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„Which animal chases the dog?

Neural correlates of syntactic transfer in German - English

late bilinguals: an ERP study "


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Master Thesis

# Which animal chases the dog? Neural correlates of syntactic transfer in German - English late bilinguals: an ERP study


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*on*

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I, Stella Serena GROSSO, declare that this thesis titled ”Which animal chases the dog? Neural correlates of syntactic transfer in German-English late bilinguals: an ERP Study” and the work presented in it are my own. I confirm that:

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*"If you talk to a man in a language he understands, that goes to his head. If you talk to him in his own language, that goes to his heart."*

Nelson Mandela

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# Abbreviations

| | |
|---|---|
| **EEG** | **E**lectro**e**ncephalo**g**raphy |
| **MEG** | **M**agneto**e**ncephalo**g**raphy |
| **fMRI** | **f**unctional **M**agnetic **R**esonance **I**maging |
| **MRI** | **M**agnetic **R**esonance **I**maging |
| **ERPs** | **E**vent-**R**elated **P**otentials |
| **BESA** | **B**rain **E**lectrical **S**ource **A**nalysis |
| **P600** | **P**ositive (syntactic related) component at **600** ms from stimulus onset |
| **N400** | **N**egative (semantic related) component at **400** ms from stimulus onset |
| **LAN** | **L**eft **A**nterior **N**egativity |
| **ELAN** | **E**arly **L**eft **A**nterior **N**egativity |
| **ERAN** | **E**arly **R**ight **A**nterior **N**egativity |
| **SEP** | **S**omatosensory **E**voked **P**otential |
| **MMN** | **M**is**m**atch **N**egativity |
| **BAEP** | **B**rainstem **A**uditory **E**voked **P**otential |
| **Cz** | **C**entral Electrode following the 10-20 International System |
| **FCz** | **F**rontal **C**entral Electrode following the 10-10 International System |
| **Pz** | Centro-**P**arietal Electrode following the 10-20 International System |
| **L1** | First (Native) **L**anguage |
| **L2** | Second **L**anguage |
| **AoA** | **A**ge of **O**nset of **A**cquisition |
| **WH-** | **WH** Pronouns (e.g. Which, What, Who) |
| **VP** | **V**erb **P**hrase |
| **DP** | **D**eterminative **P**hrase |
| **IP** | **I**nflection **P**hrase |
| **CP** | **C**omplementizer **P**hrase |

| | |
|---|---|
| **Aux** | **Aux**iliary Verb |
| **NOM** | **Nom**inative Case |
| **ACC** | **Acc**usative Case |
| **MASC** | **Masc**uline Gender |
| **FEM** | **Fem**inine Gender |
| **NEUT** | **Neut**er Gender |
| **3SG** | Third Person **S**in**g**ular |
| **ANOVA** | **An**alysis **O**f **Va**riance |
| **AC** | **A**lternating **C**urrent |

# Chapter 1

# Introduction

## 1.1 Bilingualism Nowadays

In today's globalized society, the importance of learning and acquiring strong skills in languages other than our native one is becoming more and more evident.

In the last decades significant attention has been paid to the study of the cognitive benefits of early bilingualism (Adesope et al., 2010, Bialystok and Craik, 2010, Bialystok et al., 2005, Diaz, 1983) probably also in the attempt to move the public opinion and the media in the direction of supporting the early acquisition of a second language in new generations. On one hand, the majority of early bilinguals have learned their second mother tongue in an unsupervised parental setting, soon developing dominance for the language mostly used in the surrounding environment and subsequently leaving the second language to informal and familiar contexts. On the other hand, only a minority of monolingual raised children have the chance to learn properly, i.e. at high levels of proficiency, a second language in the school setting nowadays.

Nevertheless, mastering a foreign language is becoming necessary not only for professional translators or international migrants seeking better opportunities for their life and career, but also for whoever needs to communicate with non-native speakers in their own country and test the level of proficiency in a foreign language.

## 1.2 Research in Second Language Acquisition

Research on second language learning and acquisition, which covers various disciplines ranging from applied linguistics to cognitive psychology, has become an important field of study for understanding which factors influence the development and the outcomes of one's abilities in comprehension and production in a foreign language. Because of the international prestige acquired after the Second World War (being the language of commerce, politics and, recently, the Internet), English and the processes underneath its acquisition have become the focus of the majority of the studies involved in second language learning.

High motivation, early and constant contact in life with the second language and individual aptitude for language learning have been found as some of the key points necessary for reaching high levels of fluency and proficiency in a foreign language. Nevertheless, even in highly proficient second language speakers (i.e. the *late bilinguals* mentioned in the title) misunderstandings and interpretational failures happen. Understanding why late bilinguals occasionally produce and comprehend second language sentences differently than native speakers is not only part of the "language mysteries" that applied linguistