntactic repair. Kaan, Harris, Gibson and Holcomb (2000) found the P600 as a marker of syntactic integration difficulty. They investigated sentences with varying integration difficulty and found a P600 for elements that were difficult to integrate.

Hahne and Friederici (1999) could show in an ERP study that the P600 varies with the proportion of presented correct and incorrect sentences and thus reflects second-pass parsing processes, which are of a more controlled nature.

3.4.2.4 The Neurocognitive Model of Sentence Comprehension (A. D. Friederici)

Friederici (2002) proposes a neurocognitive model of sentence comprehension, which incorporates the various linguistic processing steps considering the temporal and neurotopographical dimension (Figure 3.4). It proposes three phases:

- Phase 1 (100-300 ms): The initial syntactic structure is formed on the basis of word category information (reflected by the ELAN).
- Phase 2 (300-500 ms): Lexical-semantic and morphosyntactic information is processed with the goal of thematic role assignment (reflected by the N400 and the LAN, respectively).
- Phase 3 (500-1000 ms): Different types of information are integrated and reanalyzed (reflected by the P600).

The model is compatible with syntax-first models as it assumes autonomous syntactic phrase structure building processes that precede semantic processes in early time-windows, but it is also compatible with those interactive models that claim interaction at later stages.

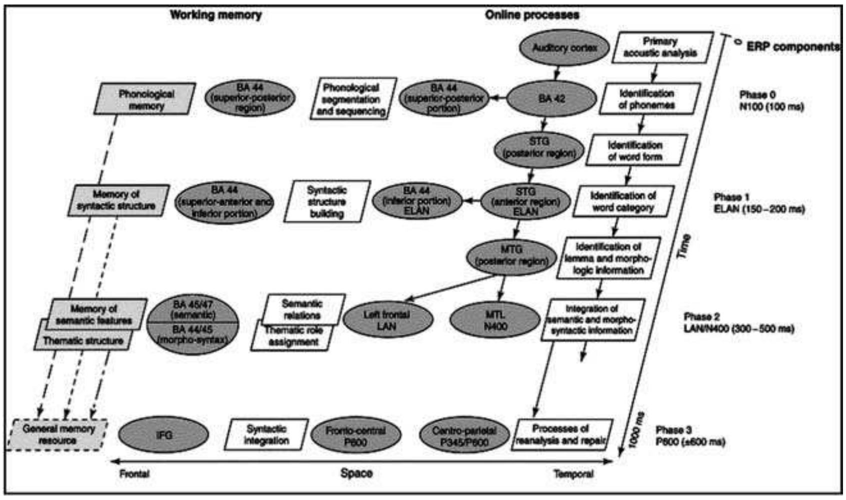

Figure 3.4: Neurocognitive model of sentence comprehension (Friederici, 2002). Squares represent the functional processes and ellipses their neuronal correlates. BA = Brodmann area; ELAN = early left anterior negativity; ERP = event-related brain potential; IFG = inferior frontal gyrus; LAN = left anterior negativity; MTG = middle temporal gyrus; MTL = middle temporal lobe; STG = superior temporal gyrus.

Chapter 4

Investigating second language processing

Research on second language mainly focuses on the investigation of the different linguistic aspects, how they are acquired and processed, considering either the modality of second language production or its comprehension. An important issue concerns the question whether age of acquisition in the sense of Lenneberg's critical period hypothesis influences the acquisition of various linguistic aspects or if other factors such as a high L2 proficiency level, the period of exposure or the learning environment can lead to native-like processing mechanisms or can enhance the learning process. Different methodological approaches have been adopted in second language research. These methods cover behavioral measures in normal and pathological persons (such as aphasics), neuroimaging methods such as fMRI and PET, and neurophysiological approaches such as EEG and MEG.

4.1 Behavioral studies

Johnson and Newport (1989) investigated Korean and Chinese native speakers, which had arrived in the United States either before age 15 (the earliest arrivals started at 3 years of age) or after age 17. Thus, they learned English as a second language via immersion in the USA. They studied 12 different syntactic and morphological features of English (past tense, plural, third person singular, present progressive, determiners, pronominalization, particle movement, subcategorization, auxiliaries, yes/no questions, wh-questions, and word order) while participants had to judge the correctness of the spoken sentences (grammaticality judgment task). The participants, who arrived in the USA prior to age 15 had a clear performance advantage on all tested grammatical aspects in contrast to persons who arrived later.

The performance was, therefore, linearly related to the age of arrival up to puberty. Persons who arrived after the age of 17 showed low performance, which was highly variable and unrelated to age of arrival. Thus, this study provides clear evidence for the existence of age of acquisition effects.

A further study (Johnson & Newport, 1991) investigated whether similar age of acquisition effects occur only in language-specific structures or may also apply to aspects of universal grammar (Chomsky, 1957, 1965, 1981), which are considered to be innate. They studied the universal principle of subjacency in English by means of a grammaticality judgment task. The material contained declarative (correct) sentences, subjacency violations with wh-questions, control sentences that were grammatical but moved a wh-word in similar sentences only over one bounding node, and no subject-auxiliary inversion sentences that contained an English-specific ungrammatical structure. These different sentence types were created in three different structures to which subjacency is relevant in English: noun-phrase complements, relative clauses, and wh-complements. As in Johnson and Newport (1989), participants were native speakers of Chinese, who either arrived early (between 4-16) or late (between 18-38) in the USA. Even though late learners started their immersion to English in the USA as adults, almost all of them had received some formal classroom training in English at an earlier age (13.5 years on average). First of all, the performance of subjacency structures was in all subjects non-native-like. However, the earlier the age of arrival in the USA the better was the performance. The performance was worst (at levels slightly above chance) for participants who learned English through immersion during adulthood, suggesting that the subjacency principle is not fully accessible to the mature second language learner. This study demonstrates that maturation effects are also present regarding principles of universal grammar and are not only restricted to language-specific structures.

Bialystok and Miller (1999) used a grammaticality judgment task to investigate five different grammatical (morphological) structures in English. The violation comprised errors of plurals, determiners, future tense, present progressive, and collocation restriction. Participants were either Chinese, Spanish or English native speakers.

The first two groups were subdivided into early (started learning L2 before age 15) and late L2 learners (started learning L2 after age 15). The results showed for the Spanish native speakers a clear age of acquisition effect. They made fewer errors when they started learning the second language early and had a higher L2 proficiency than late learners. This effect, however, was not present in the Chinese native speakers group. The authors state as a possible explanation the longer length of residence in Canada for the Spanish participants and a greater similarity between English and Spanish than between English and Chinese. In sum, the study provides further evidence in favor of the influence of the age of acquisition during the learning of syntactic aspects.

Many studies reported similar age of acquisition effects. However, an interesting question focuses on the fact whether native-like L2 proficiency can also be attained when the second language is learned after puberty. Birdsong (1992) addressed this issue by testing native speakers of English who started learning French at or post puberty (at 14.9 years on average). All subjects were tested in France and they all had been living continuously in France for at least three years immediately prior testing. They were compared with native speakers of French. The experiment involved an acceptability judgment task of French sentences containing constructions related or unrelated to universal grammar principles (*en*-avant, adjacency, *that*-trace, middle voice, *de* + modifier, *ce/il (elle)*, and prenominal past participle) and an interpretation task in which subjects had to judge the most probable interpretation of decontextualized ambiguous sentences, and a further interpretation task in which the most appropriate meaning of the adverb *bien* should be judged. The main result of the study concerns the fact that the postpubertal L2 learners performed like natives, suggesting that there must be some exceptions to the general assumption of a critical period terminating with puberty. However, AoA effects were nevertheless present, as an earlier arrival in France, even if past puberty, was related to the attainment of native norms. These results were obtained for the acceptability judgment as well as for both interpretation tasks. Furthermore, this study showed that similar to Johnson and Newport (1991) principles of universal grammar (such as *en*-avant, adjacency, *that*-trace) are not fully accessed by all L2 learners.

However, the author claims some caution in generalizing these results to all linguistic aspects as the near-native subjects of this study represent a single L1 background (English), only a small fraction of linguistic knowledge was assessed and this knowledge was tested via crude and imperfect methods. Thus, this group of subjects may represent exceptional learners.

Flege, Yeni-Komshian and Liu (1999) investigated above all the pronunciation in the second language, i.e. the accent. Korean native speakers who came to the USA between 1 and 23 years of age should repeat English sentences. Independent English native listeners judged the foreign accent on a 9-point scale (1 = very strong foreign accent; 9 = no accent). The results showed a correlation between the AoA and the foreign accent. As AoA increases, the foreign accent grew stronger. The assessment of English morphosyntactic knowledge (past tense, plural, third person singular, determiners, pronouns, participle movement, subcategorization, lexically specified subject/object raising, yes/no questions, wh-questions) was also included through a grammaticality judgment task. The results for the grammaticality judgment task also indicated AoA effects. However, subanalyses revealed that they are of different nature compared with the phonology effect. The AoA effect concerning the foreign accent was independent of confounding factors, and therefore derived directly from the increasing AoA, arguing in favor of a critical period. The morphosyntax effect, on the other hand, was mainly determined by confounding factors such as the amount of education they received in English, their length of residence in the USA, or their use of English and Korean (all factors, which were correlated with AoA), and thus indicates no direct relation to a maturationally defined critical period.

4.2 Neuroimaging studies

An important contribution to second language research was provided by the neurosciences in the last years. This area of research focuses especially on the issue whether the native language and the second language are localized in the same areas or if they are subserved by different neural regions. The investigation of aphasic patients provided interesting findings to second language research. Thus, cases of bilingual persons were described who suffered from a language impairment regarding one of the two languages after a brain lesion in the area of the thalamus or the basal ganglia (Fabbro, 1999). However, some of the patients had impairments in their native language but not in their second language, whereas others showed the vice versa pattern. Additionally, some modalities were identified, which were neither impaired in the L1 nor in the L2. These comprise aspects such as spontaneous speech, or the repetition of words. However, these results do not provide sufficient evidence in order to determine whether the same areas are involved in L1 and L2 processing or whether a network connects them with each other. An additional problem arises in aphasia research such as influencing factors like structural differences among languages or different contexts of usage depending on the native and second language. Such factors might affect the degree, type and course of aphasia.

More detailed information about the localization of native and second language processes in the brain are provided by neuroimaging techniques such as fMRI and PET. I will first refer to some studies investigating speech production and then, introducing neuroimaging studies on speech comprehension.

4.2.1 Studies on language production

Klein, Zatorre, Milner, Meyer and Evans (1994) investigated in a PET study English native speakers who learned French after the age of 5 and used both languages actively in daily usage, i.e. had a high L2 proficiency level. The subjects had to perform a repetition task of English and French words presented acoustically.

The results showed that the same regions were active during the production of first and second language words. An exception was the putamen in the left hemisphere. The activity in this area was greater when participants repeated second language words. The authors emphasize the role of the putamen for articulation processes during the production of a second language learnt late in life, indicating the need for complex motor control during L2 production.

Klein, Milner, Zatorre, Meyer and Evans (1995) showed similar results in another PET study in which participants (again English native speakers who learned French after age 5 and had a high L2 proficiency level) had to perform three tasks additionally to the repetition of words. These tasks included the generation of rhymes (phonological aspects), synonyms (semantic aspects), and the translation of words. This study again provided evidence for the same activation areas in the left inferior frontal cortex, in the adjacent posterior dorso-lateral cortex, as well as in left parietal and infero-temporal regions for both L1 and L2. No right-hemispheric activation was present.

Klein, Milner, Zatorre, Zhao and Nikelski (1999) replicated these findings in a PET study with Mandarin-Chinese native speakers who had learned English after the age of 10 and were fluent in both languages. A word repetition task of English and standard Chinese words and a verb generation task after the presentation of a noun were included. An increased cerebral blood flow was present for both languages (L1 and L2) in the left inferior frontal, the dorsolateral frontal, temporal, and parietal cortices as well as in the right cerebellum. Again the results suggest common neural substrates for the native and the second language even though the second language was learned late in time.

Also Chee, Tan and Thiel (1999) found the same activation foci for L1 and L2 in Mandarin-English bilinguals performing a word generation task (cued by a visually presented word stem). No difference was further present for early bilinguals who learned L2 before age 6 and for late bilinguals who learned L2 after the age of 12. The activated areas were located in the left prefrontal cortex, along the inferior and middle frontal gyri (BA 9/46 and BA 44/45).

The studies presented so far do not provide evidence for AoA effects during production tasks as the same cerebral representation area was active, irrespective of the usage of the native or the second language, even when it was acquired late. Kim, Relkin, Lee and Hirsch (1997) directly compared early L2 learners who learned L2 during childhood with late L2 learners who learned L2 during adulthood in an fMRI study. However, the group of participants was heterogeneous as they had different L1-L2 configurations. Prior to the imaging session subjects had to describe events that happened in the morning, afternoon, and evening of the day before. Then during the two imaging sessions the participants saw different graphic, non-linguistic, stimuli concerning the morning, afternoon, or evening. After the presentation of these cues the subjects were instructed to produce sentences silently (internal speech) in one of the two languages. In order to prevent from habituation effects the languages were alternated. The results showed common areas of activation for L1 and L2 in left frontal areas (including Broca) for early bilinguals, whereas spatially separated areas were activated in late bilinguals. In Wernicke's area, the first and second language of both early and late bilinguals were active in the same regions. This study shows AoA effects in the sense that early and late L2 learners display either common or distinct neural representations of L1 and L2.

These apparently diverging results may be explained by introducing the variable proficiency. While the participants in the former studies (Klein et al, 1994; 1995; 1999; Chee et al., 1999) had a high proficiency in the second language the subjects in Kim et al. (1997) had an inferior proficiency. We will see the importance of these factors in the next section on language comprehension (4.2.2).

Another important factor, which resulted to influence the activation patterns between L1 and L2 is the amount of exposure to a language. Yetkin, Yetkin, Haughton and Cox (1996) investigated the activation of different languages during a silent word generation task (cued by the presentation of the initial letter) with fMRI. The participants were selected according to several criteria: apart from their native language they should speak a second language fluently and a third language non-fluently. Fluency was defined as speaking the language currently and for at least 5 years.

Non-fluency referred to subjects who studied the language for 2 to 4 years and who did not use it regularly in everyday life. The language combinations across subjects varied and were not kept constant. The activated areas were localized in the left prefrontal cortex, especially in the inferior frontal, middle frontal, and precentral gyri. However, the activation was greatest for the less fluent languages. These results emphasize the importance of language exposure for the activation of a greater network. When a language is not used regularly, a larger neural network seems to be needed for language processing.

4.2.2 Studies on language comprehension

A further line of research focuses on language comprehension and its various linguistic domains such as listening to stories, semantic and syntactic processing.
Dehaene, Dupoux, Mehler, Cohen, Paulesu, Perani, van de Moortele, Lehéricy and Le Bihan (1997) investigated with fMRI the language comprehension during listening to stories presented in their native language (French) and their second language (English), which they learned after the age of 7. The participants had a medium level of L2 proficiency. Listening to the native language led to the activation in the left temporal lobe, along the left superior temporal sulcus, whereas listening to the second language activated a variable network from left and right temporal to frontal regions, sometimes only including right-hemispheric areas. The authors concluded that the native language is related to a left-hemispheric network and the second language to a different neural substrate.

The importance of L2 proficiency for showing the same brain activation patterns was demonstrated by Perani, Paulesu, Sebastian Galles, Dupoux, Dehaene, Bettinardi, Cappa, Fazio and Mehler (1998) who showed no differences in brain activation between the native language (Italian) and the second language (English) in late second language learners (L2 acquisition after age 10) with a high L2 proficiency level. They conducted an fMRI study while participants listened to stories presented in their native, second, and an unknown language (Japanese). The high proficient L2 learners activated a broad network of areas in the temporal lobe.

On the contrary, late L2 learners with a poor second language level showed a different activation between the L1 and L2 (Perani, Dehaene, Grassi, Cohen, Cappa, Dupoux, Fazio & Mehler, 1996). Low proficient learners listening to the native language activated a greater network in temporo-parietal regions than participants listening to the L2. The study (Perani et al., 1998) also included early L2 learners (Spanish-Catalan bilinguals who learned the second language before age 4 and thus, were also high proficient) who listened to Spanish and Catalan stories. The results for this group showed, similar to the high proficient late learners, no activation difference between the dominant and the non-dominant language. From these findings the authors concluded that the acquired proficiency plays a more important role than the age of second language acquisition.

Illes, Francis, Desmond, Gabrieli, Glover, Poldrack, Lee and Wagner (1999) concentrated on semantic processing in bilinguals. They conducted an fMRI study with either English or Spanish native speakers who acquired the second language (either Spanish or English) sequentially to the native language at a mean age of acquisition of 12.25 years. They were fluent in both languages and had to perform two judgment tasks about visually presented words. The first required a semantic decision about whether words were concrete or abstract in meaning and the second required a non-semantic decision about whether words were printed in uppercase or lowercase type. A greater activation in the left and right frontal gyrus (with the maximum in the left portion) was found for semantic in contrast to non-semantic processing. However, no activation difference was present comparing English and Spanish, suggesting the same neural system underlying semantic processing in L1 and L2. These findings were also attributed to the high proficiency level of the subjects as they showed a near-perfect performance for both languages. The authors, thus, concluded that the proficiency clearly affects the cortical representation and the processing of a second language in the direction that it becomes similar to the L1 processing as the proficiency in late L2 learners increases.

A recent fMRI study by Wartenburger, Heekeren, Abutalebi, Cappa, Villringer and Perani (2003) investigated whether semantic and grammatical aspects are processed differently in the bilingual brain considering both the AoA and the proficiency level. They included three groups of subjects: Italian-German bilinguals who learned the L2 early, before age 6, and had a high proficiency and bilinguals who learned the L2 late and had either a high or low proficiency. Subjects had to perform correctness judgments concerning grammatical violations (disagreement of number, gender, or case) and semantic violations in both languages. High proficient late learners showed a more extensive activation for L2 than L1 in Broca's area during grammatical processing. High proficient early learners, on the other hand, did not show any different activation between the two languages. Because these two groups (early and late learners) displayed activation differences (without behavioral performance differences) in the grammatical task but not in the semantic task, these results speak in favor of AoA effects affecting grammatical processing to a greater extent. In contrast, during semantic processing the two late learners groups (high versus low proficiency) showed different activation areas. Low proficient late learners activated more extensively Broca's area and the right middle frontal gyrus, whereas the high proficient late learners displayed a greater activation in left middle frontal and right fusiform gyrus. In both groups, L2 led to a greater activation than L1. In sum, age of acquisition seems to have a greater impact on the cerebral correlates of grammatical processing, whereas the proficiency level affects semantic processing to a greater extent.

In a recent study Perani, Abutalebi, Paulesu, Brambati, Scifo, Cappa and Fazio (2003) underlined apart from the age of acquisition and proficiency level the importance of language exposure or usage in early bilinguals. The results showed a smaller activation in prefrontal regions in bilinguals with a high exposure to the second language than in bilinguals less exposed to L2. The lower prefrontal activation was seen in correlation with a lower activation threshold indicating more automaticity and the need for less neural resources in case of a high exposure to L2. This finding is in accord with results from production studies (Yetkin et al., 1996), which also found a smaller activation network for regularly used languages.

Rüschemeyer, Fiebach, Kempe and Friederici (2005) investigated auditorily presented syntactic and semantic anomalies in two typologically different languages such as German and Russian and compared the activation of L2 learners of German with the activation of German native speakers by means of fMRI. First, they found the same activation pattern in both German and Russian native speakers in all conditions. Second, high proficient late L2 learners, however, showed some differences regarding the syntactic anomalies suggesting increased syntactic processing costs associated with parsing a second language. Furthermore, in all conditions they activated specific portions of the frontotemporal language network including the inferior frontal gyrus (IFG), superior temporal gyrus (STG) and subcortical structures of the basal ganglia differently from those used by native speakers. Semantic anomalies, on the other hand, showed a similar activation in L2 compared to L1 reflected by overlapping activations in the left anterior IFG.

4.3 Electrophysiological studies

Many EEG studies in second language research focused primarily on the processing of semantic and different syntactic aspects. The central question concerns whether second language learners can display the same ERP components, i.e. the same processing steps, as native speakers, under which circumstances this may happen and whether the ERP components are of the same quality (amplitude and latency) as in monolinguals.

Ardal, Donald, Meuter, Muldrew and Luce (1990) investigated fluent English/French bilinguals who had acquired the second language either before or after age 11 and monolinguals. They conducted an ERP study on semantic processing in which they presented visually congruent and semantically incongruent French and English sentences to which the participants had to perform a correctness judgment task. The ERPs revealed an N400 effect when incongruous sentences were compared to congruous ones. The N400 was present in monolinguals, and in both the first and second language of bilinguals. Both monolingual groups displayed a virtually identical ERP pattern. The bilingual group, however, displayed a longer N400 latency in either their first and second language compared to the monolinguals.

The peak of the N400 in monolinguals occurred for example at right parietal electrodes at a mean latency of 365 ms, then the first language of the bilinguals was next at 371 ms and the longest latency was observed for the second language in bilinguals at 408 ms. Further the results did not show any age of acquisition effect concerning the N400 between the early and late second language learners.

An ERP study (McLaughlin, Osterhout & Kim, 2004) investigated the N400 component for pseudowords, words that were semantically unrelated to the preceding word, and words that were semantically related to the preceding context in late L2 learners of French at different learning stages (session 1: mean 14 hours of formal instruction; session 2: mean 63 h; session 3: mean 138 h). For native speakers the N400 amplitude was largest for pseudowords, intermediate for unrelated words, and smallest for related words. These amplitude differences in L2 learners were found to correlate positively (r=.72) with the hours of instruction, i.e. language exposure. Already after 14 hours of L2 instruction sensitivity between pseudowords and words was observed. After about 60 hours effects of word meaning, i.e. differences between related and unrelated words, were present, and at the end of the learning period (after about 9 months) the amplitude of the word/non-word differences approximated that typically observed in native speakers. The authors concluded that adult word learning changes rapidly within a relatively short learning period.

A recent ERP investigation on semantic anomalies (Moreno & Kutas, 2005) studied Spanish-English bilinguals while reading semantically correct and incorrect sentences. Bilinguals were subdivided into Spanish-dominant bilinguals who had late exposure and reduced vocabulary proficiency in L2 (English) and English-dominant bilinguals who had early exposure to both Spanish and English but had a greater proficiency in English. In both groups an N400 effect was present but it occurred later (concerning both the onset latency and the peak latency) for the non-dominant in contrast to the dominant language. The authors further found, that vocabulary proficiency and age of exposure were both important in determining the timing of semantic integration effects during written sentence comprehension.

The processing of conceptual-semantic aspects can also be investigated by a semantic priming paradigm. During this paradigm first a word (prime) is presented and a second, related or unrelated, word is afterwards presented. Such a paradigm predicts faster response times to targets that are semantically related to the prime. Semantic priming is, thus, used to study the conceptual activation of an L2 word in bilinguals. If concepts are shared between different languages equal semantic priming effects should be visible for L1 and L2. Kotz (2001) investigated fluent early L2 learners (L2 acquisition prior to age 4) using a semantic priming paradigm that included both categorical (junior-boy) and associative priming (girl-boy) by means of ERPs. Participants had to perform a single word presentation lexical decision task. The ERP results showed no differences regarding the N400 pattern between the first and second language in high proficient early L2 learners for both categorical and associative priming. These results suggest that fluent bilinguals can directly access conceptual representations in L1 and L2 and do not confirm the revised hierarchical model by Kroll and Stewart (1994) that assumes a weaker conceptual link for L2 words than for L1 words and thus predicts asymmetrical priming effects between L1 and L2.

Kotz and Elston-Güttler (2004) used the same experimental paradigm to study the role of proficiency in late second language learners. High and low proficient German late (age of acquisition after 11 years) L2 learners of English performed a word lexical decision task while the EEG was recorded. Both the high and low proficient group displayed N400 priming effects concerning associative priming but with some qualitative differences. The N400 effect in high proficient learners lasted longer indicating difficulty in relating a prime to the target word. However, the N400 of the low proficient group was very similar to that of native speakers or early learners (Kotz, 2001). This different pattern was seen as a developmental change during late L2 processing that suggests high proficient learner’s ability to more fully process semantic information in contrast to low proficient learners. The results for associative processing thus indicate an influence determined by the proficiency level.

Categorical information, on the other hand, showed very limited (in high proficient L2 learners) or no (in low proficient L2 learners) N400 priming effects suggesting that the link between a word and its concept is not strong enough in late L2 processing, neither for the high nor for the low proficient learners. From these results the authors draw the conclusion that categorical information processing might be more likely determined by age of acquisition effects.

Phillips, Segalowitz, O'Brien and Yamasaki (2004) found similar ERP results concerning the processing of associative information using a semantic priming paradigm. They investigated the ERPs of high and low proficient L2 learners of French (English was the native language, French was learned at about 6 years of age). The results showed, similar to Kotz and Elston-Güttler (2004), clear differences in associative processing between high and low proficient L2 learners. An N400 priming effect was present in the high proficiency group in both L1 and L2. Low proficient learners, however, did not show any priming effect in L2, but in L1 processing. Further, the N400 effect in the high proficient group was delayed by approximately 50 ms in the L2 when compared to the L1 suggesting a slower processing probably due to the need to access L2 words via the L1 lexicon. This interpretation would fit with the revised hierarchical model (Kroll & Stewart, 1994).

Several other studies investigated both semantic and syntactic processing within one study pointing to the question whether the processing of a second language displays differences between these two linguistic aspects or if one is more difficult than the other.

Weber-Fox and Neville (1996) investigated by means of ERPs semantically and syntactically anomalous sentences in Chinese native speakers who learned English at different ages (between 1-3 years, 4-6 years, 7-10 years, 11-13 years, and above 16 years). The syntactic violation included above all a word category violation elicited by an inverted word order variation (The scientist criticized Max's <u>of</u> proof the theorem.). The sentences were presented visually and the subjects had to judge the correctness of the sentences. The results are summarized in Table 4.1.

Table 4.1: Summary of the ERP results found in Weber-Fox and Neville (1996).

Age of L2 acquisition	*Semantic violation*	*Word category violation*
1-3 years	N400	No early negativity Negativity 300-500 (left) P600
4-6 years	N400	No early negativity Negativity 300-500 (left) P600
7-10 years	N400	No early negativity Negativity 300-500 (left) P600
11-13 years	Delayed N400	Early negativity (right) Negativity 300-500 (bilateral) Delayed P600
> 16 years	Delayed N400	Early negativity (right) Negativity 300-500 (bilateral) No P600

The semantic violation showed an N400 associated with lexical-semantic integration processes in all bilingual groups. However, this ERP component was delayed in bilinguals who acquired L2 after the age of 11. ERPs for the syntactic violation were subject to more alteration by age of acquisition delays. AoA effects were present in case of reduced asymmetries of syntactic negativities and the absence of the late positivity in bilinguals who were exposed to L2 after the age of 11.

Hahne and Friederici (2001) investigated by means of ERPs semantic and syntactic processing in Japanese native speakers who started learning German after puberty and who had some knowledge of L2 but had not reached a very high second language level. Participants had to perform a judgment task to correct and semantically (selectional restriction error: “Der Vulkan wurde gegessen.” / “The volcano was eaten.”) and syntactically incorrect sentences (word category error: “Das Eis wurde im gegessen.” / “The ice cream was in-the eaten.”) that were presented acoustically. The results showed an N400 effect regarding the semantic condition, which was similar to that of native listeners. However, concerning the syntactic anomaly no expected ERP component, neither an ELAN nor a P600, was observed.

In another study, Hahne (2001) tested Russian native speakers who had learned German after the age of 10. These participants who had a higher level of second language performance showed a late positivity (P600) reflecting reanalysis processes in the same syntactic condition as in Hahne and Friederici (2001). The ELAN component, however, was not present. The author interpreted these results as the consequence of the higher L2 proficiency compared to the Japanese native speakers (Hahne & Friederici, 2001). The absence of the early automatic ERP component also in more proficient L2 learners indicated that automatic processing mechanisms might not be available to late L2 learners. Concerning the semantic condition, this study again revealed an N400 effect, which however showed a reduced amplitude and a longer peak latency compared with German native speakers. These differences arose from the fact that L2 learners displayed an increased N400 also for correct sentences suggesting that semantic integration of the sentence final word was more difficult for second language learners than for native listeners.

Friederici, Steinhauer and Pfeifer (2002) addressed the question whether apart from controlled processes such as P600 also automatic syntactic first-pass parsing processes reflected by the ELAN component can be elicited in late second language learners with a high proficiency level. They trained German native speakers in Brocanto, a miniature artificial grammar, which contained four nouns, four verbs, two adjective, two adverbs, and two determiners. Simple 5-8 word-sentences were constructed, the half of which were syntactically anomalous containing a word category violation. After subjects underwent a training that ensured a high degree of proficiency, they were presented acoustically the correct and incorrect sentences while they had to perform a grammaticality judgment task. The ERP results showed an ELAN and a P600 to syntactically anomalous sentences. These findings suggest that at least in second language acquisition of a miniature language a native-like ERP pattern can be elicited provided that fact that participants have a high proficiency level.

Thus, the results confirm the so-called "less is more hypothesis" proposed by Newport (1990), which assumes that children have cognitive limitations, i.e. when they are exposed to a word they can only store a limited amount of forms and meanings, and this limitations provide a computational advantage. Thus, because in the Brocanto language only a restricted amount of rules and words had to be learned and processed, this can lead to native-like processing mechanisms.

A recent ERP study by Mueller, Hahne, Fujii and Friederici (2005) also investigated above all word category violations in a miniature grammar of Japanese in trained German natives. However, they failed to find such an early syntactic ERP component as in Friederici et al. (2002). Only a P600 was present. The authors found instead of an early anteriorly distributed negativity to word category violations a central negativity, which could be attributed to the processing of prosodic phrase boundaries reflected by a positivity (closure positive shift = CPS, see Steinhauer, Alter & Friederici, 1999; Steinhauer & Friederici, 2001) occurring in correct sentences. Thus, no typical ELAN component was present in late L2 learners of a miniature language of Japanese despite a high proficiency level.

In a recent series of MEG studies Kubota and colleagues investigated the role of proficiency in late second language learners of English (Japanese native speakers) performing a grammaticality judgment regarding different syntactic anomalies. An early magnetic syntactic response, peaking at about 150 ms post-onset, was found in late L2 learners with a high proficiency level concerning syntactic NP-raising structures (Kubota, Ferrari & Roberts, 2004) and infinitive c-selection violations (Kubota, Inouchi, Ferrari & Roberts, 2005) but not in late L2 learners with a lower proficiency level (Kubota, Ferrari & Roberts, 2003).

Morphosyntactic aspects have less been investigated using ERPs in second language research, so far. One study (Sabourin, 2003) investigated the processing of finiteness, subject-verb agreement, and grammatical gender violations in Dutch native speakers and L2 learners of Dutch. The L2 learners were subdivided in three groups according to their native language German, Spanish, or English.

The aim of the study was to see how the second language processing is influenced by the L1 (i.e. language transfer versus UG accessibility). The native speakers of Dutch showed a P600 in each condition. The L2 groups also showed a P600 for the finiteness and the subject-verb agreement violations. However, concerning the latter one the P600 was similar to that of native speakers only in the German group, whereas Spanish and English native speakers displayed some differences in latency and distribution. Concerning the gender violations only the German group showed a significant P600. The results indicate that L2 learners can partially achieve native-like processing steps but at the same time the L1 has some impact on the L2 processing. This was visible as the German group had the most similar processing to native speakers due to the fact that German has a very similar gender system as Dutch, in contrast to Spanish or English.

Tokowicz and MacWhinney (2005) investigated different morphosyntactic aspects in English native speakers learning Spanish as an L2 (they were all beginners enrolled in the first four semesters of Spanish classes). Apart from a grammaticality judgment task, they conducted an ERP study while participants read sentences on a screen containing correct and incorrect sentences. Anomalies comprised a tense marking mismatch, a gender and a number agreement mismatch. Tense marking is similar in English and Spanish, whereas gender agreement is unique to the L2 and number agreement is formed differently in the L1 and L2 of the participants. The authors took the P600 as an index of syntactic processing and found that even though participants performed near chance on an explicit grammaticality judgment task, the implicit online ERP responses were sensitive to some violations in L2. This sensitivity, i.e. the presence of a P600, was observed for the tense marking condition, which was similar in L1 and L2, and in gender agreement violations, which were unique to L2. The authors interpret the latter finding in terms of no transfer from L1 to L2, because the L1 has no gender system. Thus, an implicit sensitivity is present for grammatical information that is unique to L2. Concerning the number agreement condition, no P600, i.e. no sensitivity is found for L2 learners. Because number agreement is formed differently in L1 and L2, L2 learners tend to think that L2 works like the L1 and thus a transfer from L1 to L2 occurs and leads to insensitivity of such violation types.

4.4 Overview over the experiments of the present study

The central aim of the present study was to investigate in a series of ERP experiments the role of proficiency in syntactic second language processing. Many previous studies found native-like processing mechanisms during processing of semantic aspects. However, the processing of syntactic information revealed to be more difficult in second language learners and thus, led to a different ERP pattern. In order to address systematically the impact proficiency has on the brain processing steps during acoustically presented syntactic information, only the L2 proficiency was varied whereas the age of L2 acquisition was kept constant.

The syntactic anomalies included in the present study were a word category violation, realized by the omission of a noun after a preposition, a morphosyntactic subject-verb agreement violation, realized by an inflexion error on the verb, and a combination of both violations containing both a word category and an agreement error.

Two different languages were investigated, namely German and Italian. These two languages were chosen because they belong to two different linguistic lines within the Indoeuropean languages, namely the Germanic and Romance line, but allow the realization of two equivalent materials with the same syntactic anomalies, the same amount of words per sentence, and the same word order. These different linguistic lines display several formal differences concerning the phonology, morphology, and syntax. The present study aimed to test whether such formal differences are reflected also in the neuronal correlates, i.e. the ERP pattern, even though the German and Italian material are equivalent. On the basis of several studies in the literature using the same conditions in different languages, I assume the same brain processing steps in both languages.

ERP studies on different syntactic information types had already been conducted in several languages, including German. However, there is no study so far, investigating word category violations in Italian. Thus, it was especially of great interest to analyze the ERPs of this violation in Italian in order to see whether the same processing steps can be replicated as found in other languages.

Experiment 1, therefore, investigated the ERPs of Italian native speakers listening to Italian sentences, containing correct and syntactically incorrect sentences (word category violation, agreement violation, and a combination of the two). The word category violation was expected to show the same processing steps as observed in previous studies using different languages, namely an early anterior negativity reflecting processes of phrase structure building and a P600 reflecting reanalysis and repair. Because a recent ERP study using the German material of the present study in German native speakers found apart from the early anterior negativity and the P600 a negativity in between, this additional negativity was also expected to show up in Italian native speakers. This negativity is assumed to reflect reference-related processes because of the specific sentence structure (prepositional phrase part of the subject noun phrase and thus, specifying the subject noun). Concerning the agreement violation again the same processing steps were also expected for Italian, namely an anterior negativity reflecting the detection of the morphosyntactic error and a P600. Concerning the combined condition several previous studies including a word category violation found the same processing steps as in the pure word category violation (for details see Chapter 5.1) suggesting primacy of word category information over other linguistic information types.

Experiment 2 and *Experiment 4* aimed to investigate high proficient L2 learners of German and Italian, respectively. Because of a high proficiency the ERP pattern should reflect that of native speakers. Especially in the light of interest is the early anterior negativity in word category violations. This ERP component is assumed to be automatic in nature and has never been found before in ERP studies on second language learners. However, this early component could be elicited in an ERP study embedding word category violations in an artificial miniature language with a restricted amount of syntactic rules and words. The present experiments aim to study whether such an early ERP component can be also elicited in late second language learners in the context of natural languages such as German and Italian provided the fact that L2 learners have a very high L2 proficiency level.

Experiment 3 and *Experiment 5* investigated low proficient L2 learners of German and Italian, respectively. The disadvantage of the proficiency level should lead to a differential ERP pattern concerning all syntactic anomalies, both of quantitative and qualitative kind. Thus, low proficient L2 learners are expected to suffer from either absence of ERP components and/or more latency delays and amplitude reductions.

Empirical Part

Chapter 5

Experiment 1:

Syntactic processing in Italian native speakers

5.1 Introduction

Morphosyntactic and word category information in native speakers have already been investigated in several ERP studies in different languages. I will briefly give an overview of the relevant studies.

Morphosyntactic subject-verb agreement violations typically showed electrophysiological correlates such as a left anterior negativity (LAN) approximately between 300 and 500 ms, which reflects the detection of the morphosyntactic mismatch, followed by a late positivity (P600) indicating processes of reanalysis or repair.
Friederici et al. (1993) violated German sentences morphosyntactically by replacing a correct participle in sentence-final position ("Der Finder wurde belohnt." / "The finder was rewarded.") with a verb in the first person singular ("Das Parkett wurde bohnere." / "The parquet was polish."). This acoustically presented agreement violation gave rise to a LAN and a subsequent P600.
Osterhout and Mobley (1995) also found a biphasic ERP pattern in English subject-verb-number violations ("The elected officials hope/*hopes to succeed.") presented in a word-by-word manner on a screen.
Gunter et al. (1997) investigated subject-verb agreement violations in Dutch by replacing the correct participle with the incorrect infinitive. The visually presented sentences of their first experiment only showed a tendency toward a LAN followed by a P600. The negativity effect, however, did not reach significance. In the second experiment of this study, the sentence complexity was varied.

In simple sentences the main clause followed a subordinate clause, whereas in complex sentences the subordinate clause was embedded in a main clause. In complex sentences, where increased working memory is required, morphosyntactic violations gave rise to a LAN and a P600.

Morphosyntactic violations were also investigated in Romance languages such as Italian and Spanish. Angrilli et al. (2002) and De Vincenzi et al. (2003) investigated Italian singular-plural mismatches ("Il cameriere anziano serve/*servono con espressione distratta." / "The old water serves/*serve with inattentive expression.") in the visual modality and found, also in Italian, a LAN followed by a P600.

Hinojosa et al. (2003) presented visually a verb-inflection violation in Spanish sentences created by the replacement of the correct third person singular with the incorrect first person singular ("La prueba ocultada por el fiscal apareció/*aparecí." / The proof hidden by the public prosecutor appeared$_{\text{3rd p. sing.}}$/*appeared$_{\text{1st p. sing}}$."). The results showed a LAN and a P600.

Barber and Carreiras (2005) also investigated Spanish grammatical gender and number violations in the visual modality. Again a LAN-P600 pattern was observable.

Word category violations, on the other hand, were found to typically elicit an early anterior negativity, sometimes more left lateralized (ELAN), which reflects processes of initial phrase structure building, followed by a late positivity (P600) indicating processes of reanalysis. This biphasic ERP pattern was found in different languages such as English (Neville et al., 1991), German (Friederici et al., 1993; Hahne & Friederici, 1999; 2002), Dutch (Hagoort et al., 2003), French (Isel et al., 2004), and Spanish (Hinojosa et al., 2003). Recent studies on word category violations reported apart from an ELAN and a P600 a negativity in between. Hinojosa et al. (2003) realized the word category error by omitting a noun in a prepositional phrase embedded in a relative clause ("La prueba ocultada por el Ø apareció." / "The proof hidden by the Ø appeared.").

A similar word category violation was also elicited in French sentences in Isel et al. (2004) ("L'enfant qui est dans la Ø dort." / "The child who is in-the Ø is sleeping.") and in German sentences in Rossi, Gugler, Hahne and Friederici (2005) ("Der Junge im Ø singt ein Lied." / "The boy in-the Ø sings a song.") and in Gugler, Rossi, Friederici and Hahne (submitted) ("Der Clown im Ø lacht." / "The clown in-the Ø laughs."). In all these studies the violation was part of a prepositional phrase, which specified the noun of the main clause, in contrast to other studies in which the violation was part of a verb phrase and which did not show this additional negativity (Hahne & Friederici, 1999; 2002; Hagoort et al., 2003; Friederici et al., 2004; and Gugler et al., submitted in sentences like "Der Clown hat im Ø gelacht." / "The clown has in-the Ø laught."). Thus, this negativity was assumed to reflect unsatisfied specificity reference processes due to the omission of a highly expected noun in the prepositional phrase (Isel et al., 2004; Gugler et al., submitted).

Many ERP studies combined different linguistic information types in order to investigate the interplay between them, how they are coordinated in time, if one information precedes the other or if they interact with each other.
Serial or modular models (Frazier, 1987; Fodor, 1983), on the one hand, assume autonomous processes mainly based on word category information, which do not interact with each other (see Chapter 1.3). If different types of information are processed in such a way, this means in terms of ERPs that each autonomous ERP component (e.g. an N400 and a P600) should be present and thus add up in the ERP pattern. This additivity is described as the *Helmholtz superposition principle*, which assumes different generators underlying different ERP components. These generators are autonomous and as such do not overlap, but add up.
Parallel or interactive models (Marslen-Wilson & Tyler, 1980), on the other hand, propose that information is processed in parallel as soon as information is available and different information types may interact at different stages. This would lead to ERP components that either interact at the same time, i.e. the amplitude should therefore be bigger or smaller than the sum of the two single ERP components, or influence each other over the time course.

Osterhout and Nicol (1999) state more precisely in this regard that in case of non-perfect additivity in ERP studies, i.e. only some effects summate, this does not necessarily mean that interactive processes take place. They mention some reasons, why non-perfect additivity may occur: first, ERPs reflect the added postsynaptic response in big groups of neurons. Thus, the sources are not limited to the effect of interest; second, perfect additivity of ERP components requires perfect additivity of the two sources that lead to the two effects; third, the neocortex has a complex dynamic as distant sources may suffer from non-linear interactions.

The most ERP studies looked at the combination of semantic and syntactic information. Here, one line of research focused on the relationship between semantic and morphosyntactic information and the other investigated the combination of word category and semantic information.

Gunter et al. (1997) combined an agreement error with a semantic violation. In the single conditions they found, in their first experiment, a P600 for the agreement and an N400 for the semantic condition. The combined violation led to a N400/P600 pattern and thus, suggests no interaction but additivity effects. In a second experiment, in which the working memory load was enhanced, the agreement violation in isolation showed a LAN and a P600 and the semantic condition alone an N400. The combination resulted in a LAN/N400 plus a P600, which, however, had a reduced amplitude. This indicates that in this experiment, the P600 was affected by semantic congruence and thus, led to non-additive effects.

Hagoort (2003) found interactive effects in a gender agreement-semantic combination. The violations in isolation elicited a P600 and N400, respectively. The combination resulted in an enhanced N400 referred to as a “syntactic boost” and a P600. In this case, an interaction, i.e. no additivity, was visible.

Osterhout and Nicol (1999) combined a verb tense agreement with a semantic error and found a P600 for the agreement and an N400 for the semantic violation alone. The combination gave rise to an approximately linear (but not perfect) summation of the two ERP components, suggesting additivity effects.

When looking at word category plus semantic combinations the relationship between semantic and syntactic information shows a somewhat different picture.

Hahne and Jescheniak (2001) investigated word category violations in real and jabberwocky sentences. Jabberwocky sentences are assumed to contain no semantic content and thus are considered semantically anomalous. In both the real and the jabberwocky sentences Hahne and Jescheniak (2001) found the same ERP pattern to word category violations, namely an ELAN and a P600, but no N400. These results indicate that word category information (reflected by the ELAN) is processed autonomously at an initial stage and blocks further semantic processes.

Hahne and Friederici (2002) found similar results in a word category-semantic combination in real sentences. However, an ELAN and a P600 for the combined violation was only observable when participants judged the overall correctness of the sentences. When they had to judge semantic coherence and to ignore syntactic aspects the combination of the two error types gave rise to an ELAN and an N400, but no P600. The authors concluded from these findings that there might exist no strict division between autonomy and interaction but that more complex processes seem to take place. Thus, autonomous processes occur in the first stage as this is postulated by modular syntax-first models, and interactive aspects come into play at later stages.

Friederici et al. (2004) combined a word category and a semantic violation. However, they addressed the issue whether phrase structure building processes reflected by the ELAN also occurred prior to semantic processes or block these in a combined condition when the semantic error precedes the word category error. In order to test this hypothesis they created word category violations in which the category information was encoded in the suffix of the critical item, in contrast to previous studies, which encoded this information mostly in the prefix (e.g. Hahne & Friederici, 1999; 2002; Hahne & Jescheniak, 2001). The word category violation gave rise to a LAN effect (this effect was not as early as in previous studies due to the late word category recognition point) followed by a P600, whereas the semantic condition displayed an N400, as usual. The combined condition showed a LAN and a P600 but no N400, suggesting primacy of syntactic word category information over semantic information at early stages.

The P600 in the combined violation, however, was increased when compared to the P600 in the word category in isolation, indicating that interaction of both information types can occur at later processing stages.

In sum, the studies on syntax-semantic combinations presented so far suggest that whenever word category information occurs together with a semantic error the former is processed immediately and continues with reanalysis without considering the semantic information. Only few studies combined two types of syntactic information. Frisch, Hahne and Friederici (2004) investigated the relationship between word category and argument structure information. The violations in isolation showed an ELAN/P600 pattern and an N400/P600 pattern, respectively. The combination resulted in an ELAN/P600 pattern, but no occurrence of an N400. Again, also when two syntactic information types are combined in one sentence the word category drives the processing and blocks the additional information, in this case reflected by an N400.

The aim of the first experiment was to test whether the same ERP pattern as in Rossi et al. (2005) is also replicable in Italian word category and morphosyntactic violations in native speakers.
Rossi et al. (2005) investigated in an ERP study word category and morphosyntactic agreement violations in German. Apart from the single violations the study also included a combined violation, which contained both a word category and a morphosyntactic error. The ERP results showed for the word category violation in isolation an ELAN, an additional negativity, and a P600 and for the morphosyntatic agreement violation a LAN and a P600. The investigation in the first experiment of the present study focused especially on the word category violation, as no ERP study so far has investigated this type of syntactic information in Italian. Although German and Italian display some structural differences (see Chapter 1.2) the kind of violation (the omission of a noun in a prepositional phrase, which is part of the subject noun phrase), the word order and the amount of words was kept the same as in Rossi et al. (2005).

Based on the assumption that universal mechanisms (Chomsky, 1957, 1965, 1981) act on such structures because there is no variation and in both German and Italian a prepositional phrase requires a noun after the preposition (word category violation) and both languages have a similar morphosyntactic person system (both have three persons in both singular and plural), the same processing mechanisms are expected in Italian as in the previous study in German. Thus, the following predictions were made:

- *Word category violation*: early anterior negativity reflecting initial phrase structure building processes, additional negativity reflecting specificity reference processes, and a late positivity (P600) reflecting processes of reanalysis and repair.
- *Morphosyntactic agreement violation*: anterior negativity reflecting the detection of the morphosyntactic subject-verb agreement mismatch, and a P600 as reanalysis and repair.

Concerning the combination of both error types Rossi et al. (2005) observed the same ERP steps as in the word category violation in isolation, namely an ELAN, an additional negativity, and a P600. No LAN effect, i.e. the processing of the morphosyntactic error, was present. Similar to other studies containing a word category violation in the combined condition, Rossi et al. (2005) provide further evidence for primacy of word category information also over other syntactic aspects, in this case over morphosyntactic information. The P600, however, suffered from an interactive effect of both violations as the amplitude of the combined violation was smaller than the P600 in the agreement and larger than the P600 in the word category violation. On the basis of these results, the first experiment of the present study makes the following predictions for Italian sentences:

- *Combined violation*: The same ERP pattern as the pure word category violation, namely an early anterior negativity, an additional negativity, and a P600, but no LAN as a marker for the processing of the additional morphosyntactic error.

From a more general perspective, the first experiment should provide evidence about the processing of different syntactic anomalies in native speakers in order to be compared to that of second language learners with either a high or low proficiency level (see further experiments). The investigation of these different syntactic information types in Italian is particularly of interest because only few ERP studies were conducted in this language and especially none of these included either a word category violation in isolation or a combination of a word category and a morphosyntactic violation in one condition.

5.2 Methods

5.2.1 Subjects

20 right-handed (assessed according to Oldfield, 1971) native speakers of Italian took part in the first experiment. One participant was excluded from ERP and statistical analyses due to technical problems during the EEG acquisition. The 19 remaining subjects (10 female) were 27 years on average (range: 19-40 years). Almost all were university students, they were paid for participation, had no known hearing deficits and normal or corrected-to-normal vision.

5.2.2 Materials

This Italian material was constructed analogously to the German material used in Rossi et al. (2005), which was used in experiment 2 and 3 to test high and low proficient L2 learner of German. The present Italian material did not represent a literal translation of the German one in order to ensure a high degree of naturalness in this material. The Italian material contained 420 sentences in the active voice in indicative present tense (subject noun phrase including the prepositional phrase – verb – object) with the same amount of words per sentence and with the same word order as in German. The material consisted of four experimental conditions (word category violation, morphosyntactic agreement violation, combined violation) and three correct filler conditions (Table 5.1). For each condition 60 different sentences were generated.

Table 5.1: Experimental items used in Experiment 1, 4, 5.

Experimental conditions	*Example sentences*
Correct	Il signore nel bar beve un caffè. (The man in-the bar drinks a coffee.)
Category	Il signore nel Ø beve un caffè. (The man in-the Ø drinks a coffee.)
Agreement	Il signore nel bar bev*o* un caffè. (The man in-the bar drink a coffee.)
Combined	Il signore nel Ø bev*o* un caffè. (The man in-the Ø drink a coffee.)
Filler 1	Il signore pensa: io bevo un caffè. (The man thinks: I drink a coffee.)
Filler 2	Il signore nel ristorante beve un tè. (The man in-the restaurant drinks a tea.)
Filler 3	Il signore nel locale beve un aperitivo. (The man in-the pub drinks an aperitif.)

In the *category violation*, the verb directly followed the preposition, so that the expected noun of the prepositional phrase was absent. This absence created a word category violation.

In the *agreement violation*, the verb was violated morphosyntactically. The correct 3rd person singular inflexion was altered and replaced with the 1st person singular.

The *combined violation* contained both types of error, the category and the agreement error.

One filler condition was included in order to balance the morphosyntactic error by using the 1st person singular in a correct sentence. Two further filler conditions were constructed to balance the amount of correct and syntactically incorrect sentences with the same sentence structure.

All initial nouns referred to persons and were constructed only in the singular form. The nouns following the preposition were only of male gender as required by the merged preposition and represented only places. Further, the nouns after the preposition neither began with an S + a consonant or the initial letter Z or X (e.g. studio – office) because such words would have required another determiner prolonged by the letters *lo* (nello – in the) nor began with a vowel because such words would request an apostrophe after the preposition and a supplemental letter in the preposition (e.g. nell' – in the).

The verbs of the material were all regular and transitively used. I paid attention that no verb had the form of a noun neither in the first nor in the third person singular as this would have possibly led to confounding effects in the category violation in which a verb should follow immediately after the preposition in order to create a word category violation.

The sentences were spoken by a female native speaker of Italian in a soundproof booth and recorded digitally with 16 bits. Because the reading of sentences without a noun after the preposition – as was the case for the phrase structure and combined violation – may alter the prosody of the sentence, a complete prepositional phrase including a filler word after the preposition was integrated for the recording and afterwards excised from the digital speech file. To ensure the same transition from the last phoneme of the preposition to the first phoneme of the verb also by the filler word, this additional noun was constructed in a way that the first phoneme of the filler word corresponded to the first phoneme of the following verb and the last phoneme of the filler word corresponded to the last phoneme of the preposition (cf. Hahne & Friederici, 1999). After the recording of the sentences they were normalized at 70% of the maximum amplitudes of each sentence. The additional noun was afterwards excised from the acoustic file using a speech editing software (Cooledit, 2000).

The mean duration time of the critical items (verbs) in the Italian material was:

- Correct: 505 ms (SD: 115)
- Category: 538 ms (SD: 126)
- Agreement: 542 ms (SD: 125)
- Combined: 527 ms (SD: 110)

The material was pseudorandomized and resulted in 21 different randomization versions, which enabled the presentation of one randomization list for each person in the experiment. The randomization procedure was processed according to different criteria: not more than 4 correct or incorrect sentences in succession, not more than 2 sentences of one condition in succession, not more than 2 sentences with the same preposition in succession, at least 15 trials between two sentences with the same verb, in each of 7 presentation blocks the same amount of sentences with the same preposition and in each presentation block the seven experimental conditions should occur at least 7 times and not more than 9 times.

5.2.3 Procedure

During the experiment participants listened to the acoustically presented sentences in a soundproof booth with dimming light seating in a comfortable chair one meter in front of a computer monitor. The presentation of the trials was as following (Figure 5.1). First a fixation star appeared on the monitor for 500 ms, and then the acoustic presentation of the sentence followed via loud speakers for approximately 3500 ms while on the screen the fixation star remained to help the participants avoiding oculomotor movements. After the auditory presentation the fixation star was still visible for 1500 ms and afterwards the response sign appeared for 2000 ms where the persons were instructed to press one of two buttons on a response pad (left and right button for correct sentences were matched across participants) in order to judge the correctness of the sentence (grammaticality judgment task). An interstimulus-interval of 1000 ms followed before the next trial started. Before the experiment the participants were instructed to minimize eye and body movements during the presentation of the fixation star. At the beginning of the experiments the participants were presented 21 training trials.

Acoustic presentation of the sentence					
Visible on the screen	✶	✶	✶	☺ ☹	
Time (in ms)	500	sentence (about 3500)	1500	2000	1000

Figure 5.1: Schematic description of the experimental procedure (details in the text).

5.2.4 ERP recording

The EEG was recorded with 23 AgAgCl electrodes placed in an elastic cap (EASY CAP) at the following positions (see Figure 3.2): F3, F4, FC3, FC4, F7, F8, FT7, FT8, FZ, C3, C4, T7, T8, CZ, CP5, CP6, P3, P4, P7, P8, PZ, O1 and O2 (nomenclature based on Sharbrough, Chatrian, Lesser, Lüders, Nuwer, and Picton, 1991). The vertical electro-oculogram (VEOG) was recorded from two electrodes placed above and below the right eye and the horizontal electro-oculogram (HEOG) was recorded from two electrodes at the outer canthus of each eye. The EEG recording was online referenced to the left mastoid and offline rereferenced to averaged mastoids. Electrode impedance was kept below 3 kΩ and the EEG-signal was digitized with 250 Hz and amplified within a bandpass from DC to 70 Hz.

5.2.5 Data Analyses

Only correctly answered trials in the judgment task were included into data analysis. Trials affected with artifacts were excluded. Eye artifacts were first detected automatically due to exceeding values on EOG (33.75 µV) and CZ (20.00 µV) and then manually inspected to eventually exclude more detailed artifacts. If participants had a lot of eye movement artifacts their trials were corrected with an EOG algorithm ("xeog", part of EEP software 3.2 for Unix by M. Grigutsch). In the present experiment 15.3% of trials were rejected on average (correct: 14.5%, category: 15.5%, agreement: 15.6%, combined: 15.5%).

Behavioral data comprised the accuracy rates (in %) and the reaction times (in ms) during the judgment task. Concerning reaction times extreme values that exceeded 1.5 standard deviation within subjects and conditions were excluded from further analyses. For both behavioral measures a repeated measure one-way ANOVA was computed with the factor "condition", which included the four experimental conditions (correct, category, agreement, combined). If the ANOVA revealed a significant main effect of condition ($p < .05$) subsequent paired *t*-tests between the single conditions were computed. The significance level was adapted according to Bonferroni.

ERPs were computed for each participant and each experimental condition and afterwards averaged for the whole group. A 1500 ms time range after onset of the verb was averaged with a 100 ms post-stimulus onset baseline. This baseline was chosen because different word categories preceded the critical verb in the different conditions (cf. Hahne & Friederici, 1999). For the statistical ERP analysis on the mean amplitudes the following time windows were chosen according to literature and visual inspection:

- 100-250 ms (ELAN)
- 250-550 ms (additional negativity)
- 250-500 ms (LAN)
- 700-1200 ms (P600)

Repeated measure ANOVAs were computed according to a hierarchical analysis schema. First a global analysis for each relevant time window with the factors condition (correct vs. incorrect), region (anterior, posterior), and hemisphere (left, right) was computed. If this analysis showed a significant ($p < .05$) two-way interaction subsequent region or hemisphere analyses were performed. In case of a significant three-way interaction a subsequent regions-of-interest (ROI) analysis was processed. For this purpose 4 ROIs were defined: left anterior (F7, F3, FT7, FC3), right anterior (F8, F4, FT8, FC4), left posterior (CP5, P7, P3, O1), and right posterior (CP6, P8, P4, O2). This proceeding was applied for the lateral electrodes whereas for the middle electrodes FZ, CZ and PZ only a global analysis with the factors condition and electrode was carried out. If a significant interaction resulted subsequent *t*-tests for the single electrodes were computed.

If the degree of freedom exceeded 1 in the numerator, a correction according to Greenhouse and Geisser (1959) was computed and reported here as the corrected significance.

5.3 Results

5.3.1 Behavioral data

Native speakers of Italian performed the judgment task with high accuracy (96.7% correct answers on average). The mean reaction time for correctly answered trials was 343.81 ms. Detailed information on the behavioral measures for each condition are displayed in Table 5.2.

Table 5.2: Mean and standard deviation of accuracy rates (first row) and reaction times (second row) during the judgement task in Experiment 1, indicated per experimental condition.

Correct		**Category**		**Agreement**		**Combined**	
Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
98.8%	1.8	97.4%	2.4	92.5%	5.3	98.3%	3.1
383.9 ms	117.1	334.7 ms	78.8	326.8 ms	79.2	329.9 ms	76.8

A one-way ANOVA concerning the percentage of correctly answered trials revealed a significant main effect of condition ($F_{(3,54)}$=18.71, p<.001, MS_e=14.41). Subsequent paired t-tests showed that in the agreement condition significantly more percentages of errors were made compared to all other conditions. The analysis of the reaction times, on the other hand, also revealed a significant main effect of condition ($F_{(3,54)}$=8.69, p<.001, MS_e=2587.00) resulting in the fact that responses concerning the correct condition were slowest in contrast to the other conditions.

5.3.2 ERP data

The ERP data for single incorrect conditions versus the correct are displayed in Figure 5.2, 5.3, 5.4. The reported plots are filtered with an 8 Hz low pass filter for presentation purposes only.

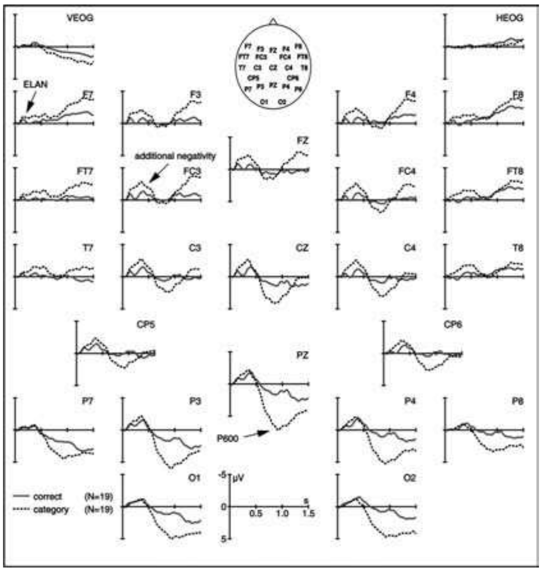

Figure 5.2: Grand average ERPs (category versus correct condition) from verb onset up to 1500 ms for Italian native speakers (Experiment 1). Negative voltage is plotted upwards.

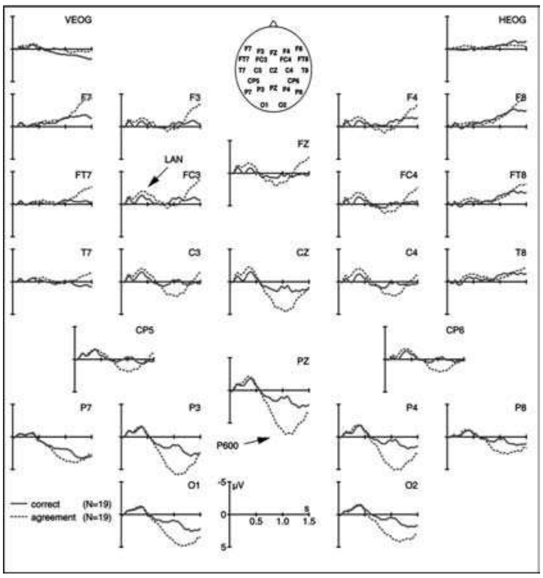

Figure 5.3: Grand average ERPs (agreement versus correct condition) from verb onset up to 1500 ms for Italian native speakers (Experiment 1). Negative voltage is plotted upwards.

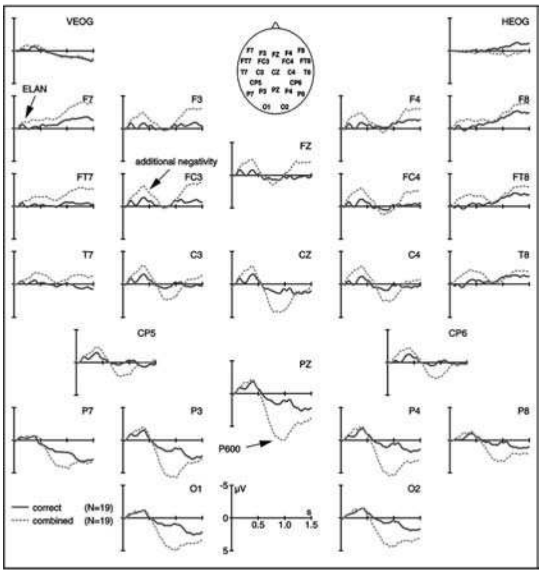

Figure 5.4: Grand average ERPs (combined versus correct condition) from verb onset up to 1500 ms for Italian native speakers (Experiment 1). Negative voltage is plotted upwards.

5.3.2.1 Word category violation

The word category violation compared to the correct condition in Italian native speakers displayed an early negativity between 100 and 250 ms with an anterior distribution, followed by an additional negativity between 250 and 550 ms, also present over anterior areas, and a late positivity (P600) in the time range 700-1200 ms with a centro-parietal distribution.

In detail, the statistical analyses for each time window provided the following results (Table 5.3, 5.4 and 5.5).

Table 5.3: ANOVAs of ERP data in the time range 100-250 ms for the category versus the correct condition in Experiment 1. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

100-250 ms	**Category versus correct**			
Source	*df*	*F*	*p*	MS_e
Cond	1,18	4.17	.056	2.19
Cond x Reg	1,18	7.94	.011*	.44
Cond x Hem	1,18	< 1		
Cond x Reg x Hem	1,18	< 1		
Anterior				
Cond	1,18	6.23	.023*	1.93
Posterior				
Cond	1,18	< 1		
Midline				
Cond	1,18	3.70	.070	3.54
Cond x elec	2,36	5.20	.021*	.21

The global analysis in the time range 100-250 ms showed a significant interaction condition x region at lateral electrode sites. Subsequent region analyses revealed a main effect in anterior regions. At midline electrodes the interaction condition x electrode reached significance and resulted in significant effects at the electrodes FZ ($t_{(19)}$= -2.15, p=.045*) and CZ ($t_{(19)}$= -2.15, p=.046*).

Table 5.4: ANOVAs of ERP data in the time range 250-550 ms for the category versus the correct condition in Experiment 1. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

250-550 ms	**Category versus correct**			
Source	*df*	*F*	*p*	MS_e
Cond	1,18	3.50	.078	4.15
Cond x Reg	1,18	10.18	.005**	.87
Cond x Hem	1,18	< 1		
Cond x Reg x Hem	1,18	2.56	.127	.10
Anterior				
Cond	1,18	6.19	.023*	3.71
Posterior				
Cond	1,18	< 1		
Midline				
Cond	1,18	1.53	.232	7.95
Cond x elec	2,36	5.54	.015*	.59

Between 250 and 550 ms the ANOVA revealed a significant interaction condition x region, which resulted in a significant main effect of condition at anterior areas for lateral sites. At midline electrodes a significant interaction condition x electrode was present. Subsequent *t*-tests revealed no significant effects (p>0.05).

Table 5.5: ANOVAs of ERP data in the time range 700-1200 ms for the category versus the correct condition in Experiment 1. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Category versus correct		
700-1200 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	15.42	.001***	3.20
Cond x Reg	1,18	43.34	<.001***	1.93
Cond x Hem	1,18	3.61	.074	.64
Cond x Reg x Hem	1,18	1.06	.317	.31
Anterior				
Cond	1,18	< 1		
Posterior				
Cond	1,18	67.01	<.001***	1.95
Midline				
Cond	1,18	14.06	.002**	8.77
Cond x elec	2,36	36.47	<.001***	1.66

In the time range 700-1200 ms the global analysis for lateral electrodes revealed a significant main effect of condition and a significant interaction condition x region. Subsequent region analyses showed a significant main effect at posterior regions. At midline electrodes, the ANOVA revealed both a main effect of condition and a significant interaction condition x electrode, which resulted in significant effects at the electrodes CZ ($t_{(19)}$=3.18, p=.005**) and PZ ($t_{(19)}$=7.14, p=<.001***).

5.3.2.2 Agreement violation

The agreement violation compared to the correct condition revealed a broadly distributed anterior negativity (LAN) between 250 and 500 ms followed by a posteriorly distributed P600 between 700 and 1200 ms.

In detail, the statistical analyses for each time window provided the following results (Table 5.6 and 5.7).

Table 5.6: ANOVAs of ERP data in the time range 250-500 ms for the agreement versus the correct condition in Experiment 1. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere for lateral electrode sites. The second row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Agreement versus correct				
250-500 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	5.52	.030*	1.00
Cond x Reg	1,18	1.14	.299	.88
Cond x Hem	1,18	< 1		
Cond x Reg x Hem	1,18	< 1		
Midline				
Cond	1,18	6.03	.025*	2.35
Cond x elec	2,36	1.53	.235	.39

In the time range 250-500 ms significant main effects of condition were present for both lateral and midline electrodes.

Table 5.7: ANOVAs of ERP data in the time range 700-1200 ms for the agreement versus the correct condition in Experiment 1. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Agreement versus correct				
700-1200 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	7.97	.011*	6.03
Cond x Reg	1,18	20.06	<.001***	1.31
Cond x Hem	1,18	< 1		
Cond x Reg x Hem	1,18	2.46	.134	.21
Anterior				
Cond	1,18	< 1		
Posterior				
Cond	1,18	18.22	<.001***	3.99
Midline				
Cond	1,18	10.36	.005**	14.96
Cond x elec	2,36	20.48	<.001***	1.06

Between 700-1200 ms the global ANOVA for lateral sites revealed a significant main effect of condition and a significant interaction condition x region. Subsequent region analyses showed a main effect of condition at posterior areas. The ANOVA for midline electrodes showed a main effect of condition and a significant interaction condition x electrode, which resulted in significant effects at CZ ($t_{(19)}$=3.18, p=.005**) and PZ ($t_{(19)}$=4.47, p=<.001***).

5.3.2.3 Combined violation

The combined violation showed, analogous to the category violation, an early anterior negativity between 100 and 250 ms, an additional anteriorly distributed negativity between 250 and 550 ms, and a late positivity with a posterior distribution between 700 and 1200 ms. The combined violation differed significantly from the agreement violation, whereas no difference could be verified compared to the category violation.

In detail, the statistical analyses for each time window provided the following results (Table 5.8, 5.9 and 5.10).

Table 5.8: ANOVAs of ERP data in the time range 100-250 ms for the combined versus the correct condition in Experiment 1. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses and the third row shows hemisphere analyses. All these analyses are performed for lateral electrode sites. The fourth row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Combined versus correct				
100-250 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	4.83	.041*	2.86
Cond x Reg	1,18	8.04	.011*	.38
Cond x Hem	1,18	11.65	.003**	.12
Cond x Reg x Hem	1,18	< 1		
Anterior				
Cond	1,18	8.17	.011*	1.82
Posterior				
Cond	1,18	1.38	.255	1.41
Left				
Cond	1,18	2.41	.138	1.35
Right				
Cond	1,18	7.34	.014*	1.62
Midline				
Cond	1,18	3.14	.093	4.53
Cond x elec	2,36	4.54	.030*	.21

Between 100 and 250 ms the global statistical analysis revealed a significant main effect of condition, a significant interaction condition x region, and a significant interaction condition x hemisphere for lateral electrode sites. Subsequent region analyses showed a main effect of condition in anterior areas and subsequent hemisphere analyses showed a significant effect in the right hemisphere. At midline electrodes the interaction condition x electrode reached significance, but did not show any significant electrode effects (p>0.05) in the t-tests.

Table 5.9: ANOVAs of ERP data in the time range 250-550 ms for the combined versus the correct condition in Experiment 1. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Combined versus correct				
250-550 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	9.53	.006**	2.80
Cond x Reg	1,18	13.64	.002**	.55
Cond x Hem	1,18	< 1		
Cond x Reg x Hem	1,18	< 1		
Anterior				
Cond	1,18	12.84	.002**	2.43
Posterior				
Cond	1,18	3.22	.090	.92
Midline				
Cond	1,18	3.48	.079	5.84
Cond x elec	2,36	6.30	.013*	.52

In the time range 250-550 ms both a significant main effect of condition and a significant interaction condition x region was present for lateral sites. Subsequent region analyses revealed a main effect of condition at anterior regions. At midline electrodes the ANOVA showed a reliable interaction condition x electrode, which resulted in a significant effect at FZ ($t_{(19)}$= -2.26, p=.036*).

Table 5.10: ANOVAs of ERP data in the time range 700-1200 ms for the combined versus the correct condition in Experiment 1. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Combined versus correct				
700-1200 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	9.34	.007**	3.83
Cond x Reg	1,18	44.27	<.001***	1.95
Cond x Hem	1,18	3.91	.064	.62
Cond x Reg x Hem	1,18	2.19	.157	.33
Anterior				
Cond	1,18	1.75	.202	3.14
Posterior				
Cond	1,18	44.21	<.001***	2.64
Midline				
Cond	1,18	17.39	<.001***	7.85
Cond x elec	2,36	27.54	<.001***	2.12

Between 700 and 1200 ms statistical analyses for lateral sites revealed a main effect of condition and a significant two-way interaction condition x region. Region analyses showed a reliable effect at posterior regions. At midline electrodes both a main effect of condition and an interaction condition x electrode were present. Subsequent *t*-tests showed significant effects at CZ ($t_{(19)}$=3.70, *p*=.002**) and PZ ($t_{(19)}$=7.18, *p*=<.001***).

5.3.2.4 Additional analyses on the combined violation

In order to test whether the combined violation resembles or differs from the pure word category violation and the agreement violation, additional ANOVAs according to the same hierarchical schema were performed between the category and the combined and between the agreement and the combined violation for each time window.

The category versus the combined violation did not reveal any significant difference in each time window, neither for lateral nor for midline electrodes.
The combined violation, however, differed significantly from the agreement condition in the time ranges 250-550 ms and 250-500 ms as they revealed a main effect of condition for lateral sites in either time range (250-550: $F_{(1,18)}$=5.92, *p*=.026*, MS_e=1.71; 250-500: $F_{(1,18)}$=7.06, *p*=.016*, MS_e=1.59). Between 700-1200 ms a significant interaction condition x region ($F_{(1,18)}$=9.80, *p*=.006**, MS_e=1.78) was present for lateral sites, but it did not reach significance at subsequent region analyses. At midline electrodes an interaction condition x electrode ($F_{(2,36)}$=8.57, *p*=.005**, MS_e=1.07) was reliable, too. Again subsequent *t*-tests did not show significant electrode effects. Although no statistical difference is observable in the time range 700-1200 ms between the combined and the agreement violation, an observable difference is visible on the plot (see Figures 5.3 and 5.4). Because the peak of the P600 in the agreement violation is somewhat delayed in contrast to the P600 peak in the combined violation, the statistical comparison in the whole time range 700-1200 ms leads to reversed effects in the first and second part of the time window. An additional ANOVA splitting the time window in two parts (700-1000 ms and 1000-1200 ms) revealed a clear difference in the earlier time range.

The ANOVA between 700-1000 ms showed a reliable interaction condition x region ($F_{(1,18)}$=14.74, p=.001***, MS_e=1.64), resulting in a reliable difference in posterior areas ($F_{(1,18)}$=5.22, p=.035*, MS_e=4.33). At midline electrodes a similar pattern was visible. The ANOVA revealed a reliable interaction condition x electrode ($F_{(2,36)}$=14.31, p<.001***, MS_e=1.04), resulting in a significant difference at PZ ($t_{(19)}$=2.62, p=.018*). In the second part of the time range (1000-1200 ms) no reliable effect was present neither for lateral nor for midline electrodes.

5.4 Discussion

The present experiment aimed to investigate a word category violation, a morphosyntactic subject-verb agreement violation, and a combination of the two in Italian and to see whether the same ERP pattern is replicable in this language, in contrast to the same experimental conditions in a German material (Rossi et al., 2005).

As at present there is no ERP study in the literature, which investigates *word category violations* in Italian, this condition was of great interest in the present experiment. Because word category violations in other languages gave rise to an ELAN-P600 pattern, this was also predicted for the Italian violation. As expected, the word category violation compared to the correct condition showed an early anterior negativity (ELAN) between 100 and 250 ms and a P600 with a centro-parietal distribution between 700 and 1200 ms. The ELAN component is seen in correlation with phrase structure building processes (Hahne & Friederici, 1999) as soon as the word category error (the omission of a noun in the prepositional phrase) is detected. At a later stage the reanalysis (Hahne & Friederici, 1999; Osterhout & Holcomb, 1992; 1993) or repair (Friederici et al., 1993; Hahne & Friederici, 1999; 2002; Friederici, 2002) of the incorrect sentence follows. This process is reflected by a centro-parietal positivity (P600). In the German study (Rossi et al., 2005) as well as in other studies with a word category violation embedded in the subject noun phrase (Hinojosa et al., 2003; Isel et al., 2004), in addition to the ELAN and the P600 component a further negativity in between was observed. Also in the present experiment an additional negativity with an anterior distribution was found between 250 and 550 ms.

This ERP component is seen in correlation with reference-related processes arising due to the omission of a highly expected noun in a prepositional phrase, which specifies the noun of the main clause. The absence of this noun leads to a disrupted reference process, which is reflected in a negativity prior to the reanalysis process. Such a negativity was observed in French (Isel et al., 2004) and Spanish word category violations (Hinojosa et al., 2003) that were embedded in a relative clause specifying the noun of the main clause, and in German sentences (Rossi et al., 2005) in a similar violation as in the present experiment.

The *morphosyntactic agreement violation* in the present experiment gave rise to a broadly distributed LAN effect between 250 and 500 ms reflecting the detection of the morphosyntactic inflection error and a subsequent P600 between 700 and 1200 ms indicating reanalysis processes. These findings are in line with other studies in different languages (Osterhout & Mobley, 1995; Gunter et al., 1997; Friederici et al., 1993; Barber & Carreiras, 2005) and successfully replicate the same ERP processing steps also in Italian subject-verb agreement violations created by a person error (Angrilli et al., 2002; De Vincenzi et al., 2003).

Concerning the *combined condition* the ERP pattern in Italian native speakers showed the same pattern as the pure word category violation, namely an ELAN, and additional negativity, and a P600. These ERP components occurred in the same time ranges as those in the category violation and with the same amplitude as the comparative analyses between the combined and the category violation showed. No difference could be found between these two conditions in neither time range, whereas the combined differed from the agreement violation in several time windows. These results suggest that also in Italian the combination of two syntactic anomalies leads to the same pattern as the word category violation. This indicates that word category information incorporated in a combined violation is immediately processed and continues its course without considering the additional error type, in the present experiment an additional morphosyntactic error.

This suggests primacy of word category information not only over semantic processes, as observed in many previous studies (Hahne & Jescheniak, 2001; Hahne & Friederici, 2002; Friederici et al., 2004), and verb-argument-structure mismatches (Frisch et al., 2004), but also over morphosyntax. The present experiment with Italian material provides evidence that these primacy effects on the basis of word category information are also present in Romance languages such as Italian. No previous study to date has included a combination of word category information and another anomaly of any kind in an Italian material. Previous studies using a combination paradigm mostly used Germanic languages such as German (Hahne & Jescheniak, 2001; Hahne & Friederici, 2002; Friederici et al., 2004; Frisch et al., 2004; Rossi et al., 2005), Dutch (Gunter et al., 1997; Hagoort, 2003), or English (Osterhout & Nicol, 1999). In contrast to the German material (Rossi et al., 2005) the present experiment showed a differential P600 pattern in the combined violation. Whereas in Rossi et al. (2005) the P600 of the combined violation experienced a modulation, i.e. it had a smaller amplitude than the P600 of the agreement violation and a greater amplitude than the category violation, indicating interactive processes at a later stage, the P600 in the present experiment resembled the P600 of the word category violation and only differed from the agreement violation. Similar modulations of the P600 had also been found in Gunter et al. (1997) in a Dutch agreement-semantic combination as well as in Friederici et al. (2004) in German word category-semantic combinations. Even though this modulation has already been observed in some studies, it is not clear what mechanisms lead to a modulation and which do not. It is still unknown whether a specific information type or other confounding factors might produce these interactive effects. Noticeably, these three studies were all conducted in Germanic languages (Dutch and German) and thus, these languages may display some commonalities that might affect the reanalysis process when certain types of information are combined. This idea could be strengthened by the fact that the same combination in Italian did not lead to a modulation in contrast to the German material. However, because even within Germanic languages this pattern does not seem to be consistent as some studies did not show any modulation effects in German combinations (e.g. Hahne & Friederici, 2002), further research on this issue is certainly necessary in order to better capture these slight differences in processing.

In sum, the present findings successfully replicate the findings of the German material, and thus speak for universal brain processing mechanisms, at least when the violations are kept exactly the same and the syntactic information types are present in both languages, even though differences at a formal linguistic level (e.g. differences in the rigidity of word order or in specific agreement features) are present between both languages.

Chapter 6

Experiment 2:

Syntactic processing in high proficient L2 learners of German

6.1 Introduction

As introduced in Chapter 2 and 4 of the theoretical part, several factors may influence the processing of a second language such as age of acquisition or the proficiency level achieved in the second language.

The aim of Experiment 2 is to investigate the processing in high proficient late second language learners of German. The beneficial effect of proficiency was verified using imaging techniques by Perani and colleagues (Perani et al., 1996; 1998) who found the same activation foci in the brain of late second language learners with a high L2 proficiency level, in contrast to low proficient learners. This indicates that the same neural substrates subserve both L1 and L2 processing provided a high level of second language. Discussions mainly focus on which linguistic aspects are influenced by proficiency, i.e. can show native-like brain processing mechanisms. Many ERP studies found that semantic processing can also be acquired later in time, as the N400 component was also present in L2 learners who had learned L2 during or after puberty (Ardal et al., 1990; Weber-Fox & Neville, 1996; Hahne, 2001; Hahne & Friederici, 2001; Kotz, 2001; Kotz & Elston-Güttler, 2004). However, concerning the processing of syntactic aspects the pattern seems to be different. ERP studies on syntactic processing showed more variation in the processing mechanisms, i.e. some steps did not occur at all or with different asymmetries, latencies or amplitudes. Especially word category violations were in the light of second language research.

Concerning this kind of syntactic information Hahne and Friederici (2001), for example, found neither an early anterior negativity reflecting initial phrase structure building processes neither late reanalysis processes. However, when the L2 proficiency level was increased (Hahne, 2001) a P600 was present whereas the ELAN was still absent. The question arises whether such automatic first-pass parsing processes (Hahne & Friederici, 1999) as reflected by the ELAN component may not be acquired during late L2 acquisition and thus suffer from critical period effects, or if it is possible to elicit such early processes and if so, under which circumstances. Only one ERP study (Friederici et al., 2002), so far, was able to found an ELAN in second language processing, however, in an artificial language context consisting of a restricted amount of words and syntactic rules. On the basis of these findings, one major goal of Experiment 2 was to test whether native-like early syntactic processing mechanisms can also be elicited in a context of natural languages such as German when a high proficiency level in the second language is assured. This issue is of great importance concerning the debate on whether age of acquisition plays such an important role in syntax that automatic processes may not be acquired or whether the proficiency may challenge the notion of a principled difference of language processes in the brain between native and late second language learners. Thus, in Experiment 2 above all a word category violation was included in the material with the prediction that native-like ERP components, namely an ELAN and a P600, should be present in high proficient L2 learners of German. An ELAN was expected on the assumption that high proficient L2 learners should have already established an implicit representation of word category information due to the simple sentence structure chosen in this material. The sentences were S-V-O (subject-verb-object) sentences realized in the active voice. Active is normally learned prior to passive voice in German and Italian language development and is therefore assumed to be easier to be processed (Guasti, 2004). The simple S-V-O structure was chosen for the following reasons: first, to guarantee equivalency between the German and the Italian material without any word order difference, and second, in order to ensure that also low proficient L2 learners (see Experiments 3 and 5) understand this kind of sentence structure.

Additionally to the ELAN and the P600, a further negativity in between was expected in second language learners of German, as this ERP component was found in native speakers of German (Rossi et al., 2005), French (Isel et al. 2004), Spanish (Hinojosa et al., 2003), and Italian (Experiment 1 of the present study) who listened to or read sentences in which the word category violation was part of a phrase, which specified the noun phrase of the main clause and thus, provided a reference to this noun.
Experiment 2 apart from word category violations also included another syntactic information type, namely a subject-verb agreement mismatch. Only few ERP studies investigated the processing of morphosyntactic aspects in second language research, so far. Thus, it is of great interest whether native-like processing mechanisms can also be found in high proficient L2 learners when they have to deal with morphosyntactic information. Concerning this type of violation, again native-like ERP processing steps were expected in high proficient L2 learners, namely a LAN and a P600.
As the combination of two syntactic anomalies gave rise to the same processing steps as the pure word category violation in native speakers (Experiment 1 and Rossi et al., 2005), also for the processing in second language learners with a high proficiency level the same processing steps as in native speakers were predicted.

6.2 Methods

6.2.1 Subjects

In total 20 right-handed (assessed according to Oldfield, 1971) persons took part in the second experiment. 4 participants were excluded from statistical analyses because of too many artifacts. The 16 remaining subjects (10 female) were 27 years on average (range: 19-40 years). All participants were Italian native speakers who had learned German after the age of 10 and had acquired a high second language proficiency level. Detailed information about their age of acquisition, language-learning history, self rating on linguistic proficiency, and performance on translation tests are displayed in Table 6.1 (for details on the tests see Chapter 6.2.3). Almost all were university students, they were paid for participation, had no known hearing deficits and normal or corrected-to-normal vision.

Table 6.1: Behavioral proficiency information in Experiment 2.
On the left the mean values and on the right the range is reported.

Behavioral measure	**High proficient L2 learners of German (n=16)**	
Age (in yrs)	27.3	19-40
Age of acquisition (in yrs)	18.4	10-27
Time spent in L2 speaking countries (in yrs)	3.8	0.5-20
L2 learning period (in yrs)	8.1	2-20
L2 Self Rating Test (6-point-scale)		
Listening	4.9	4-6
Reading	4.9	3-6
Speaking	4.4	3-6
Writing	4.1	3-6
Vocabulary Translation Test (errors in %)	8.2	2.5-17.1
Preselection Translation Test (errors in %)	7.8	2.5-20.0

6.2.2 Materials

The German material used in this experiment was kindly provided by Manfred F. Gugler and is equivalent to the Italian material in Experiment 1. The German material also contained 420 sentences in the active voice in indicative present tense (subject noun phrase including the prepositional phrase – verb – object), with the same amount of words per sentence and with the same word order as in Italian. The material consisted of the same four experimental conditions (word category violation, morphosyntactic agreement violation, combined violation) and three correct filler conditions. For each condition 60 different sentences were generated.

Table 6.2: Experimental items used in Experiment 2 and 3.

Experimental conditions	*Example sentences*
Correct	Der Junge im Kindergarten singt ein Lied. (The boy in-the kindergarden sings a song.)
Category	Der Junge im Ø singt ein Lied. (The boy in-the Ø sings a song.)
Agreement	Der Junge im Kindergarten singst ein Lied. (The boy in-the kindergarden sing a song.)
Combined	Der Junge im Ø singst ein Lied. (The boy in-the Ø sing a song.)
Filler 1	Der Junge denkt: Du singst ein Lied. (The boy thinks: You sing a song.)
Filler 2	Der Junge im Chor singt eine Hymne. (The boy in-the choir sings a hymn.)
Filler 3	Der Junge im Theater singt eine Melodie. (The boy in-the theatre sings a melody.)

In the *category violation*, the noun of the prepositional phrase was omitted and the verb directly followed the preposition, i.e. the phrase structure was violated. The prepositions used in the experiment were merged forms consisting of a preposition and a determiner (e.g. im = in dem – in the).

In the *agreement violation*, the verb was violated morphosyntactically. The correct 3rd person singular inflexion was altered and replaced with the incorrect 2nd person singular in German. The exact violating element (2nd p. sing.) differed from the Italian material as here the 1st person singular created the violation. There was no possibility to take constant the violating person in both languages because the 1st person singular in German and the 2nd person singular in Italian would have created correct sentences in the present subjunctive.

The *combined violation* contained both types of error, the category and the agreement error.

The first filler condition was included in order to balance the morphosyntactic error by using the 2nd person singular in a correct sentence. Two additional filler conditions were constructed to balance the amount of correct and syntactically incorrect sentences with the same sentence structure.

As in the Italian material also in the German one all initial nouns referred to persons and were constructed only in the singular form, the nouns following the preposition were only of male gender as required by the merged preposition and represented only places.
The sentences were spoken by a female native speaker of German in a soundproof booth and recorded digitally with 16 bits. As in the Italian material the sentences of the word category violation contained an additional noun in the prepositional phrase realized according to the same criteria as in Experiment 1 (cf. Hahne & Friederici, 1999) in order to prevent possible prosodic influences. This additional noun was afterwards excised from the acoustic file.
The mean duration time of the critical items (verbs) in the German material was:

- Correct: 567 ms (SD: 147)
- Category: 596 ms (SD: 160)
- Agreement: 629 ms (SD: 127)
- Combined: 636 ms (SD: 136)

The material was pseudorandomized applying the same criteria as in the Italian material (see Chapter 5.2.2) and resulted in 21 different randomization versions.

6.2.3 Procedure

To control for proficiency in the second language each participant had to pass a "Preselection Translation Test" before being allowed to take part in the experiment. At the telephone 10 German sentences with the same structure as the experimental trials but composed of quite selective words were read out. Participants should translate these sentences from the second language to the native language. To belong to the high proficient group participants had to make less than 20% translation errors. During the experiment participants listened to the second language sentences in a soundproof booth with dimming light seating in a comfortable chair one meter in front of a computer monitor. The presentation of the trials and the grammaticality judgment task were the same as for the Italian material (see Chapter 5.2.3).

After the EEG-experiment the participants performed a “Vocabulary Translation Test” in which they had to translate lists containing the 60 verbs and the 60 initial nouns of the German and Italian material each from the second language to the mother tongue and vice versa. This should provide an additional measure of second language proficiency. Finally a questionnaire concerning demographic, medical and general information about the age of second language acquisition, language-learning history, self-rating scales on linguistic proficiency in both languages and other speech-relevant information had to be filled out by each participant (see Table 6.1). The L2 proficiency level concerning listening, reading, speaking, and writing was assessed above all by self-rating scales, which were constructed as 6-point Likert scales (1= no capacities; 6= capacity as a native speaker).

6.2.4 ERP recording

The EEG recording procedure was exactly the same as in Experiment 1.

6.2.5 Data Analyses

Data analyses procedure was analogous to Experiment 1. The mean percentage of rejected trials due to artifacts in Experiment 2 was 11.2% on average (correct: 11.3%, category: 11%, agreement: 12.1%, combined: 10.4%).
Behavioral (accuracy rates and reaction times) and ERP data were analyzed with the same procedure as in Experiment 1. For the statistical ERP analysis on the mean amplitudes the following time windows were chosen according to literature and visual inspection:

- 100-250 ms (ELAN)
- 250-650 ms (additional negativity)
- 500-700 ms (LAN)
- 800-1300 ms (P600)

6.3 Results

6.3.1 Behavioral data

High proficient L2 learners of German performed the judgment task accurately (93.9% on average). The mean reaction time for correctly answered trials was 429.00 ms. Detailed information on the behavioral measures for each condition are displayed in Table 6.3.

Table 6.3: Mean and standard deviation of accuracy rates (first row) and reaction times (second row) during the judgement task in Experiment 2, indicated per experimental condition.

Correct		**Category**		**Agreement**		**Combined**	
Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
96.4%	3.5	94.5%	6.0	87.9%	15.5	96.8%	3.2
469.4 ms	172.2	423.0 ms	137.2	404.8 ms	139.5	418.8 ms	155.2

A one-way ANOVA concerning the accuracy rates revealed a significant main effect of condition ($F_{(3,45)}$=4.89, p=.032, MS_e=131.24). Subsequent paired *t*-tests, however, did not show any significant differences among conditions. The analysis of the reaction times, on the other hand, also revealed a significant main effect of condition ($F_{(3,45)}$=7.51, p=.003, MS_e=2739.35). Subssequent paired t-tests showed that the agreement condition was answered significantly faster than the correct condition.

6.3.2 ERP data

The ERP data for single incorrect conditions versus the correct are displayed in Figure 6.1, 6.2, 6.3. The reported plots are filtered with an 8 Hz low pass filter for presentation purposes only.

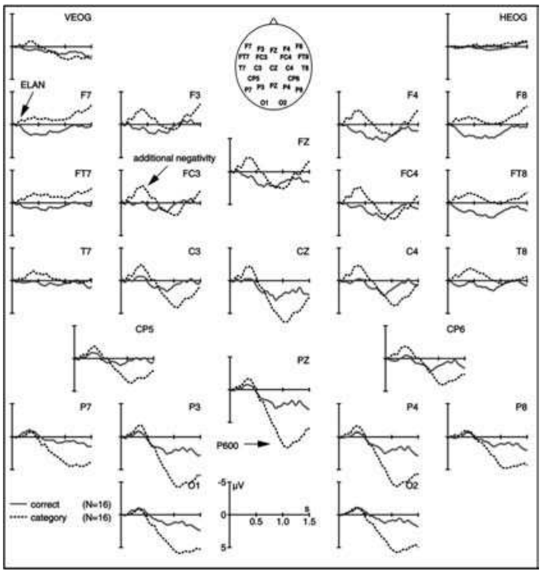

Figure 6.1: Grand average ERPs (category versus correct condition) from verb onset up to 1500 ms for high proficient L2 learners of German (Experiment 2). Negative voltage is plotted upwards.

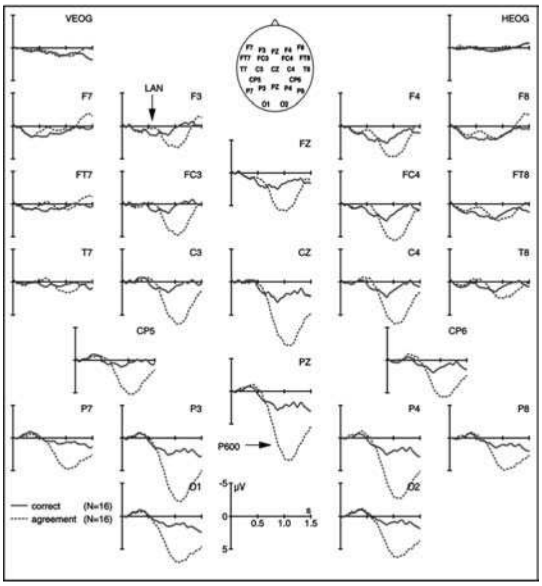

Figure 6.2: Grand average ERPs (agreement versus correct condition) from verb onset up to 1500 ms for high proficient L2 learners of German (Experiment 2). Negative voltage is plotted upwards.

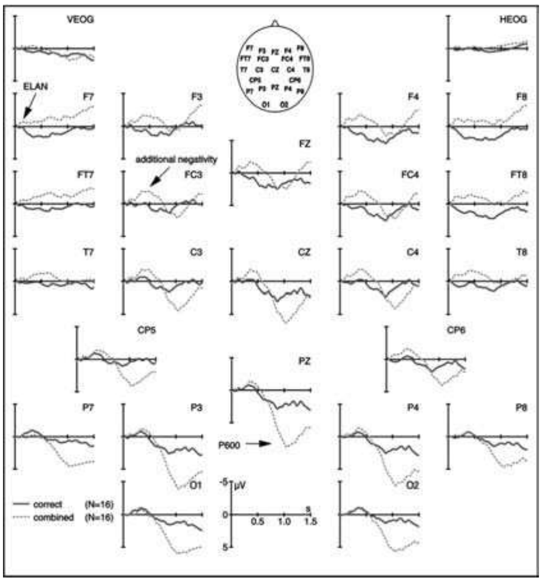

Figure 6.3: Grand average ERPs (combined versus correct condition) from verb onset up to 1500 ms for high proficient L2 learners of German (Experiment 2). Negative voltage is plotted upwards.

6.3.2.1 Word category violation

The word category violation compared to the correct condition revealed in high proficient L2 learners of German an early anterior negativity between 100 and 250 ms, followed by an anterior negativity between 250 and 650 ms and a posteriorly distributed P600 between 800 and 1300 ms.

In detail, the statistical analyses for each time window provided the following results (Table 6.4, 6.5 and 6.6).

Table 6.4: ANOVAs of ERP data in the time range 100-250 ms for the category versus the correct condition in Experiment 2. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses and the third row shows hemisphere analyses. All these analyses are performed for lateral electrode sites. The fourth row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Category versus correct		
100-250 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	5.34	.036*	2.47
Cond x Reg	1,15	8.31	.011*	.66
Cond x Hem	1,15	8.23	.012*	.21
Cond x Reg x Hem	1,15	< 1		
Anterior				
Cond	1,15	14.09	.002**	1.26
Posterior				
Cond	1,15	< 1		
Left				
Cond	1,15	2.13	.165	1.27
Right				
Cond	1,15	8.64	.010**	1.41
Midline				
Cond	1,15	1.42	.252	4.00
Cond x elec	2,30	< 1		

The global analysis in the time range 100-250 ms showed a significant main effect of condition and significant interactions condition x region and condition x hemisphere at lateral electrode sites. Subsequent region analyses revealed reliable main effects of condition in anterior regions and hemisphere analyses revealed a reliable effect in the right hemisphere. Midline electrodes did not show any significant effect in this time range.

Table 6.5: ANOVAs of ERP data in the time range 250-650 ms for the category versus the correct condition in Experiment 2. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

	Category versus correct			
250-650 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	14.79	.002**	3.47
Cond x Reg	1,15	41.72	<.001***	.97
Cond x Hem	1,15	2.48	.136	.31
Cond x Reg x Hem	1,15	< 1		
Anterior				
Cond	1,15	45.52	<.001***	2.01
Posterior				
Cond	1,15	< 1		
Midline				
Cond	1,15	6.36	.024*	6.53
Cond x elec	2,30	22.04	<.001***	.41

Between 250 and 650 ms the ANOVA revealed a main effect of condition and a significant interaction condition x region, which resulted in a significant main effect of condition at anterior areas for lateral sites. At midline electrodes a main effect of condition and a significant interaction condition x electrode were present resulting in reliable effects at FZ ($t_{(16)}$= -4.05, p=.001***) and CZ ($t_{(16)}$= -2.25, p=.040*).

Table 6.6: ANOVAs of ERP data in the time range 800-1300 ms for the category versus the correct condition in Experiment 2. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

	Category versus correct			
800-1300 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	16.82	<.001***	3.36
Cond x Reg	1,15	170.94	<.001***	.78
Cond x Hem	1,15	< 1		
Cond x Reg x Hem	1,15	< 1		
Anterior				
Cond	1,15	3.57	.079	2.28
Posterior				
Cond	1,15	97.50	<.001***	1.87
Midline				
Cond	1,15	29.93	<.001***	6.57
Cond x elec	2,30	61.41	<.001***	.83

In the time range 800-1300 ms the global analysis for lateral electrodes revealed a significant main effect of condition and a significant interaction condition x region at lateral sites. Subsequent region analyses showed a significant positivity effect at posterior regions. At midline electrodes, the ANOVA revealed both a main effect of condition and a significant interaction condition x electrode, which resulted in significant effects at the electrodes CZ ($t_{(16)}$=5.65, p=<.001***) and PZ ($t_{(16)}$=8.24, p=<.001***).

6.3.2.2 Agreement violation

The agreement violation in comparison to the correct sentences showed an anterior negativity (LAN) between 500 and 700 ms followed by a broadly distributed P600 between 800 and 1300 ms.

In detail, the statistical analyses for each time window provided the following results (Table 6.7 and 6.8).

Table 6.7: ANOVAs of ERP data in the time range 500-700 ms for the agreement versus the correct condition in Experiment 2. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Agreement versus correct				
500-700 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	2.73	.120	3.70
Cond x Reg	1,15	10.87	.005**	.54
Cond x Hem	1,15	1.45	.247	.15
Cond x Reg x Hem	1,15	< 1		
Anterior				
Cond	1,15	7.07	.018*	2.22
Posterior				
Cond	1,15	< 1		
Midline				
Cond	1,15	< 1		
Cond x elec	2,30	1.14	.319	.40

Between 500-700 ms a reliable interaction condition x region was present for lateral electrodes resulting in a main effect of condition in anterior areas. Midline electrodes did not show any significant effect in this time range.

Table 6.8: ANOVAs of ERP data in the time range 800-1300 ms for the agreement versus the correct condition in Experiment 2. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Agreement versus correct		
800-1300 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	48.69	<.001***	5.45
Cond x Reg	1,15	73.57	<.001***	.90
Cond x Hem	1,15	< 1		
Cond x Reg x Hem	1,15	1.62	.222	.29
Anterior				
Cond	1,15	10.77	.005**	3.08
Posterior				
Cond	1,15	91.13	<.001***	3.28
Midline				
Cond	1,15	85.28	<.001***	8.24
Cond x elec	2,30	27.10	<.001***	.99

Between 800-1300 ms for lateral electrodes a main effect of condition and an interaction condition x region reached significance. Subsequent region analyses showed a broadly distributed positivity effect in anterior and posterior regions. At midline electrodes a main effect of condition and an interaction condition x electrode were found resulting in main effects at FZ ($t_{(16)}$=5.98, p=<.001***), CZ ($t_{(16)}$=9.19, p=<.001***), and PZ ($t_{(16)}$=9.36, p=<.001***).

6.3.2.3 Combined violation

The combined violation in contrast to correct sentences displayed an early anterior negativity between 100 and 250 ms, an additional negativity with an anterior distribution between 250 and 650 ms, and a P600 posteriorly distributed between 800 and 1300 ms. The combined resembled the category violation and did not show any difference in any time window. The combined condition, however, displayed clear differences in any time range when compared with the agreement violation.

In detail, the statistical analyses for each time window provided the following results (Table 6.9, 6.10 and 6.11).

Table 6.9: ANOVAs of ERP data in the time range 100-250 ms for the combined versus the correct condition in Experiment 2. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses and the third row shows hemisphere analyses. All these analyses are performed for lateral electrode sites. The fourth row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

	Combined versus correct			
100-250 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	11.45	.004**	1.26
Cond x Reg	1,15	18.56	<.001***	.51
Cond x Hem	1,15	15.41	.001***	.23
Cond x Reg x Hem	1,15	1.26	.280	.09
Anterior				
Cond	1,15	37.85	<.001***	.63
Posterior				
Cond	1,15	< 1		
Left				
Cond	1,15	2.95	.107	.64
Right				
Cond	1,15	18.83	<.001***	.85
Midline				
Cond	1,15	2.25	.155	2.19
Cond x elec	2,30	3.98	.052	.24

Between 100-250 ms for lateral sites a main effect of condition and the interactions condition x region and condition x hemisphere reached significance. Region analyses showed main effects in anterior areas and hemisphere analyses showed a main effect in the right hemisphere. At midline sites no reliable effect was present.

Table 6.10: ANOVAs of ERP data in the time range 250-650 ms for the combined versus the correct condition in Experiment 2. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Combined versus correct				
250-650 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	19.18	<.001***	2.68
Cond x Reg	1,15	32.30	<.001***	1.09
Cond x Hem	1,15	2.89	.110	.30
Cond x Reg x Hem	1,15	< 1		
Anterior				
Cond	1,15	31.73	<.001***	1.66
Posterior				
Cond	1,15	< 1		
Midline				
Cond	1,15	7.38	.016*	6.47
Cond x elec	2,30	10.87	.002**	.52

In the time window 250-650 ms a main effect of condition and an interaction condition x region were present for lateral electrodes. Subsequent region analyses showed a reliable effect for anterior sites. Midline sites showed a main effect of condition and an interaction with electrodes resulting in effects at FZ ($t_{(16)}$= -4.09, p=.001***) and CZ ($t_{(16)}$= -2.39, p=.030*).

Table 6.11: ANOVAs of ERP data in the time range 800-1300 ms for the combined versus the correct condition in Experiment 2. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Combined versus correct				
800-1300 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	8.93	.009**	5.04
Cond x Reg	1,15	97.02	<.001***	1.52
Cond x Hem	1,15	1.41	.254	.69
Cond x Reg x Hem	1,15	< 1		
Anterior				
Cond	1,15	3.52	.080	4.21
Posterior				
Cond	1,15	75.40	<.001***	2.36
Midline				
Cond	1,15	18.86	<.001***	8.69
Cond x elec	2,30	43.20	<.001***	1.14

Between 800-1300 ms for lateral electrodes a main effect of condition and an interaction with region were present resulting in significant effects in posterior areas. At midline sites a main effect of condition and an interaction with electrode were found. *T*-tests showed effects at CZ ($t_{(16)}$=4.27, p=<.001***) and PZ ($t_{(16)}$=7.69, p=<.001***).

6.3.2.4 Additional analyses on the combined violation

In order to test whether the combined violation resembles the pure word category violation, additional ANOVAs according to the same hierarchical schema were performed between the category and the combined and between the agreement and the combined violation for each time window.

The category versus the combined violation did not reveal any significant difference in each time window for lateral electrodes. Only for midline electrodes a reliable difference was present in the time range 500-700 ms ($F_{(1,15)}$=6.13, p=.026*, MS_e=2.74). The combined violation, however, differed significantly from the agreement condition in all time ranges. At lateral sites main effects of condition (100-250: $F_{(1,15)}$=9.72, p=.007**, MS_e=1.28; 250-650: $F_{(1,15)}$=14.32, p=.002**, MS_e=2.03; 500-700: $F_{(1,15)}$=7.59, p=.015*, MS_e=2.93; 800-1300: $F_{(1,15)}$=28.42, p=<.001***, MS_e=3.23) and reliable interactions condition x region (100-250: $F_{(1,15)}$=40.33, p=<.001***, MS_e=.31; 250-650: $F_{(1,15)}$=27.83, p=<.001***, MS_e=.78; 500-700: $F_{(1,15)}$=15.11, p=.002**, MS_e=1.18; 800-1300: $F_{(1,15)}$=12.45, p=.003**, MS_e=1.28) were present in all time windows. Subsequent region analyses showed significant differences in anterior regions in the time windows 100-250 ($F_{(1,15)}$=35.20, p=<.001***, MS_e=.71), 250-650 ($F_{(1,15)}$=40.31, p=<.001***, MS_e=1.25), and 500-700 ($F_{(1,15)}$=22.65, p=<.001***, MS_e=1.76). Between 800-1300 ms region analyses revealed reliable differences in anterior ($F_{(1,15)}$=32.81, p=<.001***, MS_e=2.81) and posterior regions ($F_{(1,15)}$=9.16, p=.009**, MS_e=1.70).

At midline electrodes a similar pattern was observable. Between 100-250 ms a reliable interaction condition x electrode was present ($F_{(2,30)}$=10.75, p=<.001***, MS_e=.23), resulting in significant effects at FZ ($t_{(16)}$= -2.88, p=.012*). In the time range 250-650 ms a reliable main effect of condition ($F_{(1,15)}$=6.59, p=.022*, MS_e=4.69) and an interaction condition x electrode ($F_{(2,30)}$=9.42, p=.003**, MS_e=.59) reached significance. Subsequent t-tests revealed reliable differences at FZ ($t_{(16)}$= -3.88, p=.002**) and CZ ($t_{(16)}$= -2.48, p=.025*). Between 500-700 ms an interaction with electrodes was reliable ($F_{(2,30)}$=4.83, p=.029*, MS_e=.86) and resulted in effects at FZ ($t_{(16)}$= -2.67, p=.018*). Finally, between 800-1300 ms both a main effect of condition ($F_{(1,15)}$=26.71, p=<.001***, MS_e=7.04) and the interaction condition x electrode ($F_{(2,30)}$=4.59, p=.033*, MS_e=1.52) reached significance. Subsequent t-tests showed reliable effects at FZ ($t_{(16)}$= -4.93, p=<.001***), CZ ($t_{(16)}$= -5.06, p=<.001***), and PZ ($t_{(16)}$= -2.84, p=.012*).

6.4 Discussion

Experiment 2 aimed to investigate the syntactic processing in late second language learners (Italian native speakers) who had learned L2 (German) after the age of 10 and had acquired a high L2 proficiency level. The role of proficiency in late L2 learners for using the same brain regions or adopt the same brain processing mechanisms as for the native language was shown in several neuroimaging and electrophysiological studies.
Three different syntactic anomalies, namely a word category violation, a morphosyntactic agreement violation, and a combination of the two error types, were presented acoustically in Experiment 2 while the EEG was recorded. The participants had to perform a grammaticality judgment task after each sentence. The aim was to test whether the same brain processing steps can be observed also in second language learners provided the fact that they have a high proficiency level. The most electrophysiological studies so far, found similar processing steps when participants were confronted with semantic information (Ardal et al., 1990; Weber-Fox & Neville, 1996; Hahne, 2001; Hahne & Friederici, 2001), but they showed different ERP patterns concerning different syntactic information types. Especially in ERP studies investigating word category violations, the early anterior negativity was absent in late learners (Hahne, 2001; Hahne & Friederici, 2001).

Only in an ERP study in which the word category violation was presented in an artificial miniature language with a restricted amount of rules and words, high proficient late learners showed up an ELAN component. The present experiment could also find such an early anterior negativity between 100 and 250 ms in German *word category violations* in high proficient L2 learners, suggesting that this automatic ERP component reflecting processes during initial phrase structure building can be elicited in case of a high proficiency level. Thus, this experiment provides the first ERP evidence (apart from MEG evidence provided by Kubota et al., 2004 in NP raising phrase structure violations; 2005 in infinitive c-selection violations) that early syntactic phrase structure building processes can also be processed in a native-like manner in the context of a natural language such as German, even when L2 was acquired later in time when a high proficiency level is ensured. A recent ERP study (Mueller, Hahne, Fujii & Friederici, 2005), which investigated syntactic processing in a miniature grammar extracted from Japanese, did not find such an early anterior negativity in word category violations although they trained late L2 learners until they had reached a high proficiency level on behavioral tests. Besides a differential learning period, a possible explanation could lie in the difference between the native language (which was German) and the L2 (Japanese). Thus, Japanese is typologically different to Indoeuropean languages to which German belongs. This may have led to the absence of an early syntactic word category processing in Mueller et al. (2005) despite a high proficiency. Similarity between the native language and the L2 was shown to play an important role and to lead to a faster acquisition of L2 (Steinberg, Nagata & Aline, 2001). Sensitivity to linguistic aspects, which are similar in L1 and L2 have been also found in other ERP studies investigating in particular morphosyntactic aspects (Sabourin, 2003; Tokowicz & MacWhinney, 2005). Further, the ELAN component was followed by an anterior negativity between 250 and 650 ms, which was found to reflect reference-related processes due to the omission of a highly expected noun in the prepositional phrase, which itself creates a reference to the subject noun which the prepositional phrase is specifying. After this additional negativity a P600 follows in the time range 800-1300 ms, suggesting that reanalysis processes take place at the same time as in German native speakers (Rossi et al., 2005).

Concerning the *morphosyntactic subject-verb agreement violation* compared to the correct condition high proficient L2 learners of German also displayed a native-like ERP pattern, namely a LAN effect between 500 and 700 ms reflecting the detection of the morphosyntactic agreement mismatch, followed by a P600 between 800 and 1300 ms indicating processes of reanalysis. Both ERP components occurred in approximately the same time range as in German native speakers (Rossi et al., 2005) and displayed a very similar topographical distribution. These findings indicate that also other syntactic information types like morphosyntax can show native-like processing mechanisms in late L2 learners provided that a high proficiency level is ensured.

The *combination of both syntactic anomalies* showed the same ERP pattern as the pure word category violation, namely an early anterior negativity, followed by an additional anteriorly distributed negativity and a P600. These ERP components in the combined condition occurred in exactly the same time range as in the pure word category violation and did not differed from each other. This indicates that also high proficient late L2 learners process the combined violation as the word category violation and do not take into account the additional agreement error. One difference between high proficient L2 learners of German and German native speakers arises concerning the P600. Whereas German native speakers display a modulation in this time range, no modulation is present for L2 learners processing German. One might speculate whether they adopt strategies from their L1 (Italian) and transfer them to the L2. Because Italian native speakers did not show a P600 modulation, either, this explanation might hold for the L2 learners of German. However, more detailed studies on combined violations in both different native languages and in second language learners as well, are certainly necessary in order to gain more clarity on the complex mechanisms underlying combined violation types. But one thing that can be clearly stated from Experiment 2 is that also in high proficient L2 learners of German primacy of word category information over other information types, in this case morphosyntax, is present as in native speakers (Rossi et al., 2005).

In general, the results of Experiment 2 challenge the assumption of the existence of a critical period for language acquisition ending with puberty, at least for morphosyntactic and phrase structure aspects in language comprehension. The acquired proficiency plays an important role in gaining native-like brain processing mechanisms even though the second language is acquired late in time (after puberty).

Chapter 7
Experiment 3:
Syntactic processing in low proficient L2 learners of German

7.1 Introduction

As low proficient L2 learners are assumed to have more difficulties processing especially syntactic information, also the brain responses are supposed to be different to that of native speakers of German and to differ to a greater extent from L1 processing mechanisms. This was visible in electrophysiological studies on word category violations by the absence of early syntactic components (Hahne & Friederici, 2001; Kubota et al., 2003), but indices of different processing mechanisms could also be observed in delays of ERP components (Hahne, 2001) or reduced amplitudes (Ardal et al., 1990; Hahne, 2001). Low proficient late L2 learners further showed different neural substrates for the processing of the second language (Perani et al., 1996) and are assumed to suffer more from age of acquisition effects.

The investigation of low proficient L2 learners might also be interesting in the light of Universal Grammar or whether an access is possible or not to such aspects like word category and morphosyntactic agreement information. As a high proficiency might provide an additional help for the learner to rely on UG, a low proficient learner at the beginning of his or her learning process probably might rely less or not at all on UG. Further, it is of interest whether different syntactic information types are processed in a similar way and a possible access to UG, if there is any, either applies to different syntactic information types or is only related to some of them.

In contrast to high proficient L2 learners of German, low proficient learners were expected to be more affected by latency delays or amplitude differences of the ERP components due to the fact that they may have learned or know explicitly all types of syntactic anomalies present in the study but may have not internalized them implicitly yet. In detail, concerning the word category violation, the presence of a P600 and a reference-related additional negativity was predicted, but no early anterior negativity as this ERP component is assumed to be automatic (Hahne & Friederici, 1999) and thus is not expected to occur in participants with a low L2 proficiency level.

Concerning the agreement violation, in particular the detection of the morphosyntactic error reflected by the LAN effect and the subsequent reanalysis indicated by the P600, low proficient learners of German were expected to suffer from latency delays and amplitude variation effects.

Regarding the combined violation, low proficient late L2 learners may be more disrupted by the presence of two syntactic anomalies. This may cause more processing problems, probably resulting in a more inconsistent ERP pattern. However, if low proficient learners also show a similar pattern as the pure word category violation this would indicate that they follow the same processing steps as high proficient learners or native speakers also when they encounter two error types in one sentence.

7.2 Methods

7.2.1 Subjects

In total 22 right-handed (assessed according to Oldfield, 1971) persons took part in the third experiment. 3 participants were excluded from statistical analyses because of too many artifacts. The 19 remaining subjects (13 female) were 23 years on average (range: 21-27 years). All participants were Italian native speakers who had learned German after the age of 10 and had acquired a low second language proficiency level. Detailed information about their age of acquisition, language-learning history, self rating on linguistic proficiency, and performance on translation tests are displayed in Table 7.1. Almost all were university students, they were paid for participation, had no known hearing deficits and normal or corrected-to-normal vision.

Table 7.1: Behavioral proficiency information in Experiment 3.
On the left the mean values and on the right the range is reported.

Behavioral measure	Low proficient L2 learners of German (n=19)	
Age (in yrs)	23.1	21-27
Age of acquisition (in yrs)	18.1	11-24
Time spent in L2 speaking countries (in yrs)	0.5	0.1-2
L2 learning period (in yrs)	3.5	0.3-7
L2 Self Rating Test (6-point-scale)		
Listening	3.0	2-4
Reading	3.2	2-4
Speaking	3.1	2-4
Writing	3.1	2-4
Vocabulary Translation Test (errors in %)	34.0	15-57.9
Preselection Translation Test (errors in %)	76.1	45-95

7.2.2 Materials

The German material used in this experiment was the same as in Experiment 2 (see Chapter 6.2.2).

7.2.3 Procedure

All subjects had to first perform the “Preselection Translation Test” before being allowed to take part in the experiment. To belong to the low proficient group participants had to do maximally 50% of correct translations. Then the EEG experiment with the same presentation procedure and grammaticality judgment task as in Experiment 1 and 2 followed. After the EEG-experiment the participants performed the “Vocabulary Translation Test” and filled out the general questionnaire.

7.2.4 ERP recording

The EEG recording procedure was exactly the same as in Experiment 1 and 2.

7.2.5 Data Analyses

Data analyses procedure was analogous to Experiment 1 and 2. The mean percentage of rejected trials due to artifacts in Experiment 3 was 8.5% on average (correct: 8.9%, category: 8.3%, agreement: 8.2%, combined: 8.7%).

Behavioral (accuracy rates and reaction times) and ERP data were analyzed with the same procedure as in Experiment 1 and 2. For the statistical ERP analysis on the mean amplitudes the following time windows were chosen according to literature and visual inspection:

- 100-250 ms (ELAN)
- 250-750 ms (additional negativity)
- 650-850 ms (LAN)
- 1100-1500 ms (P600)

7.3 Results

7.3.1 Behavioral data

Low proficient L2 learners of German performed the judgment task with an accuracy rate of 86.2% on average. The mean reaction time for correctly answered trials was 510.79 ms. Detailed information on the behavioral measures for each condition are displayed in Table 7.2.

Table 7.2: Mean and standard deviation of accuracy rates (first row) and reaction times (second row) during the judgement task in Experiment 3, indicated per experimental condition.

Correct		**Category**		**Agreement**		**Combined**	
Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
90.0%	7.2	81.0%	11.3	81.4%	11.1	92.5%	4.8
573.4 ms	249.9	506.7 ms	190.6	471.9 ms	210.2	491.2 ms	183.3

A one-way ANOVA concerning the accuracy rates revealed a significant main effect of condition ($F_{(3,54)}$=11.39, p<.001, MS_e=73.93). Subsequent paired t-tests revealed that the participants did the fewest errors in the combined violation, which differed significantly from the category and the agreement violation. Additionally, in the correct condition they performed better than in the category and the agreement violation.

The analysis of the reaction times also revealed a significant main effect of condition ($F_{(3,54)}$=8.85, p=.003, MS_e=9201.93). Subsequent paired t-tests showed that the agreement condition was answered significantly faster than the correct condition.

7.3.2 ERP data

The ERP data for single incorrect conditions versus the correct are displayed in Figure 7.1, 7.2, 7.3. The reported plots are filtered with an 8 Hz low pass filter for presentation purposes only.

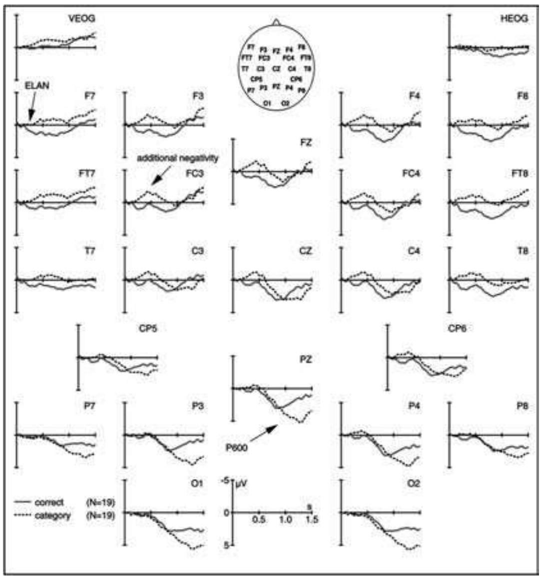

Figure 7.1: Grand average ERPs (category versus correct condition) from verb onset up to 1500 ms for low proficient L2 learners of German (Experiment 3). Negative voltage is plotted upwards.

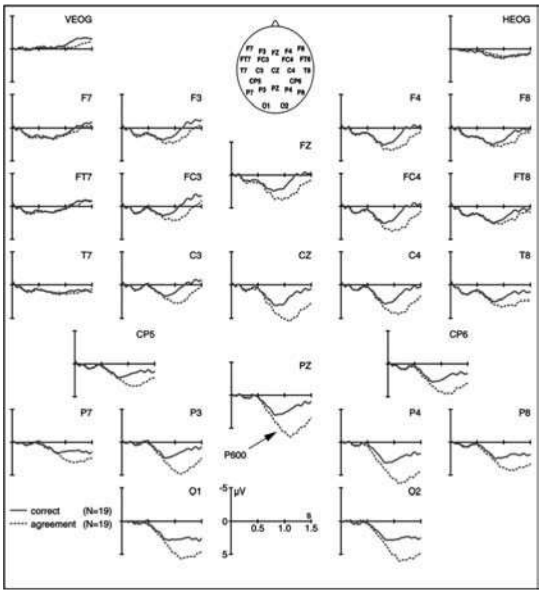

Figure 7.2: Grand average ERPs (agreement versus correct condition) from verb onset up to 1500 ms for low proficient L2 learners of German (Experiment 3). Negative voltage is plotted upwards.

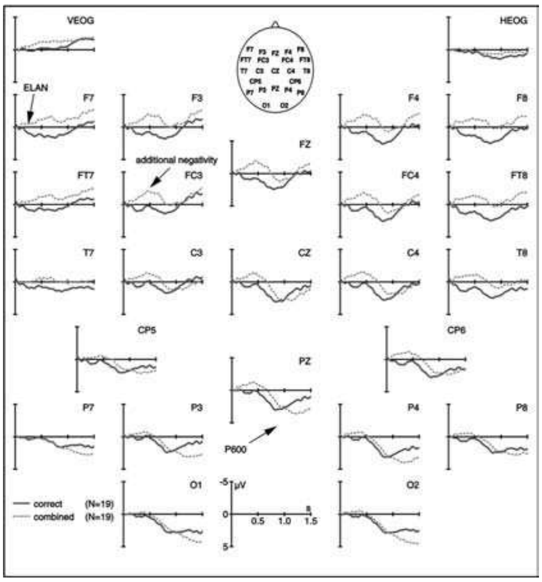

Figure 7.3: Grand average ERPs (combined versus correct condition) from verb onset up to 1500 ms for low proficient L2 learners of German (Experiment 3). Negative voltage is plotted upwards.

7.3.2.1 Word category violation

The word category violation in comparison with the correct condition showed in low proficient L2 learners of German an early anterior negativity between 100 and 250 ms, followed by an additional anterior negativity between 250 and 750 ms and a P600 with a posterior distribution (and a reduced amplitude) between 1100 and 1500 ms.

In detail, the statistical analyses for each time window provided the following results (Table 7.3, 7.4 and 7.5).

Table 7.3: ANOVAs of ERP data in the time range 100-250 ms for the category versus the correct condition in Experiment 3. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses and the third row shows hemisphere analyses. All these analyses are performed for lateral electrode sites. The fourth row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Category versus correct				
100-250 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	3.01	.100	2.13
Cond x Reg	1,18	10.86	.004**	.43
Cond x Hem	1,18	6.14	.023*	.24
Cond x Reg x Hem	1,18	< 1		
Anterior				
Cond	1,18	10.29	.005**	1.07
Posterior				
Cond	1,18	< 1		
Left				
Cond	1,18	< 1		
Right				
Cond	1,18	5.15	.036*	1.35
Midline				
Cond	1,18	1.01	.329	3.10
Cond x elec	2,36	4.81	.028*	.22

In the time window 100-250 ms both two-way interactions reached significance for lateral sites. Subsequent region analyses revealed a reliable main effect of condition in anterior regions and hemisphere analyses revealed a reliable effect in the right hemisphere. Midline electrodes only showed an interaction with electrodes, which did not show any significant electrode effect.

Table 7.4 ANOVAs of ERP data in the time range 250-750 ms for the category versus the correct condition in Experiment 3. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Category versus correct				
250-750 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	17.30	<.001***	2.49
Cond x Reg	1,18	56.04	<.001***	.45
Cond x Hem	1,18	< 1		
Cond x Reg x Hem	1,18	< 1		
Anterior				
Cond	1,18	42.21	<.001***	1.60
Posterior				
Cond	1,18	< 1		
Midline				
Cond	1,18	11.26	.004**	4.18
Cond x elec	2,36	11.18	<.001***	.40

Between 250-750 ms a main effect of condition and an interaction condition x region were present at lateral sites. Region analyses revealed a main effect in anterior areas. At midline electrodes a main effect of condition and an interaction with electrode were found resulting in reliable effects at FZ ($t_{(19)}$= -4.64, *p*=<.001***) and CZ ($t_{(19)}$= -3.14, *p*=.006**).

Table 7.5: ANOVAs of ERP data in the time range 1100-1500 ms for the category versus the correct condition in Experiment 3. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Category versus correct				
1100-1500 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	2.11	.163	5.22
Cond x Reg	1,18	30.83	<.001***	2.15
Cond x Hem	1,18	< 1		
Cond x Reg x Hem	1,18	< 1		
Anterior				
Cond	1,18	2.12	.162	5.47
Posterior				
Cond	1,18	34.67	<.001***	1.89
Midline				
Cond	1,18	5.01	.038*	9.82
Cond x elec	2,36	20.07	<.001***	1.12

Between 1100-1500 ms an interaction condition x region was found for lateral sites. Region analyses showed a positivity effect in posterior regions. At midline sites both a main effect and an interaction with electrode were present and resulted in reliable effects at PZ ($t_{(19)}$=5.43, p=<.001***).

7.3.2.2 Agreement violation

Concerning the agreement versus the correct condition no reliable negativity (LAN) effect was statistically observable. However, a late positivity was present between 1100 and 1500 ms distributed in anterior and posterior regions and displaying a reduced amplitude.

In detail, the statistical analyses for each time window provided the following results (Table 7.6 and 7.7).

Table 7.6: ANOVAs of ERP data in the time range 650-850 ms for the agreement versus the correct condition in Experiment 3. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere for lateral electrode sites. The second row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Agreement versus correct				
650-850 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	1.78	.199	2.60
Cond x Reg	1,18	< 1		
Cond x Hem	1,18	< 1		
Cond x Reg x Hem	1,18	< 1		
Midline				
Cond	1,18	4.26	.054	4.47
Cond x elec	2,36	< 1		

No reliable main effect of condition or interaction of any kind were found in the time window 650-850 ms neither for lateral nor for midline electrodes.

Table 7.7: ANOVAs of ERP data in the time range 1100-1500 ms for the agreement versus the correct condition in Experiment 3. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Agreement versus correct				
1100-1500 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	39.85	<.001***	2.81
Cond x Reg	1,18	8.29	.010**	1.74
Cond x Hem	1,18	4.19	.056	.62
Cond x Reg x Hem	1,18	< 1		
Anterior				
Cond	1,18	10.89	.004**	2.11
Posterior				
Cond	1,18	42.39	<.001***	2.44
Midline				
Cond	1,18	34.14	<.001***	6.12
Cond x elec	2,36	5.19	.027*	1.23

Between 1100-1500 ms for lateral electrodes a main effect of condition and an interaction condition x region reached significance. Subsequent region analyses showed a main effect in anterior and posterior regions. At midline electrodes a main effect of condition and an interaction condition x electrode were found resulting in main effects at FZ ($t_{(19)}$=3.93, p=.001***), CZ ($t_{(19)}$=5.27, p=<.001***), and PZ ($t_{(19)}$=5.48, p=<.001***).

7.3.2.3 Combined violation

The combined versus the correct condition revealed an early anterior negativity between 100 and 250 ms, an additional anteriorly distributed negativity between 250 and 750 ms, and a centro-parietal P600 (with a reduced amplitude) between 1100 and 1500 ms. The combined compared with the category violation did not show any difference, whereas the combined differed from the agreement violation in all time ranges.

In detail, the statistical analyses for each time window provided the following results (Table 7.8, 7.9 and 7.10).

Table 7.8: ANOVAs of ERP data in the time range 100-250 ms for the combined versus the correct condition in Experiment 3. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses and the third row shows hemisphere analyses. All these analyses are performed for lateral electrode sites. The fourth row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Combined versus correct

100-250 ms

Source	*df*	*F*	*p*	MS_e
Cond	1,18	17.15	<.001***	1.49
Cond x Reg	1,18	8.02	.011*	.46
Cond x Hem	1,18	12.97	.002**	.14
Cond x Reg x Hem	1,18	1.10	.309	.04
Anterior				
Cond	1,18	31.06	<.001***	.78
Posterior				
Cond	1,18	4.23	.054	1.16
Left				
Cond	1,18	7.69	.013*	.89
Right				
Cond	1,18	27.75	<.001***	.74
Midline				
Cond	1,18	6.51	.020*	3.08
Cond x elec	2,36	< 1		

Between 100-250 ms for lateral sites a main effect of condition and the interactions condition x region and condition x hemisphere reached significance. Region analyses showed a main effect in anterior and hemisphere anlyses showed main effects in the left and right hemisphere. At midline sites only a reliable main effect of condition was present.

Table 7.9: ANOVAs of ERP data in the time range 250-750 ms for the combined versus the correct condition in Experiment 3. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Combined versus correct		
250-750 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	26.01	<.001***	3.25
Cond x Reg	1,18	44.69	<.001***	.56
Cond x Hem	1,18	1.60	.222	.47
Cond x Reg x Hem	1,18	< 1		
Anterior				
Cond	1,18	59.36	<.001***	1.70
Posterior				
Cond	1,18	4.15	.057	2.11
Midline				
Cond	1,18	16.05	<.001***	5.63
Cond x elec	2,36	6.74	.009**	.41

In the time window 250-750 ms a main effect of condition and an interaction with region were present for lateral electrodes. Subsequent region analyses showed a reliable effect in anterior areas. Midline sites showed a main effect of condition and an interaction with electrodes resulting in effects at FZ ($t_{(19)}$= -5.33, p=<.001***), CZ ($t_{(19)}$= -3.21, p=.005**), and PZ ($t_{(19)}$= -2.82, p=.011*).

Table 7.10: ANOVAs of ERP data in the time range 1100-1500 ms for the combined versus the correct condition in Experiment 3. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Combined versus correct		
1100-1500 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,18	< 1		
Cond x Reg	1,18	26.10	<.001***	1.92
Cond x Hem	1,18	< 1		
Cond x Reg x Hem	1,18	< 1		
Anterior				
Cond	1,18	5.90	.026*	3.86
Posterior				
Cond	1,18	6.07	.024*	4.53
Midline				
Cond	1,18	1.20	.287	12.44
Cond x elec	2,36	10.75	.003**	1.22

Between 1100-1500 ms for lateral electrodes an interaction with region was found resulting in significant positivity effects in posterior areas. At midline sites an interaction with electrode was present. *T*-tests showed effects at PZ ($t_{(19)}$=2.42, p=.027*).

7.3.2.4 Additional analyses on the combined violation

Comparative analyses between the category and the combined violation revealed no difference in neither time range apart from a reliable interaction condition x electrode in the time range 100-250 ms for midline electrodes ($F_{(2,36)}$=5.43, p=.015*, MS_e=.08), resulting in a significant effect at PZ ($t_{(19)}$= -2.30, p=.034*).
The combined violation, however, differed significantly from the agreement condition in all time ranges:

- 100-250 ms: The global analysis revealed a reliable main effect of condition ($F_{(1,18)}$=10.12, p=.005**, MS_e=2.36) and a reliable interaction condition x region ($F_{(1,18)}$=4.91, p=.040*, MS_e=.55) for lateral sites. Subsequent region analyses revealed reliable main effects at anterior regions ($F_{(1,18)}$=14.44, p=.001***, MS_e=1.48). At midline electrodes the ANOVA revealed a significant main effect of condition ($F_{(1,18)}$=5.45, p=.031*, MS_e=4.27).
- 250-750 ms: The global analysis revealed a reliable main effect of condition ($F_{(1,18)}$=21.40, p=<.001***, MS_e=4.39) and a reliable interaction condition x region ($F_{(1,18)}$=34.28, p=<.001***, MS_e=.70) for lateral sites. Subsequent region analyses revealed reliable main effects at anterior ($F_{(1,18)}$=32.66, p=<.001***, MS_e=2.20) and posterior regions ($F_{(1,18)}$=5.05, p=.038*, MS_e=2.28). At midline electrodes the ANOVA revealed a significant main effect of condition ($F_{(1,18)}$=15.55, p=.001***, MS_e=7.46) and a reliable interaction condition x electrode ($F_{(2,36)}$=6.67, p=.013*, MS_e=.58), which resulted in reliable effect at FZ ($t_{(19)}$= -4.77, p=<.001***), CZ ($t_{(19)}$= -3.20, p=.005**), and PZ ($t_{(19)}$= -3.00, p=.008**).

- 650-850 ms: The global analysis revealed a reliable main effect of condition ($F_{(1,18)}$=21.23, p=<.001***, MS_e=6.60) and a reliable interaction condition x region ($F_{(1,18)}$=11.81, p=.003**, MS_e=1.60) for lateral sites. Subsequent region analyses revealed reliable main effects at anterior ($F_{(1,18)}$=26.36, p=<.001***, MS_e=4.96) and posterior regions ($F_{(1,18)}$=8.67, p=.009**, MS_e=3.23). At midline electrodes the ANOVA revealed a significant main effect of condition ($F_{(1,18)}$=18.04, p=<.001***, MS_e=10.31).
- 1100-1500 ms: The ANOVA only revealed a main effect of condition for lateral ($F_{(1,18)}$=15.61, p=<.001***, MS_e=6.73) and midline electrodes ($F_{(1,18)}$=10.62, p=.004**, MS_e=10.55).

7.4 Discussion

The goal of Experiment 3 was to test low proficient L2 learners of German and to see whether they display a differential ERP pattern in contrast to high proficient L2 learners of German and concerning which kind of syntactic information potential differences are present. Different brain processing mechanisms are assumed on the assumption that more critical period effects should affect the syntactic processing of late L2 learners when the proficiency level is not as experienced as in high proficient learners.
From a general point of view, the ERPs for this group of L2 learners clearly displayed differences in contrast to learners with a higher proficiency level concerning both syntactic anomalies. Differences were of qualitative and/or quantitative kind with respect to different ERP components in the different syntactic information types.

In detail, *word category violations* in low proficient L2 learners of German displayed a triphasic ERP pattern as high proficient learners but with some quantitative differences. Between 100 and 250 ms an early anterior negativity was present. This effect was followed by an additional negativity between 250 and 750 ms with an anterior distribution and a centro-parietal P600 between 1100 and 1500 ms. Differences were visible first in the additional negativity, which had a longer extension in low proficient learners than in high proficient ones (250-650 ms).

A similar ERP component extension was also found in Kutas and Kluender (1991) and Hahne and Friederici (2001) and Moreno and Kutas (2005) with respect to the N400 in semantic violations. They argue that participants take more time to integrate the word in the prior context and that this might indicate more uncertainty in processing. This explanation could also account for the longer additional negativity in the present experiment in low proficient learners of German indicating that the use of subject specificity information in word category violations is not as experienced as in high proficient learners and thus needs more time to be processed. A second difference arising in low proficient learners of German concerns the latency and amplitude of the P600. This component occurred later in time in low proficient learners (between 1100 and 1500) with reduced amplitude in contrast to high proficient learners (between 800 and 1300 ms as in German native speakers, Rossi et al., 2005). The P600 in L2 learners was also somewhat delayed in Hahne (2001). The latency delay and amplitude reduction indicate some reanalysis problems in low proficient learners maybe due to the fact that they need more time to initiate the reanalysis of the sentence and to try to integrate the occurred errors. This seems plausible, as low proficient L2 learners presumably cannot use enough resources to reanalyze the sentence and thus take more time to integrate all syntactic features. Surprisingly, an ELAN effect was also found in low proficient L2 learners. This might be attributed to the active sentence structure of the presented materials, in contrast to other L2 studies with passive sentences (Hahne & Friederici, 2001; Hahne, 2001) where no early negativity was found. The development of first language acquisition may provide some hints in explaining this difference. In first language acquisition passive voice is learned after active voice and in general, passive sentences are more complex and mostly require additional auxiliary verbs and moving elements to another position (Guasti, 2004). This complexity difference in passive versus active sentences was also found in ERP studies with children. Whereas the ELAN with the same latency and distribution as in adults was not present until the age of 13 when presenting acoustically passive word category violations (Hahne, Eckstein & Friederici, 2004), this left anterior negativity similar to that of adults was present in children between 31 and 34 months when word category violations embedded in active sentences were presented (Oberecker, Friedrich & Friederici, in press).

Thus, these results provide ERP evidence that this early anterior negativity can also be elicited by low proficient L2 learners of German in simple active voice sentences. Additionally, the presentation setting in the present study, which contained only syntactic and no semantic violations, may have facilitated participants to concentrate on syntactic processing of a restricted amount of syntactic rules (word category information, morphosyntactic features, and a combination of the two). The relatively high accuracy rates during the judgement task in low proficient L2 learners of German (81% correct judgements concerning the category violation) provide additional evidence that the low proficient L2 learners realized the word category violation quite well despite the low proficiency displayed in other behavioral measures (see Table 7.1). Therefore it seems plausible that they display an early syntactic ERP component related to the processing of word category information.

Concerning *morphosyntactic agreement violations* the participants of the present experiment displayed both qualitative and quantitative differences in the ERP pattern in contrast to high proficient learners. Low proficient learners of German failed to show a LAN effect, suggesting that they have problems with the detection of the morphosyntactic mismatch. Again first language development may provide a hint for the absence of this ERP component. In first language acquisition word category information in terms of knowing what is a noun, a verb etc. is acquired quite early. First words, which are mostly nouns, are produced by the child at about 12 months of age. Between 18 to 24 months two word utterances follow, mostly consisting of a noun and a verb without any morphology. Morphological features arise at about 2 years of age and consolidate until the age of 5 and beyond (Guasti, 2004). A parallel development might be observed in late L2 acquisition. In an initial stage category information is acquired and in following stages the whole variety of morphological features follows (Hawkins, 2001). Because morphosyntax seems to be acquired later than word category information it seems plausible to assume that low proficient L2 learners have more problems in processing morphosyntactic aspects (and therefore not showing reliable LAN effects) whereas word category violations embedded in a simple sentence context, in contrast, are able to be processed also by persons with a lower proficiency level.

Concerning the P600 in low proficient L2 learners a quantitative difference arose as this ERP component, analogous to the P600 in word category violations, was delayed. Latency delays in L2 learners seem to reflect more processing problems when initiating the different processing steps, in this case the process of reanalysis.

The processing of the *combined violation* behaved like the pure word category violation also in low proficient learners of German. Thus, the same ERP components were present in the same time ranges and with the same distribution as for the word category violation. They did not differ from each other, whereas differences were present between the combined and the agreement violation. The observed ERP components in relation to the combined violation were an early anterior negativity between 100 and 250 ms, an additional negativity between 250 and 750 ms, and a P600 between 1100 and 1500 ms. The additional negativity again displayed a prolonged latency and the P600 occurred later in time and showed a reduced amplitude in contrast to high proficient learners. These findings indicate that a primacy of word category information over morphosyntactic aspects is also present in low proficient learners, and thus suggest that the same processing mechanisms are activated as for high proficient L2 learners. Similarly to high proficient L2 learners of German, even the participants in this group did not show a modulation of the P600 as German native speakers (Rossi et al., 2005). This may suggest that similar transfer effects from L1 to L2 are taken into consideration even in low proficient L2 learners as the native language of the subjects in Experiment 3 was Italian. Italian native speakers (Experiment 1) also showed no modulating effects concerning the P600 in the combined violation.

Chapter 8

Experiment 4:

Syntactic processing in high proficient L2 learners of Italian

8.1 Introduction

In principle, the expectations for high proficient L2 learners of Italian were the same as for the high proficient L2 learners of German (Experiment 2). Thus, the same processing mechanisms as in native speakers were expected, namely an ELAN, an additional negativity, and a P600 for the word category violation, a LAN and a P600 for the morphosyntactic agreement violation, and the same ERP pattern as the pure word category violation for the combination of both violation types.

The motivation for investigating L2 learners of German and Italian was driven by the fact that both languages display many differences as they belong to two different language directions such as the Germanic and the Romance languages. Despite these formal differences, both violation types – the word category and the morphosyntactic error – could be created in the same manner, ensuring the same placement into the sentence, the same word order, and the same amount of words in both sentences. As a consequence, both violation types could be kept equal and possible differences in the ERP pattern may be attributable to different processing mechanisms arising from formal differences between the two languages rather than from the different realization of the violations.

Because the native language of this group was German, i.e. the second language of the L2 learners of Experiment 2 and the investigated second language in this experiment was German, i.e. the native language of the participants in Experiment 2, the native and second languages are equally crossed over the experiments. Thus, it is guaranteed that eventually occurring effects arising from the native language are controlled for.

8.2 Methods

8.2.1 Subjects

In total 20 right-handed (assessed according to Oldfield, 1971) persons took part in the fourth experiment. 4 participants were excluded from statistical analyses because of too many artifacts. The 16 remaining subjects (12 female) were 28 years on average (range: 21-33 years). All participants were German native speakers who had learned Italian after the age of 10 and had reached a high second language proficiency level. Detailed information about their age of acquisition, language-learning history, self rating on linguistic proficiency, and performance on translation tests are displayed in Table 8.1. Almost all were university students, they were paid for participation, had no known hearing deficits and normal or corrected-to-normal vision.

Table 8.1: Behavioral proficiency information in Experiment 4.
On the left the mean values and on the right the range is reported.

Behavioral measure	High proficient L2 learners of Italian (n=16)	
Age (in yrs)	27.5	21-33
Age of acquisition (in yrs)	20.8	14-28
Time spent in L2 speaking countries (in yrs)	1.0	0-5
L2 learning period (in yrs)	4.8	1.5-9.5
L2 Self Rating Test (6-point-scale)		
Listening	4.6	4-5
Reading	4.7	4-6
Speaking	4.3	3-5
Writing	3.8	3-5
Vocabulary Translation Test (errors in %)	12.4	2.5-27.5
Preselection Translation Test (errors in %)	11.1	0-20

8.2.2 Materials

The Italian material used in this experiment was the same as in Experiment 1 (see Chapter 5.2.2).

8.2.3 Procedure

All subjects had to first perform the "Preselection Translation Test" before being allowed to take part in the experiment. To belong to the high proficient Italian group participants had to make less than 20% errors during translations from Italian (L2) to German (L1). Then the EEG experiment with the same presentation procedure and grammaticality judgement task as in Experiment 1, 2, and 3 followed. After the EEG-experiment the participants performed the "Vocabulary Translation Test" and filled out the general questionnaire.

8.2.4 ERP recording

The EEG recording procedure was exactely the same as in Experiment 1, 2 and 3.

8.2.5 Data Analyses

Data analyses procedure was analogous to Experiment 1, 2, and 3. The mean percentage of rejected trials due to artifacts in Experiment 4 was 11.8% on average (correct: 10.4%, category: 12.2%, agreement: 12.5%, combined: 12.0%).

Behavioral (accuracy rates and reaction times) and ERP data were analyzed with the same procedure as in Experiment 1, 2, and 3. For the statistical ERP analysis on the mean amplitudes the same time windows as for high proficient L2 learners of German were chosen:

- 100-250 ms (ELAN)
- 250-650 ms (additional negativity)
- 500-700 ms (LAN)
- 800-1300 ms (P600)

8.3 Results

8.3.1 Behavioral data

High proficient L2 learners of Italian performed the judgement task high accurately (96.6% on average). The mean reaction time for correctly answered trials was 414.79 ms. Detailed information on the behavioral measures for each condition are displayed in Table 8.2.

Table 8.2: Mean and standard deviation of accuracy rates (first row) and reaction times (second row) during the judgement task in Experiment 4, indicated per experimental condition.

Correct		**Category**		**Agreement**		**Combined**	
Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
97.6%	5.7	97.3%	6.0	92.6%	7.0	99.0%	4.6
444.8 ms	150.2	408.4 ms	126.4	399.7 ms	127.4	406.1 ms	130.7

A one-way ANOVA concerning the accuracy rates revealed a significant main effect of condition ($F_{(3,45)}$=11.92, p<.001, MS_e=14.76). Subsequent paired t-tests revealed that participants made more errors in the agreement violation than in the correct, category, and combined violation. The analysis of the reaction times, on the other hand, also revealed a significant main effect of condition ($F_{(3,45)}$=6.10, p=.008, MS_e=1840.63). Subsequent paired t-tests showed that the agreement condition was answered significantly faster than the correct condition.

8.3.2 ERP data

The ERP data for single incorrect conditions versus the correct are displayed in Figure 8.1,8.2, 8.3. The reported plots are filtered with an 8 Hz low pass filter for presentation purposes only.

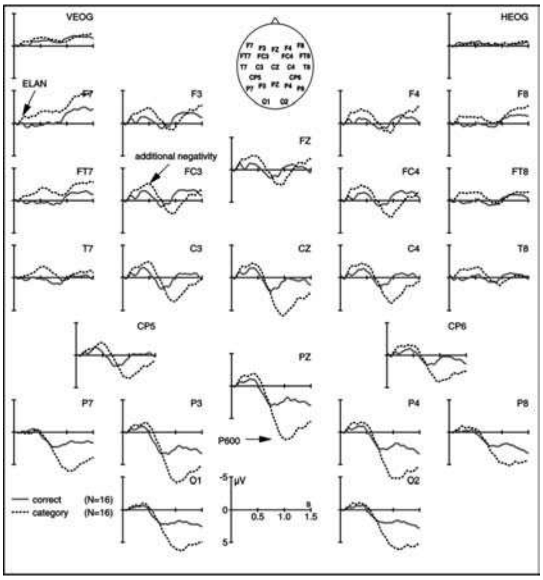

Figure 8.1: Grand average ERPs (category versus correct condition) from verb onset up to 1500 ms for high proficient L2 learners of Italian (Experiment 4). Negative voltage is plotted upwards.

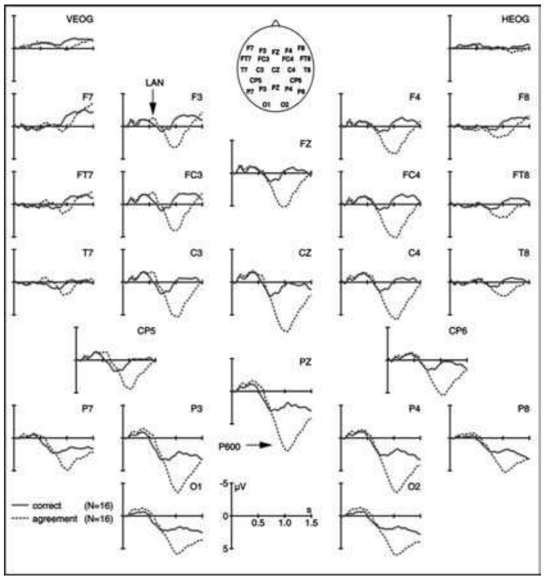

Figure 8.2: Grand average ERPs (agreement versus correct condition) from verb onset up to 1500 ms for high proficient L2 learners of Italian (Experiment 4). Negative voltage is plotted upwards.

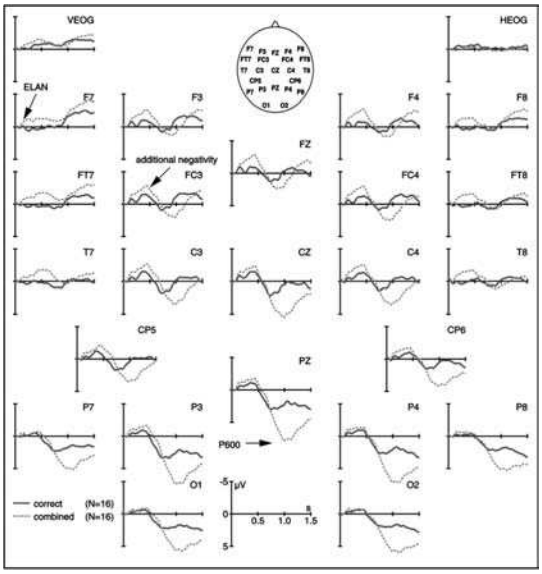

Figure 8.3: Grand average ERPs (combined versus correct condition) from verb onset up to 1500 ms for high proficient L2 learners of Italian (Experiment 4). Negative voltage is plotted upwards.

8.3.2.1 Word category violation

The word category violation compared to the correct condition revealed in high proficient L2 learners of Italian a broadly distributed early negativity between 100 and 250 ms, an additional anterior negativity between 250 and 650 ms, and a posteriorly distributed P600 between 800 and 1300 ms.

In detail, the statistical analyses for each time window provided the following results (Table 8.3, 8.4 and 8.5).

Table 8.3: ANOVAs of ERP data in the time range 100-250 ms for the category versus the correct condition in Experiment 4. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere for lateral electrode sites. The second row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Category versus correct		
100-250 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	9.49	.008**	1.09
Cond x Reg	1,15	1.51	.238	.94
Cond x Hem	1,15	1.69	.213	.20
Cond x Reg x Hem	1,15	< 1		
Midline				
Cond	1,15	5.05	.040*	1.96
Cond x elec	2,30	< 1		

In the time window 100-250 ms a main effect of condition was present for lateral and midline sites.

Table 8.4: ANOVAs of ERP data in the time range 250-650 ms for the category versus the correct condition in Experiment 4. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Category versus correct		
250-650 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	7.55	.015*	3.66
Cond x Reg	1,15	8.40	.011*	.61
Cond x Hem	1,15	< 1		
Cond x Reg x Hem	1,15	< 1		
Anterior				
Cond	1,15	10.45	.006**	2.70
Posterior				
Cond	1,15	2.88	.111	1.56
Midline				
Cond	1,15	2.84	.113	7.64
Cond x elec	2,30	< 1		

Between 250-650 ms a main effect of condition and an interaction condition x region were present at lateral sites resulting in reliable effects in anterior regions. Midline electrodes did not show any significant effect.

Table 8.5: ANOVAs of ERP data in the time range 800-1300 ms for the category versus the correct condition in Experiment 4. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Category versus correct		
800-1300 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	11.94	.004**	7.88
Cond x Reg	1,15	34.77	<.001***	2.09
Cond x Hem	1,15	< 1		
Cond x Reg x Hem	1,15	2.13	.165	.46
Anterior				
Cond	1,15	< 1		
Posterior				
Cond	1,15	32.92	<.001***	5.04
Midline				
Cond	1,15	13.50	.002**	18.34
Cond x elec	2,30	20.94	<.001***	1.41

Between 800-1300 ms a main effect of condition and an interaction condition x region were found for lateral sites. Region analyses showed a positivity effect in posterior regions. At midline sites both a main effect of condition and an interaction with electrodes were present and resulted in reliable effects at CZ ($t_{(16)}$=3.55, p=.003**) and PZ ($t_{(16)}$=5.65, p=<.001***).

8.3.2.2 Agreement violation

The agreement violation in comparison with correct sentences revealed a left-lateralized anterior negativity (LAN) between 500 and 700 ms followed by a broadly distributed positivity (P600) between 800 and 1300 ms.

In detail, the statistical analyses for each time window provided the following results (Table 8.6 and 8.7).

Table 8.6: ANOVAs of ERP data in the time range 500-700 ms for the agreement versus the correct condition in Experiment 4. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows hemisphese anayses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Agreement versus correct		
500-700 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	1.72	.210	3.79
Cond x Reg	1,15	2.65	.124	.64
Cond x Hem	1,15	6.36	.024*	.56
Cond x Reg x Hem	1,15	< 1		
Left				
Cond	1,15	4.98	.041*	1.98
Right				
Cond	1,15	< 1		
Midline				
Cond	1,15	< 1		
Cond x elec	2,30	2.46	.128	.69

Between 500-700 ms only a reliable interaction with hemisphere reached significance for lateral sites. Subsequent hemisphere analyses revealed a main effect in the left hemisphere. At midline electrodes no reliable effect was found.

Table 8.7: ANOVAs of ERP data in the time range 800-1300 ms for the agreement versus the correct condition in Experiment 4. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere for lateral electrode sites. The second row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Agreement versus correct		
800-1300 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	52.66	<.001***	4.50
Cond x Reg	1,15	1.66	.217	1.88
Cond x Hem	1,15	2.84	.113	1.02
Cond x Reg x Hem	1,15	1.22	.287	.23
Midline				
Cond	1,15	61.21	<.001***	8.58
Cond x elec	2,30	2.33	.139	1.75

Between 800-1300 ms only a main effect of condition was present for both lateral and midline electrodes.

8.3.2.3 Combined violation

The combined versus the correct condition showed a broadly distributed early negativity between 100 and 250 ms, followed by an additional anterior negativity between 250 and 650 ms and a centro-parietal P600 between 800 and 1300 ms. The combined condition did not show any difference compared with the category violation, whereas the combined in contrast to the agreement violation displayed clear differences in the time ranges 250-650 ms and 800-1300 ms.

In detail, the statistical analyses for each time window provided the following results (Table 8.8, 8.9 and 8.10).

Table 8.8: ANOVAs of ERP data in the time range 100-250 ms for the combined versus the correct condition in Experiment 4. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere for lateral electrode sites. The second row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Combined versus correct				
100-250 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	7.63	.015*	1.68
Cond x Reg	1,15	2.05	.173	.65
Cond x Hem	1,15	< 1		
Cond x Reg x Hem	1,15	< 1		
Midline				
Cond	1,15	3.76	.072	2.67
Cond x elec	2,30	.11	.780	.40

Between 100-250 ms a main effect of condition was only present for lateral sites. No reliable effect was found for midline electrodes.

Table 8.9: ANOVAs of ERP data in the time range 250-650 ms for the combined versus the correct condition in Experiment 4. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Combined versus correct		
250-650 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	7.43	.016*	3.55
Cond x Reg	1,15	7.32	.016*	.72
Cond x Hem	1,15	1.52	.236	.32
Cond x Reg x Hem	1,15	< 1		
Anterior				
Cond	1,15	12.42	.003**	2.22
Posterior				
Cond	1,15	1.98	.180	2.05
Midline				
Cond	1,15	3.04	.102	6.38
Cond x elec	2,30	2.38	.121	.59

In the time window 250-650 ms a main effect of condition and an interaction with region were found for lateral electrodes. Subsequent region analyses showed a reliable effect in anterior areas. Midline sites did not show any reliable effect.

Table 8.10: ANOVAs of ERP data in the time range 800-1300 ms for the combined versus the correct condition in Experiment 4. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Combined versus correct		
800-1300 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,15	19.09	<.001***	4.84
Cond x Reg	1,15	21.01	<.001***	2.47
Cond x Hem	1,15	< 1		
Cond x Reg x Hem	1,15	< 1		
Anterior				
Cond	1,15	1.04	.323	2.78
Posterior				
Cond	1,15	31.24	<.001***	4.52
Midline				
Cond	1,15	28.47	<.001***	7.36
Cond x elec	2,30	14.67	<.001***	1.60

Between 800-1300 ms for lateral electrodes a main effect of condition and an interaction condition x region were found resulting in significant positivity effects in posterior areas. At midline sites a main effect of condition and an interaction with electrode were present. Subsequent *t*-tests showed reliable effects at CZ ($t_{(16)}$=4.75, p=<.001***) and PZ ($t_{(16)}$=5.91, p=<.001***).

8.3.2.4 Additional analyses on the combined violation

Comparative analyses between the category and the combined violation did not reveal any significant effect. In detail, only a significant three-way interaction was present for lateral electrodes in the time windows 250-650 ms ($F_{(1,15)}$=6.28, p=.024*, MS_e=.08) and 800-1300 ms ($F_{(1,15)}$=5.16, p=.038*, MS_e=.19), which, however, did not show any subsequent ROI effect.

The combined violation, however, differed significantly from the agreement condition in the time ranges 250-650 ms and 800-1300 ms. In detail, between 250-650 ms a reliable interaction condition x region ($F_{(1,15)}$=8.31, p=.011*, MS_e=1.37) was present for lateral sites, resulting in a significant effect in anterior regions ($F_{(1,15)}$=7.70, p=.014*, MS_e=3.09). At midline electrodes in this time window the interaction condition x electrode ($F_{(2,30)}$=5.42, p=.023*, MS_e=.61) reached significance and resulted in a reliable electrode effect at FZ ($t_{(16)}$= -2.40, p=.030*). Between 800-1300 ms a significant main effect of condition ($F_{(1,15)}$=9.62, p=.007**, MS_e=3.47) and a reliable interaction condition x region ($F_{(1,15)}$=8.06, p=.012*, MS_e=3.67) were present for lateral sites. Subsequent region analyses revealed a reliable difference in anterior regions ($F_{(1,15)}$=18.85, p=<.001***, MS_e=3.34). At midline electrodes both the main effect of condition ($F_{(1,15)}$=13.31, p=.002**, MS_e=5.35) and the interaction condition x electrode ($F_{(2,30)}$=5.05, p=.031*, MS_e=1.96) reached significance and resulted in reliable electrode effects at FZ ($t_{(16)}$= -5.27, p=<.001***) and CZ ($t_{(16)}$= -2.86, p=.012*).

8.4 Discussion

The goal of Experiment 4 was to investigate the syntactic processing in late L2 learners of Italian with a high L2 proficiency level. The experimental procedure was kept the same as in Experiment 2, i.e. the auditory presentation of sentences (in this experiment in Italian) containing correct sentences, word category violations, morphosyntactic agreement violations, a combination of both error types, and correct filler conditions. The word order, word amount per sentence and the anomaly type were identical in Italian as in German. Just the creation of the morphosyntactic agreement violation differed slightly between the two languages as the inflection error was realized by the first instead of the third person singular in Italian, whereas it was created by the second instead of the third person singular in German. There was no possibility to keep the violation exactly equivalent because the reversed pattern in each language would have led to a correct form in the present subjunctive. Thus, these two languages were chosen because equivalent material construction was possible, even though Romance and Germanic languages per se display several formal differences, which could potentially lead to a differential brain processing. However, previous studies had already shown that word category violations and morphosyntactic violations give rise to comparable ERP patterns across different languages, at least in native speakers. Thus, universal processing mechanisms are assumed, also for late second language learners with a high proficiency level. A native-like ERP pattern was found in the present experiment for all conditions. Further, the processing steps did not differ at all from high proficient learners of German. Therefore the assumption of universal processing mechanisms between different languages, which allow the same violation types and thus contain the same syntactic aspects, can be borne out also in second language acquisition.

In detail, the *word category violation* gave rise to an early negativity between 100 and 250 ms, an additional anterior negativity between 250 and 650 ms, and a centro-parietal P600 between 800 and 1300 ms. The time ranges in which these ERP components occurred were the same as in high proficient L2 learners of German and varied minimally from native speakers of Italian.

These results suggest that the same processing steps, namely initial phrase structure building processes, reference-related processes, and late reanalysis processes, are observed also for late learners of a different language such as Italian provided the fact that they have reached a high proficiency level.

Regarding the *morphosyntactic agreement violation*, high proficient L2 learners of Italian showed a LAN effect between 500 and 700 ms suggesting that the subject–verb agreement mismatch was successfully detected and afterwards reanalyzed (reflected by the P600 between 800 and 1300 ms).

Concerning the *combined condition*, again the same ERP pattern as in the pure word category violation was observed, namely an ELAN, an additional negativity, and a P600. The P600 did not suffer from modulation effects. Both the positivity and the preceding negativities did not differ at all from the category violation in contrast to more differences between the combined and the agreement violation. The speculative interpretation raised for Experiment 2 and 3 that the absence of a modulation might arise from a possible transfer from L1 to L2 might not hold for this group of L2 learners. Their native language was German and German native speakers (Rossi et al., 2005) showed a P600 in the combined violation, which differed from both the category and the agreement violation. The detailed mechanisms that are responsible for these slight differences in the P600 are still unclear and surely have to be systematically investigated in further studies.

However, from a more global perspective, also for high proficient L2 learners of Italian the same processing steps were visible as for Italian native speakers, suggesting that also in this language a further error type such as the morphosyntax is ignored whenever it occurs together with a word category information.

Together with Experiment 2, this experiment provides strong evidence that despite a late exposure to L2 when a high proficiency is gained, native-like processing mechanisms can be shown for different syntactic information types. This leads further to the conclusion that at least for language comprehension an intensive language training can lead to a native-like performance, even at a later learning age (after puberty). In particular, Experiment 2 and 4 provide the first ERP evidence that also early automatic first-pass parsing processes as reflected by the ELAN component in word category violations can occur in the context of natural languages such as German and Italian. So far, this component has only been described in an ERP study with an artificial language containing very restricted linguistic information, and in phrase structure violations in high proficient late L2 learners of English by means of MEG (Kubota et al., 2004; 2005).

Chapter 9

Experiment 5:

Syntactic processing in low proficient L2 learners of Italian

9.1 Introduction

Experiment 5 aimed, in analogy to Experiment 3 to investigate the syntactic processing in low proficient L2 learners. However, in this experiment the participants were German native speakers who had learned Italian as L2 and the presented material was Italian.

Analogous to Experiment 3 the same predictions can be made also for low proficient L2 learners of Italian. It was expected that concerning the word category violation a P600, and an additional negativity reflecting reference-related processes should be occur and probably suffer from amplitude reduction or delay effects. Because in Experiment 3 the word category violation gave rise to an early anterior negativity, too, probably due to the simple active sentences, also for low proficient learners of Italian such an early syntactic ERP component was expected as also the Italian material was constructed in the active voice and thus is simpler to be processed than, for example, passive sentences (cf. Hahne, Eckstein & Friederici, 2004).

For the agreement violation, the absence of a LAN effect, but the presence of a P600 effect was predicted. However, similar to Experiment 3 the P600 should be reduced in amplitude and its occurrence should be delayed.

For the combined violation again the same ERP pattern as the pure word category was expected, namely an ELAN, an additional negativity, and a P600.

In general, because of the same violation types embedded in an equivalent material to the German one, no differential ERP patterns were expected in contrast to low proficient learners of German, enhancing the idea that universal brain processing mechanisms must underlie the same syntactic information types.

9.2 Methods

9.2.1 Subjects

In total 22 right-handed (assessed according to Oldfield, 1971) persons took part in the fifth experiment. 4 participants were excluded from statistical analyses because of too many artifacts. The 18 remaining subjects (10 female) were 25 years on average (range: 19-30 years). All participants were German native speakers who had learned Italian after the age of 10 and had acquired a low second language proficiency level. Detailed information about their age of acquisition, language-learning history, self rating on linguistic proficiency, and performance on translation tests are displayed in Table 9.1. Almost all were university students, they were paid for participation, had no known hearing deficits and normal or corrected-to-normal vision.

Table 9.1: Behavioral proficiency information in Experiment 5.
On the left the mean values and on the right the range is reported.

Behavioral measure	**Low proficient L2 learners of Italian (n=18)**	
Age (in yrs)	24.8	19-30
Age of acquisition (in yrs)	19.0	12-25
Time spent in L2 speaking countries (in yrs)	0.2	0-1.2
L2 learning period (in yrs)	2.1	0-6
L2 Self Rating Test (6-point-scale)		
Listening	2.9	2-4
Reading	3.2	2-4
Speaking	2.7	2-4
Writing	2.9	2-4
Vocabulary Translation Test (errors in %)	53.4	35.4-74.2
Preselection Translation Test (errors in %)	70.0	57.5-82.5

9.2.2 Materials

The Italian material used in this experiment was the same as in Experiment 1 and 4 (see Chapter 5.2.2).

9.2.3 Procedure

All subjects had to first perform the “Preselection Translation Test” before being allowed to take part in the experiment. To belong to the low proficient Italian group participants had to make maximally 50% correct translations from Italian (L2) to German (L1). Then the EEG experiment with the same presentation procedure and grammaticality judgement task as in all previous experiments followed. After the EEG-experiment the participants performed the “Vocabulary Translation Test” and filled out the general questionnaire.

9.2.4 ERP recording

The EEG recording procedure was exactely the same as in the previous experiments.

9.2.5 Data Analyses

Data analyses procedure was analogous to the previous experiments. The mean percentages of rejected trials due to artifacts in Experiment 5 was 13.8% on average (correct: 13.8%, category: 13.3%, agreement: 13.6%, combined: 14.4%).

Behavioral (accuracy rates and reaction times) and ERP data were analyzed with the same procedure as in the previous experiments. For the statistical ERP analysis on the mean amplitudes the same time windows as for low proficient L2 learners of German were chosen:

- 100-250 ms (ELAN)
- 250-750 ms (additional negativity)
- 650-850 ms (LAN)
- 1100-1500 ms (P600)

9.3 Results

9.3.1 Behavioral data

Low proficient L2 learners of Italian performed the judgement task with an accuracy rate of 86.6% on average. The mean reaction time for correctly answered trials was 436.63 ms. Detailed information on the behavioral measures for each condition are displayed in Table 9.2.

Table 9.2: Mean and standard deviation of accuracy rates (first row) and reaction times (second row) during the judgement task in Experiment 5, indicated per experimental condition.

Correct		**Category**		**Agreement**		**Combined**	
Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
91.2%	10.0	85.1%	14.6	78.8%	11.7	91.4%	8.5
488.5 ms	222.0	411.9 ms	128.6	431.8 ms	181.8	414.4 ms	117.6

A one-way ANOVA concerning the accuracy rates revealed a significant main effect of condition ($F_{(3,51)}$=9.77, p<.001, MS_e=82.41). Subsequent paired t-tests showed a higher amount of errors in the agreement violation than in the correct and the combined violation. The analysis of the reaction times, on the other hand, revealed a significant main effect of condition ($F_{(3,51)}$=6.10, p=.015, MS_e=8421.99). Subsequent paired t-tests showed that the agreement condition was answered significantly faster than the correct condition.

9.3.2 ERP data

The ERP data for single incorrect conditions versus the correct are displayed in Figure 9.1, 9.2, 9.3. The reported plots are filtered with an 8 Hz low pass filter for presentation purposes only.

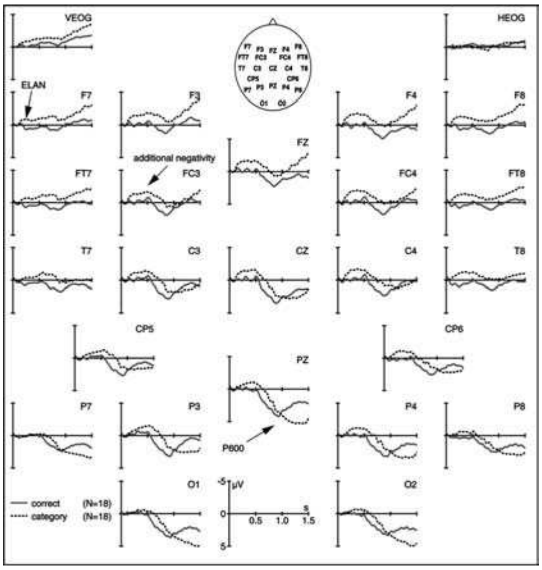

Figure 9.1: Grand average ERPs (category versus correct condition) from verb onset up to 1500 ms for low proficient L2 learners of Italian (Experiment 5). Negative voltage is plotted upwards.

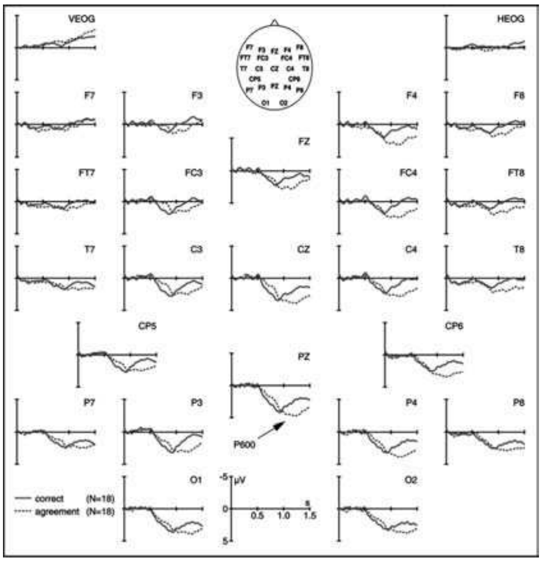

Figure 9.2: Grand average ERPs (agreement versus correct condition) from verb onset up to 1500 ms for low proficient L2 learners of Italian (Experiment 5). Negative voltage is plotted upwards.

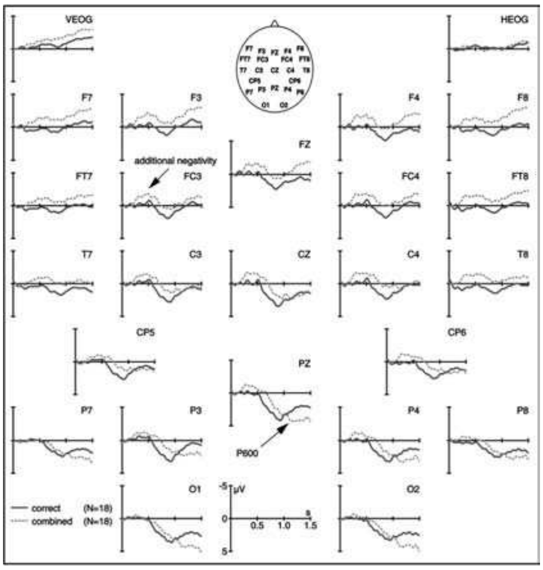

Figure 9.3: Grand average ERPs (combined versus correct condition) from verb onset up to 1500 ms for low proficient L2 learners of Italian (Experiment 5). Negative voltage is plotted upwards.

9.3.2.1 Word category violation

The word category violation compared to correct sentences revealed in low proficient L2 learners of Italian an early anterior negativity between 100 and 250 ms, followed by an additional broadly distributed negativity between 250 and 750 ms and a P600 with a posterior distribution (and a reduced amplitude) between 1100 and 1500 ms.

In detail, the statistical analyses for each time window provided the following results (Table 9.3, 9.4 and 9.5).

Table 9.3: ANOVAs of ERP data in the time range 100-250 ms for the category versus the correct condition in Experiment 5. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Category versus correct				
100-250 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,17	4.84	.042*	2.66
Cond x Reg	1,17	7.23	.016*	.72
Cond x Hem	1,17	1.98	.177	.61
Cond x Reg x Hem	1,17	< 1		
Anterior				
Cond	1,17	7.36	.015*	2.34
Posterior				
Cond	1,17	< 1		
Midline				
Cond	1,17	2.98	.102	4.64
Cond x elec	2,34	2.91	.098	.41

In the time window 100-250 ms both a main effect of condition and an interaction with region reached significance for lateral sites. Subsequent region analyses revealed a reliable main effect of condition in anterior areas. Midline electrodes did not show any reliable effect.

Table 9.4: ANOVAs of ERP data in the time range 250-750 ms for the category versus the correct condition in Experiment 5. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere for lateral electrode sites. The second row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Category versus correct				
250-750 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,17	10.98	.004**	4.70
Cond x Reg	1,17	< 1		
Cond x Hem	1,17	< 1		
Cond x Reg x Hem	1,17	< 1		
Midline				
Cond	1,17	6.35	.022*	7.91
Cond x elec	2,34	< 1		

Between 250-750 ms a main effect of condition was present for lateral and midline sites.

Table 9.5: ANOVAs of ERP data in the time range 1100-1500 ms for the category versus the correct condition in Experiment 5. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

1100-1500 ms	**Category versus correct**			
Source	*df*	*F*	*p*	MS_e
Cond	1,17	< 1		
Cond x Reg	1,17	19.70	<.001***	4.17
Cond x Hem	1,17	< 1		
Cond x Reg x Hem	1,17	< 1		
Anterior				
Cond	1,17	5.11	.037*	8.24
Posterior				
Cond	1,17	7.88	.012*	5.09
Midline				
Cond	1,17	< 1		
Cond x elec	2,34	25.17	<.001***	2.19

Between 1100-1500 ms an interaction condition x region was found for lateral sites. Region analyses showed a positivity effect in posterior regions. At midline sites an interaction with electrodes was present and resulted in reliable effects at PZ ($t_{(18)}$=3.55, p=.003**).

9.3.2.2 Agreement violation

The agreement violation versus the correct condition did not reveal statistically the presence of an anterior negativity (LAN) between 650 and 850 ms, even though a slight negativity is visible descriptively on the plot (see Figure 9.2). Between 1100 and 1500 ms a broadly distributed positivity (P600) with a reduced amplitude was present.

In detail, the statistical analyses for each time window provided the following results (Table 9.6 and 9.7).

Table 9.6: ANOVAs of ERP data in the time range 650-850 ms for the agreement versus the correct condition in Experiment 5. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere for lateral electrode sites. The second row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Agreement versus correct				
650-850 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,17	1.49	.240	4.64
Cond x Reg	1,17	< 1		
Cond x Hem	1,17	1.45	.244	.74
Cond x Reg x Hem	1,17	1.50	.237	.14
Midline				
Cond	1,17	2.28	.150	8.55
Cond x elec	2,34	1.31	.278	.64

No reliable main effect of condition or interaction of any kind were found in the time window 650-850 ms neither for lateral nor for midline electrodes.

Table 9.7: ANOVAs of ERP data in the time range 1100-1500 ms for the agreement versus the correct condition in Experiment 5. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows ROI analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Agreement versus correct				
1100-1500 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,17	13.61	.002**	4.17
Cond x Reg	1,17	< 1		
Cond x Hem	1,17	1.92	.184	1.56
Cond x Reg x Hem	1,17	6.10	.024*	.17
Left anterior				
Cond	1,17	1.93	.183	9.18
Right anterior				
Cond	1,17	9.67	.006**	9.49
Left posterior				
Cond	1,17	8.68	.009**	6.52
Right posterior				
Cond	1,17	8.95	.008**	8.73
Midline				
Cond	1,17	7.22	.016*	9.91
Cond x elec	2,34	1.15	.310	1.12

Between 1100-1500 ms a main effect of condition and a three-way interaction condition x region x hemisphere reached significance for lateral electrodes. Subsequent ROI analyses showed main effects in right anterior and both posterior ROIs. At midline electrodes only a main effect of condition was found.

9.3.2.3 Combined violation

The combined versus the correct condition did not show an early negativity between 100 and 250 ms. However, in the following time ranges, an additional broadly distributed negativity between 250 and 750 ms and a centro-parietal positivity (P600) with a reduced amplitude was present. The combined did not differ from the category violation in any time window except for the first time range 100-250 ms, where the combined condition did not show an early negativity. The comparison between the combined and the agreement violation, however, displayed clear differences in the time ranges 250-750 ms, 650-850 ms, and 1100-1500 ms.

In detail, the statistical analyses for each time window provided the following results (Table 9.8, 9.9 and 9.10).

Table 9.8: ANOVAs of ERP data in the time range 100-250 ms for the combined versus the correct condition in Experiment 5. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere for lateral electrode sites. The second row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Combined versus correct		
100-250 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,17	< 1		
Cond x Reg	1,17	< 1		
Cond x Hem	1,17	3.54	.077	.42
Cond x Reg x Hem	1,17	< 1		
Midline				
Cond	1,17	< 1		
Cond x elec	2,34	< 1		

Between 100-250 ms a reliable effect was found neither for lateral nor for midline sites.

Table 9.9: ANOVAs of ERP data in the time range 250-750 ms for the combined versus the correct condition in Experiment 5. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere for lateral electrode sites. The second row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Combined versus correct		
250-750 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,17	12.15	.003**	3.61
Cond x Reg	1,17	1.92	.184	2.00
Cond x Hem	1,17	1.24	.282	.44
Cond x Reg x Hem	1,17	< 1		
Midline				
Cond	1,17	7.22	.016*	6.98
Cond x elec	2,34	< 1		

In the time window 250-750 ms only a main effect of condition was present for lateral and midline electrodes.

Table 9.10: ANOVAs of ERP data in the time range 1100-1500 ms for the combined versus the correct condition in Experiment 5. The first horizontal row shows the results of a global ANOVA with the factors condition x region x hemisphere, the second row shows region analyses. All these analyses are performed for lateral electrode sites. The third row displays ANOVAs at midline electrodes. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

		Combined versus correct		
1100-1500 ms				
Source	*df*	*F*	*p*	MS_e
Cond	1,17	< 1		
Cond x Reg	1,17	14.03	.002**	4.71
Cond x Hem	1,17	< 1		
Cond x Reg x Hem	1,17	< 1		
Anterior				
Cond	1,17	4.54	.048*	9.32
Posterior				
Cond	1,17	5.11	.037*	4.89
Midline				
Cond	1,17	< 1		
Cond x elec	2,34	15.73	<.001***	2.17

Between 1100-1500 ms for lateral electrodes an interaction with region was found resulting in significant positivity effects in posterior areas. At midline sites an interaction with electrode was present. Subsequent *t*-tests showed effects at PZ ($t_{(18)}$=2.43, p=.027*).

9.3.2.4 Additional analyses on the combined violation

The category versus the combined violation did not reveal any significant difference in the time windows 250-750, 650-850, and 1100-1500 ms, neither for lateral nor for midline electrodes. The only difference was present in the time window 100-250 ms revealing a reliable main effect of condition ($F_{(1,17)}$=6.23, p=.023*, MS_e=.88) and a reliable interaction condition x region ($F_{(1,17)}$=5.24, p=.035*, MS_e=.67) for lateral electrodes, which resulted in a significant difference in anterior areas ($F_{(1,17)}$=9.86, p=.006**, MS_e=.90). At midline electrodes the interaction condition x electrode ($F_{(2,34)}$=4.58, p=.035*, MS_e=.32) was reliable and showed electrode effects at FZ ($t_{(18)}$=2.67, p=.016*).

The combined violation, however, clearly differed from the agreement condition in the time ranges 250-750 ms, 650-850 ms, and 1100-1500 ms. In detail, the following effects were present:

- 100-250 ms: The global analysis revealed a reliable interaction condition x hemisphere ($F_{(1,17)}$=4.63, p=.046*, MS_e=.66) for lateral sites, which however, did not show any subsequent hemisphere difference. At midline electrodes no effect was present.
- 250-750 ms: The global analysis only revealed a reliable main effect of condition for lateral sites ($F_{(1,17)}$=13.35, p=.002**, MS_e=3.04) and midline sites ($F_{(1,17)}$=7.91, p=.012*, MS_e=4.39).
- 650-850 ms: The global analysis revealed a reliable main effect of condition ($F_{(1,17)}$=5.88, p=.027*, MS_e=4.98) only for lateral sites. For midline sites, however, no reliable effect was observed.

- 1100-1500 ms: The ANOVA revealed a main effect of condition ($F_{(1,17)}$=6.67, p=.019*, MS_e=11.09), a reliable interaction condition x region ($F_{(1,17)}$=11.23, p=.004**, MS_e=4.99), and a reliable three-way interaction condition x region x hemisphere ($F_{(1,17)}$=6.99, p=.017*, MS_e=.25) for lateral electrodes. Subsequent ROI analyses showed reliable main effects of condition in the left anterior ($F_{(1,17)}$=6.80, p=.018*, MS_e=23.10) and right anterior quadrant ($F_{(1,17)}$=12.90, p=.002**, MS_e=29.90). Analysis at midline electrodes showed a reliable main effect of condition ($F_{(1,17)}$=4.71, p=.044*, MS_e=15.68) and a reliable interaction condition x electrode ($F_{(2,34)}$=8.86, p=.005**, MS_e=2.54), which resulted in significant electrode effect at FZ ($t_{(18)}$= -3.05, p=.007**).

9.4 Discussion

The goal of Experiment 5 was to investigate the syntactic processing of sentence comprehension in low proficient L2 learners of Italian. Because an equivalent Italian material was used as the German one in Experiment 3, the same predictions were assumed as for low proficient L2 learners of German. In general, a more inconsistent ERP pattern as compared to native speakers or high proficient L2 learners was expected reflected by either absence of ERP components (especially the LAN effect for the morphosyntactic agreement violation) or latency and amplitude variations (regarding the additional negativity in word category violations and the P600 in any syntactic anomaly). Most predictions were successfully confirmed.

Low proficient L2 learners of Italian displayed an early anterior negativity between 100 and 250 ms, an additional broadly distributed negativity between 250 and 750 ms, and a posterior P600 between 1100 and 1500 ms in *word category violations*. Quantitative differences in contrast to high proficient L2 learners were visible in a longer latency of the additional negativity and a smaller and later P600 component. These differences can be taken as further index that low proficient L2 learners show more uncertainty in processing different kinds of information such as reference-related processes concerning subject specificity information, or need more time to initiate reanalysis processes.

The fact that also low proficient L2 learners of Italian displayed an early anterior negativity as low proficient learners of German strengthens the idea that the simple active sentence context must have led to such an early processing step. Also the Italian material was created in the active voice and also in Italian first language acquisition active is learned prior to passive constructions (Guasti, 2004). Similarly to the German material, the presentation of only syntactic anomalies without any potentially distracting information types may have additionally focused the participants' attention to syntactic processing of a restricted amount of rules. Also the behavioral accuracy rates during the judgement task provide further evidence that low proficient learners of Italian must have understood quite well the word category violation, at least throughout the experimental session, as they showed 85.1% correct judgements.

Concerning the *morphosyntactic agreement violation* participants of the present experiment showed some qualitative and quantitative differences in contrast to high proficient L2 learners. Qualitative differences were present as the LAN effect was statistically absent. A visual inspection of the agreement violation in low proficient L2 learners of Italian (Figure 9.2), however, revealed a tendency toward a negativity (between 650 and 850 ms) prior to the P600 but this effect did not reach significance. This finding indicates that proficiency is not as consolidated as to provide a reliable mechanism for the detection of the morphosyntactic error. As also in Italian first language development morphological features are started to be learned at a later stage and take a lot of time to be definitely acquired (Guasti, 2004), it seems reasonable to assume that low proficient L2 learners of Italian might have more problems in identifying such syntactic features than for example word category information. Concerning the reanalysis processes reflected by the P600, analogous to low proficient learners of German, participants of the present experiment displayed quantitative differences indicated by an amplitude reduction and a later onset.

Concerning the *combined violation* in low proficient learners of Italian an additional negativity between 250 and 750 ms and a P600 between 1100 and 1500 ms not differing from the sole category violation were present. Again the additional negativity assumed to reflect subject specificity processes had a longer extension in low proficient learners compared to high proficient learners, which provides evidence for more processing problems and uncertainty in order to correctly use subject specificity information in a shorter time as high proficient L2 learners do. Also the P600 in low proficient learners differed from the high proficient learners with respect to a delayed latency and a smaller amplitude. This reflects the same reanalysis problems in the combined violation as in the category violation. However, low proficient L2 learners of Italian surprisingly did not show an ELAN effect in the combined violation. It is unclear why this group, unlike the low proficient learners of German, differed regarding this component. Maybe the cooccurrence of two error types has caused processing problems in order to disrupt the processing of the word category information in this combined violation. Low proficient L2 learners of Italian displayed some behavioral differences compared to low proficient L2 learners of German (see Tables 7.1 and 9.1). Besides the fact that the latter lived in Germany at the time of the experiment and were therefore engaged in the use of L2 in their everyday life, they also had learned L2 for a longer period, they rated themselves higher concerning the aspect Speaking in the L2 Self Rating Test, and made less errors in the Vocabulary Translation Test than low proficient L2 learners of Italian. This might indeed have led to an additional proficiency disadvantage in low proficient learners of Italian and therefore to more processing problems when encountering a double anomaly condition than low proficient learners of German. However, this explanation remains speculative and further research regarding combined violation in general and in L2 learners in particular is therefore needed in order to investigate under which circumstances two error types are processed and under which only single processing steps are considered.

Chapter 10

General Discussion and Conclusion

The major goal of the present study was to investigate different types of syntactic information during second language (L2) processing. In second language research a still open question relates to the fact whether an early age of acquisition (AoA) is a necessary prerequisite in order to gain native-like performance in the second language or whether other aspects such as the duration of exposure, the motivation or affective aspects for learning another language, and not least the attained proficiency level, may have such a strong impact on second language acquisition that they can override the beneficial effects of an early AoA. The present study focused especially on the role of proficiency in late second language acquisition and addressed the primary issue whether the brain can process a second language that was acquired after childhood in a native-like manner provided the subject has reached a high proficiency level in the L2. In particular, I concentrated on the processing of syntactic aspects, as several studies showed that syntax is more difficult to be achieved later in time than, for example, semantic aspects. Further, two different second languages were chosen for the study, namely German and Italian, in order to investigate syntactic information types in two languages, which belong to two different linguistic lines within the group of Indoeuropean languages and thus display a number of formal differences, but which contain common syntactic aspects such as word category information and morphosyntax and allow the construction of equivalent materials without word order variations and different amount of words. Thus, these two languages are an ideal investigation ground as all the previously mentioned characteristics can be fulfilled.

The methodology for addressing all these issues was the recording of event-related brain potentials (ERPs) as this electrophysiological technique captures the exact timing of online brain processing steps and can provide information about whether second language learners may have processing delays or fail to process one specific step in contrast to brain processing mechanisms in native speakers.

In order to first identify how the brain processes syntax in native speakers Experiment 1 was conducted. During this experiment Italian native speakers were tested by means of ERPs while they were listening to correct and incorrect sentences. Syntactic anomalies contained a word category violation realized by the omission of a noun after a preposition, a morphosyntactic subject-verb agreement violation realized by an inflection error (the wrong person) on the verb, and a combined violation that comprised both the word category and the morphosyntactic error. During the experiment participants had to perform a grammaticality judgement task, i.e. they had to press one of two buttons in order to judge the correctness of each heard sentence. One goal of Experiment 1 was the replication of the results previously obtained in an ERP study using the same violations in an equivalent German material (Rossi et al., 2005). This aim could be successfully achieved. Italian native speakers displayed the same processing steps as observed for German native speakers for all syntactic anomalies.
In detail, word category violations gave rise to an early anterior negativity, which was shown to reflect initial automatic phrase structure building processes on the basis of word category information (Neville et al., 1991; Friederici et al., 1993; Hahne & Friederici, 1999). This component was followed by an additional anteriorly distributed negativity assumed to reflect reference-related processes arising due to the specific sentence structure in which a highly expected noun is missing in a prepositional phrase, which is specifying the subject noun (Hinojosa et al., 2003; Isel et al., 2004; Rossi et al., 2005; Gugler et al., submitted) and a centro-parietal P600 reflecting processes of syntactic reanalysis, repair, or integration difficulty (Osterhout & Holcomb, 1992; 1993; Friederici et al., 1993; Hahne & Friederici, 1999; Kaan et al., 2000; Hagoort et al., 2003).

Italian native speakers listening to morphosyntactically anomalous sentences displayed an anterior negativity (LAN) reflecting the detection of the morphosyntactic agreement error (the first person singular instead of the correct third person singular) and a subsequent centro-parietal P600 reflecting again processes of reanalysis. These findings are in line with previous studies investigating different morphosyntactic violation types in different languages (Friederici et al., 1993; Osterhout & Mobley, 1995; Gunter et al., 1997; Angrilli et al., 2002; De Vincenzi et al., 2003; Barber & Carreiras, 2005).
The combined violation displayed the same ERP pattern as the pure word category violation, namely an early anterior negativity, an additional anterior negativity and a P600. These findings successfully replicate the results from other studies that combined different linguistic information types, mostly semantic together with syntactic information. Previous studies found interacting or additive effects but whenever a word category violation occurred in a combined condition the ERP pattern resembled that of the pure word category violation. This speaks for a primacy of phrase structure building processes elicited on the basis of word category information, which ignore the additional error type, irrespective of whether this error is a semantic (Hahne & Jescheniak, 2001; Hahne & Friederici, 2002; Friederici et al., 2004), verb argument (Frisch et al., 2004) or morphosyntactic one (Rossi et al., 2005). This pattern was also observable for the Italian combination and thus suggests that the same processing mechanisms occur also in that language. The sole difference between the Italian and the German (Rossi et al., 2005) material was observable with respect to the P600 amplitude. Whereas in German word category-morphosyntax combinations the P600 was smaller than the P600 of the agreement violation and larger than the P600 of the category violation and thus, was modulated in this time range, no such modulation was present in the Italian material. Here, the P600 did not differ from that of the category violation. Similar interactive effects have sometimes been observed also in the literature but no consistent pattern can be extracted from it, so far. Such P600 modulation effects were observed in Gunter et al. (1997) in a Dutch agreement-semantic combination as well as in Friederici et al. (2004) in German word category-semantic combinations. The detailed mechanisms underlying such modulations are still unknown.

Note, however, that the studies in which a P600 modulation was present were all conducted in Germanic languages (Dutch and German) and thus, a possible explanation might be found within the structure of these languages. However, because even within Germanic languages this pattern does not seem to be consistent as some studies did not show any modulation effects in German combinations (e.g. Hahne & Friederici, 2002), further research on that issue is certainly necessary in order to better capture these slight differences in processing.

The findings described so far, fit very well into the neurocognitive model of sentence comprehension proposed by Friederici (2002), which postulates three different phases in which different information types are processed. In the first phase the initial syntactic structure is assigned on the basis of word category information. Then, in phase 2 lexical-semantic and morphosyntactic information are processed in order to carry out the thematic role assignment. Finally, in phase 3 different types of information are integrated and reanalyzed. The phases are processed serially and thus the model assumes autonomous syntactic phrase structure building processes that precede semantic processes in early time windows, but it is also compatible with those interactive models that claim interaction at later stages.

Experiment 1 succeeded in replicating the same processing steps for word category and morphosyntactic information in Italian native speakers and provides the first ERP evidence on word category violations and on combined word category-morphosyntactic violations in Italian. Only few studies (Hinojosa et al., 2003; Isel et al., 2004), so far, investigated pure word category violations in other Romance languages (Spanish and French), and found the same processing steps as for other (non-Romance) languages. These findings indicate that universal brain mechanisms might play a role, at least during sentence comprehension and lead to typologically similar processing steps despite the formal differences, which underlie the most languages. Germanic and Romance languages, for example, differ regarding their rigidity in word order, their richness of morphological features or specific features such as the permission of dropping a subject etc. Nevertheless, different syntactic features seem to follow a common pattern of processing.

Experiments 2-5 focused on syntactic processing in late second language learners, comparing the ERP pattern elicited by high proficient learners with that of low proficient learners and investigating whether differences arise due to the second language German or Italian. For this purpose two equivalent materials containing three syntactic violations (word category, agreement, and a combination of both errors) were presented acoustically while ERPs were recorded. Analogous to the native speakers, the second language learners had to perform a grammaticality judgment task.

The division in high versus low proficient L2 learners in both languages was performed on the basis of behavioral measures, such as a preselection translation test, a vocabulary translation test, the time spent in L2 speaking countries, the L2 learning period, or an L2 self rating test including the categories listening, reading, speaking and writing in the L2. This battery of behavioral measures was chosen in accordance to other studies, which define proficiency on the basis of similar measures (Kotz, 2001; Kotz & Elston-Gütter, 2004; Hahne, 2001; Hahne & Friederici, 2001) and because of lack of standardized proficiency tests equivalent for both German and Italian. A statistical comparison (Table 10.1 and 10.2) across the four second language groups displayed clear differences regarding many behavioral aspects such as the time spent in L2 speaking countries (low proficient learners spent less time there as high proficient learners), the L2 learning period (high proficient learners had learned L2 for a longer period than low proficient L2 learners), the L2 Self Rating Test concerning Listening, Reading, Speaking, and Writing (high proficient learners rated themselves higher than low proficient learners), the Vocabulary Translation Test (low proficient learners made more percentages of errors when translating words from L2 into L1 and vice versa than high proficient learners), and the Preselection Translation Test (low proficient learners made more percentages of errors when translating from L2 into L1 than high proficient learners). The age of L2 acquisition, on the other hand, did not differ among groups, neither between high versus low proficient L2 learners nor between German and Italian learners.

Table 10.1: ANOVAs of behavioral proficiency data – high versus low proficiency groups. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Behavioral measure	High versus low proficient L2 learners of German			High versus low proficient L2 learners of Italian		
	df	*F*	*p*	*df*	*F*	*p*
Age	1,34	13.50	.001***	1,33	5.59	.024*
Age of acquisition	1,34	< 1		1,33	1.67	.206
Time spent in L2 speaking countries	1,34	9.27	.005**	1,33	5.84	.022*
L2 learning period	1,34	11.88	.002**	1,33	13.17	.001***
L2 Self Rating Test (6-point-scale)						
Listening	1,34	98.38	<.001***	1,33	79.90	<.001***
Reading	1,34	46.97	<.001***	1,33	63.09	<.001***
Speaking	1,34	29.74	<.001***	1,33	50.17	<.001***
Writing	1,34	16.99	<.001***	1,33	12.69	.001***
Vocabulary Translation Test	1,34	74.85	<.001***	1,33	135.50	<.001***
Preselection Translation Test	1,34	446.42	<.001***	1,33	522.65	<.001***

Table 10.2: ANOVAs of behavioral proficiency data – German versus Italian as L2. The significance level is coded as following: * p<0.05, ** p<0.01, *** p<0.001

Behavioral measure	High proficient L2 learners of German versus Italian			Low proficient L2 learners of German versus Italian		
	df	*F*	*p*	*df*	*F*	*p*
Age	1,31	< 1		1,36	4.96	.032*
Age of acquisition	1,31	2.26	.143	1,36	< 1	
Time spent in L2 speaking countries	1,31	5.54	.025*	1,36	4.55	.040*
L2 learning period	1,31	4.93	.034*	1,36	4.68	.037*
L2 Self Rating Test (6-point-scale)						
Listening	1,31	3.80	.061	1,36	< 1	
Reading	1,31	< 1		1,36	< 1	
Speaking	1,31	< 1		1,36	4.16	.049*
Writing	1,31	1.29	.265	1,36	< 1	
Vocabulary Translation Test	1,31	3.45	.073	1,36	26.11	<.001***
Preselection Translation Test	1,31	2.53	.122	1,36	3.15	.085

The ERPs for word category violations in late second language learners showed the following results.

High proficient L2 learners of German (Experiment 2) as well as of Italian (Experiment 4) showed the same ERP components (ELAN, additional negativity, P600) as previously found in German native speakers (Friederici et al., 1993; Hahne & Friederici, 1999; Hahne & Friederici, 2002; Rossi et al., 2005). This indicates that with a high proficiency level the same processing steps can be attained as native speakers, namely processes of initial phrase structure building reflected by the early anterior negativity between 100 and 250 ms, the processing of subject specificity information reflected by the additional negativity between 250 and 650 ms, and reanalysis processes reflected by the late positivity between 800 and 1300 ms.

These findings underline that also late L2 learners are able to attain native-like processing mechanisms during sentence comprehension. Even early automatic processes such as reflected by the early anterior negativity can be achieved by L2 learners with increased proficiency. The present study provides the first ERP evidence in late L2 learners that such early syntactic phrase structure building processes can also be elicited in the context of natural languages such as German and Italian, provided the fact that a high proficiency level is assured.

The ERP findings for low proficient L2 learners of German (Experiment 3) and Italian (Experiment 5), however displayed some quantitative differences in contrast to high proficient learners. They showed the same triphasic ERP pattern but the additional negativity had a longer extension. A similar ERP component extension was also found in Kutas and Kluender (1991) and Hahne and Friederici (2001) with respect to the N400 in semantic violations. An explanation is provided in terms of more uncertainty in processing specific information types. The authors argue that participants take more time to integrate the word into the prior context because of more uncertainty. The same explanation is plausible for the longer additional negativity in the present study in low proficient learners indicating that the use of subject specificity information in word category violations is not as experienced as in high proficient learners and thus needs more time to be processed. A second difference between high and low proficient learners concerns the latency and amplitude of the P600. This ERP component displayed a reduced amplitude and occurred later in time in low proficient learners (between 1100 and 1500) in contrast to high proficient learners (between 800 and 1300 ms). Hahne (2001) also found a P600 with a delayed latency. The latency delay and amplitude reduction suggest some reanalysis problems in low proficient learners maybe due to the fact that they need more time to initiate the reanalysis of the sentence and to try to integrate the occurred errors. This seems plausible, as low proficient L2 learners presumably cannot use enough resources to reanalyze the sentence and thus take more time to integrate all syntactic features.

Low proficient L2 learners of both languages surprisingly displayed an ELAN effect, which can be attributed to the active sentence structure of the presented materials, in contrast to other L2 studies with passive sentences (Hahne & Friederici, 2001; Hahne, 2001) where no early negativity was found. Active sentences are assumed to be easier to be learned during language acquisition and are used preferably by children. Passive, on the other hand, displays a greater complexity and mostly requires additional auxiliary verbs and moving elements to another position (Guasti, 2004). ERP studies with children also found differential patterns in passive versus active sentences. Whereas the ELAN with the same latency and distribution as in adults was not present until the age of 13 when presenting acoustically passive word category violations (Hahne, Eckstein & Friederici, 2004), this left anterior negativity similar to that of adults was present in children between 31 and 34 months when word category violations embedded in active sentences were presented (Oberecker, Friedrich & Friederici, in press).
In L2 studies using ERPs this early syntax-related component so far has only been observed in high proficient L2 learners confronted with an artificial miniature grammar (Friederici et al., 2002). Two MEG studies with high proficient late learners further showed a similar early syntactic magnetic component in response to NP raising phrase structure violations (Kubota et al., 2004) and infinitive c-selection violations (Kubota et al., 2005) in English. The present study provides ERP evidence that this early anterior negativity can also be elicited by low proficient L2 learners both of German as well as of Italian in simple active voice sentences. In this regard, it should be mentioned that the presentation setting of the present experiments, which contained only syntactic and no other kinds of violations (e.g. semantic ones), may have additionally facilitated participants to concentrate on syntactic processing of a restricted amount of syntactic rules (word category information, morphosyntactic features, and a combination of the two). The contribution of a similar restricted focus during the experimental session to the processing mechanisms involved during language comprehension was also discussed in Friederici et al. (2002) for the processing of the artificial miniature grammar Brocanto.

That low proficient L2 learners understood the word category violation quite well can be seen also from the accuracy rates during the grammaticality judgment task. Both low proficient learner groups performed this task very well (low proficient L2 learners of German made 81% correct judgments concerning the category violation and low proficient L2 learners of Italian judged 85.1% correct). This behavioral measure strengthens the idea that they captured the essence of such violations during the experimental session at least when sentences are simple and in the active voice even though they had a general low proficiency in their respective second languages. Thus, it seems plausible that they displayed an early syntactic ERP component related to the processing of word category information in simple sentences created in the active voice.

Concerning morphosyntactic agreement violations high proficient L2 learners of German (Experiment 2) as well as of Italian (Experiment 4) showed the presence of the same ERP components as native speakers (Friederici et al., 1993; De Vincenzi et al., 2003; Rossi et al., 2005), namely a LAN reflecting the detection of the morphosyntactic agreement error and a P600 reflecting reanalysis processes.

Low proficient L2 learners of German (Experiment 3) and Italian (Experiment 5), in contrast, displayed some qualitative and quantitative differences. Both low proficient learner groups failed to show a LAN effect (qualitative difference). Even though in low proficient L2 learners of Italian a descriptive tendency toward a negativity could be observed this effect did not reach significance. The absence of this ERP component can be explained by looking at the first language acquisition during childhood. Children run through different stages of language acquisition. At the beginning they start producing single phonemes, syllables till they say their first word (approximately around 12 months), which is mostly a noun. After this one-word stage, the two-word stage follows (between 18 and 24 months), in which children make noun-verb utterances. This development indicates that children must know the difference between word categories such as noun and verb quite early. At these stages so far, the utterances do not contain any morphological feature. Morphological development starts later at about 2 years of age and consolidates until the age of 5 and beyond (Guasti, 2004).

In a similar order, these two syntactic features are acquired also during second language acquisition (Hawkins, 2001). The distinction of word categories is already established from the first language. Even though morphological features are mostly learned quite early e.g. during explicit second language lessons, the process of becoming implicit mostly takes much longer.

Especially for the case of morphology, it is often argued that even though the most second language learners clearly know that the third person singular in English requires an “s” at the end of a verb, a large amount of errors are made during spontaneous speech production, suggesting that they have not internalized and automated this rule. Such a phenomenon is referred to as *fossilization* (Selinker, 1972; cited in Schachter, 1996) or *fossilized variation.* This is not a difference in competence between a second language learner and a native speaker per se but similar errors are not observed in native speakers and as such fossilization represents nevertheless a typical characteristic of adult second language learning. Because morphosyntax seems to be acquired later than word category information it seems plausible to assume that low proficient L2 learners have more problems in processing morphosyntactic aspects (and therefore not showing reliable LAN effects), whereas word category violations embedded in a simple sentence context, in contrast, are able to be processed also by persons with a lower proficiency level.

Similar to the P600 for word category violations in low proficient learners, even the P600 in agreement violations was delayed and smaller in amplitude. This quantitative difference was again present irrespective of the L2 language of low proficient learners. Especially latency delays in L2 learners reflect more processing problems when initiating the different processing steps, in this case the process of reanalysis.

The combined violation in all groups resembled the pure word category violation giving rise to the same ERP components in the same time windows with approximately the same topographical distribution, namely an early anterior negativity (except for the low proficient learners of Italian), an additional broadly distributed negativity, and a posterior P600. High proficient L2 learners of both German (Experiment 2) and Italian (Experiment 4) showed these components in the same time windows as the category violation.

This was also the case within both low proficient groups (Experiment 3 and 5) indicating the same latency effects as in the pure category violation. Similar to the differences between high and low proficient learners listening to word category violations, also concerning the combined condition the additional negativity assumed to reflect subject specificity processes had a longer extension. This provides evidence that low proficient learners have more processing problems and show more uncertainty when they have to correctly use subject specificity information. Furthermore, the P600 in low proficient learners differed from that of high proficient learners with respect to a delayed latency and a smaller amplitude. This reflects the same reanalysis problems in the combined violation as in the category violation. These findings concerning the combined violation are in accord with previous studies including a word category violation, which showed the same ERP components in the combined as in the category violation (Hahne & Friederici, 2002; Friederici et al., 2004; Frisch et al., 2004). No additivity or interaction effects between both anomalies are reported in the combined violation, at least at early stages. This reflects primacy of phrase structure building processes not only over semantics (Hahne & Jescheniak, 2001; Hahne & Friederici, 2002; Friederici et al., 2004) but also over other syntactic features such as morphosyntactic subject-verb agreement processes (Rossi et al., 2005).

Low proficient L2 learners of Italian were the only group, which did not show an ELAN effect in the combined violation. The reason why this ERP component did not occur in the combined unlike the category violation is not clear, so far. A possible explanation might refer to the cooccurrence of two error types, which may have caused processing problems in order to disrupt initial phrase structure building processes in this combined violation. But why did this disruption only occur in low proficient L2 learners of Italian and not even in low proficient L2 learners of Italian? Behavioral proficiency differences might provide a helpful hint. Low proficient L2 learners of German lived in Germany at the time of the experiment and were therefore engaged in the use of L2 in their everyday life. Further, they also had learned L2 for a longer period, they rated themselves higher concerning the aspect Speaking in the L2 Self Rating Test, and made less errors in the Vocabulary Translation Test than low proficient L2 learners of Italian.

This might indeed have led to an additional proficiency disadvantage in low proficient learners of Italian and therefore to more processing problems when encountering a double anomaly condition than low proficient learners of German. However, this explanation remains speculative and further research regarding combined violations in native and in L2 learners in particular is therefore needed in order to clarify such processing inconsistencies.

10.1 Implications for theories of second language processing

Experiments 2 to 5 provide evidence that despite a late age of L2 acquisition a high second language proficiency can lead to native-like brain processing mechanisms during sentence comprehension. This could be observed irrespective of the learned second language German or Italian. In contrast, low proficiency leads to some differential brain responses while the age of acquisition was kept the same in both proficiency groups. The findings have some implications concerning different theories of second language processing.

The critical period hypothesis (Lenneberg, 1967) assumes that a language might not be learnt after a sensitive period, which should end with puberty, and thus no native-like performance might be achieved after that time. The present study challenges this hypothesis as it could show that native-like brain processing mechanisms can be elicited even though the second language was acquired later in time provided a high L2 proficiency level is reached. This suggests that a critical period for second language acquisition cannot be strictly defined, at least for the aspect of language comprehension, and that other factors such as the achieved proficiency may have a strong impact on the processing of a second language during late L2 acquisition.

Concerning the theory of Universal Grammar (Chomsky, 1957, 1965, 1981) and to whether UG is accessed during second language the present study can provide only limited answers. Because the investigated syntactic information types are present in both German and Italian, i.e. both languages contain word category information similarly realized – in this case a verb that follows a preposition due to the omission of a noun is incorrect in both languages – and a morphosyntactic person system, no differences in UG might be assumed regarding the syntactic violations per se.

Thus, a native-like processing pattern in second language learners cannot be taken as direct evidence for a full/direct access to UG, as the information type used in the experimental setting is present in both languages. It is equally plausible to assume that a native-like L2 pattern might be due to an indirect access to UG, which is mediated via the L1. But because the native languages of the participants of the present study were German or Italian respectively, also this statement cannot be exclusively formulated. However, the proficiency level can be considered as an aspect, which plays an important role in second language processing and thus, it might have an impact also on the availability of universal grammar. As low proficient learners displayed some differences in contrast to high proficient L2 learners, e.g. they failed to show a reliable anterior negativity effect concerning morphosyntactic violations, this might be interpreted as a loss of accessibility to UG. Because low proficient learners are not so experienced in using different (syntactic) information types, they may have not a direct access to UG. As proficiency increases, this access might be available more easily and faster and thus leading, for example, to a reliable detection of the morphosyntactic mismatch between subject and verb in high proficient L2 learners.

The neurocognitive Declarative/Procedural Model proposed by Ullman (2001a, 2001b, 2004) argues that native speakers rely on the procedural memory system (implicitly accessible) for learning and using grammar, whereas second language learners mostly use the declarative memory system (explicitly accessible) and thus store and retrieve grammar from the lexicon. Ullman further assumes a shift from declarative to procedural memory in second language acquisition in correlation with factors such as age of acquisition and practice. A similar relationship could be reflected by the findings of the present study as high proficient L2 learners showed the same processing steps as native speakers because they had already automated the rules of word category and morphosyntactic information and used them implicitly in contrast to low proficient L2 learners.

Similarly, Paradis (2004) states in his Neurolinguistic Theory of Bilingualism that an increasing proficiency level enhances a shift from exclusive use of metalinguistic knowledge, which is subserved by declarative memory, to more extensive use of implicit linguistic knowledge, which is subserved by procedural memory.

Further, he argues that different aspects such as implicit language competence, metalinguistic knowledge, pragmatics, motivation, emotional input, and not least proficiency are involved in language use. The findings of the present study confirm that not only an early AoA plays a role in second language acquisition of syntactic information but also proficiency provides clear beneficial effects.

10.2 Universality of language processing mechanisms

In native speakers, in high proficient and in low proficient L2 learners each, the same processing pattern including the same inconsistencies could be seen, irrespective of whether the second language was German or Italian. Although both languages display a number of formal syntactic differences, i.e. Italian has a freer word order than German, it allows the omission of a subject in contrast to German, it has a very rich morphology in contrast to less morphological variety in German and so on, previous ERP studies found the same processing mechanisms across different native languages. Thus, universal language processing mechanisms are assumed, at least between languages, which allow for the realization of the same violation types. This assumption could be borne out by the present study, as the ERP processing steps concerning word category and morphosyntactic information could be successfully replicated also in Italian native speakers. Furthermore, the present study provides evidence that universal mechanisms are also present in late second language learners at the respective proficiency level. The selection of the languages German and Italian to be investigated in the present study was motivated by the fact that equal materials containing the same syntactic anomalies could be created without any significant differences in construction criteria (word order, amount of words, structure of sentences etc.) even though German and Italian belong to two different linguistic lines, namely Germanic and Romance languages, and thus, display several formal differences. In general, however, material equivalence was guaranteed in the present study.

10.3 "The bilingual is not two monolinguals in one person"

Another point that needs to be discussed is that differences often observed in bilinguals in contrast to monolinguals may arise from the fact that bilinguals have a unique language configuration and unique processing strategies in both languages that do not have to be necessarily the same as that of monolinguals. Grosjean (1989) pointed toward this important issue by claiming that “The bilingual is not two monolinguals in one person” (Grosjean, 1989, p. 3). He argues that a bilingual person cannot be simply broken down into two separate parts according to the two languages.

A bilingual person normally does not adopt exactly the same processing strategies as two monolinguals in their respective languages, as the bilingual’s competences are organized differently, code-switching between the two languages occurs in dependence to the persons he/she is speaking with, or the purpose he/she is pursuing. Thus, a bilingual person has a unique linguistic performance and slight differences also in the ERP pattern (e.g. the absence of a modulation of the P600 in the combined condition in all second language groups, or the absence of an ELAN component in combined but not in the pure category violation in low proficient L2 learners of Italian) may not solely be attributable to lower linguistic competence per se but could be explained by different strategies used for dealing with different situations, i.e. linguistic information.

From the assumption that a bilingual is not two monolinguals in one person the difficulty to define the proficiency or performance in both languages arises. It is quite difficult to find ideal measuring methods for assessing the proficiency of a bilingual person. There are standardized tests for assessing second language proficiency in different languages (e.g. TOEFL for English as L2; Deutsch als Fremdsprache test from the Goethe Institut for German). However, in order to compare two groups of languages in one study equivalent standardized proficiency tests would be required. Further, in order to compare the proficiency in the second language to the performance in the native language a simple translation of a test from one language in the other language does not provide equivalence.

Because languages differ also at a cultural level, as different words are more often used in a special context in one but not necessarily in the other language, test equivalence must consider also the cultural-linguistic diversity in each language (Paradis, 2004). In the present study an equivalent German-Italian proficiency assessment would have been ideal to guarantee exactly the same proficiency level across high and across low proficient learners. Because of lack of similar standardized measures for German and Italian, the proficiency level was defined according to different behavioral measures acquired through a detailed questionnaire including statements concerning the L2 learning period, the time spent in an L2 speaking country, Self Rating Tests on various aspects, and translation tests. Similar measures have often been used in studies dealing with second language learners (Kotz, 2001; Kotz & Elston-Güttler, 2004; Hahne, 2001; Hahne & Friederici, 2001; Perani et al., 1996; 1998; Birdsong, 1992; for a review see von Hapsburg & Peña, 2002).

Apart from the difficulty of uniform definition criteria for second language proficiency, several additional aspects might influence the linguistic performance, the learning process, or the strategies adopted for dealing with certain linguistic information. One of these – mostly ignored – aspects is for example the degree of individual speech talent of a person, which might lead to a better or worse performance, to a faster or slower learning period or in some cases even to native-like ultimate attainment. Today's research is far from capturing such subtle aspects like speech talent never mind to create adequate methodologies to assess similar aspects and to understand the influence it might have on language acquisition and processing.

10.4 Conclusion

One aspect that might be extracted from the present study is the fact that even early automatic syntactic processes as reflected by an ELAN in word category violations can be elicited also in late second language learners. Because the occurrence apart from the high proficiency might be partly codetermined by the fact that the presented sentences were simple (in the active voice) and were not mixed with other different linguistic information, the generalization of the results of the present study should be considered carefully. Although the proficiency proofed to be an important factor in consolidating the competences in the second language and should therefore be improved as much as possible, we have to keep in mind that the present study only investigated syntactic language comprehension and did not consider other linguistic aspects such as accent or other linguistic modalities such as language production, as well. The generalization about the occurrence of native-like brain processing mechanisms in high proficient late L2 learners should be thus limited to sentence comprehension. Several studies showed that language production or phonological aspects such as accent suffer from strong age of acquisition effects and in the most cases do not lead to native-like second language performance. Further research is certainly indispensable in order to investigate if similar "native-like" brain responses as observed in the present study for the processing of different syntactic information types are also present in high proficient late bilinguals performing not only language comprehension tasks but also production tasks, e.g. concerning the pronunciation of words in second language.

As event-related brain potentials proofed to be a suitable technique in order to investigate the online temporal dynamics of brain responses to different stimuli in second language learners, future investigations might use this electrophysiological methodology for example to track systematically whether the same processing stages as in children's first language acquisition are run through even by adult second language learners, whether the order of the stages differs, or whether some stages are not required at all.

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1997 – March 2003	studies of Psychology at the University of Salzburg (Austria)
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1998 – 1999	studies of Psychology at the University of Würzburg (Germany) with an exchange program (Erasmus)
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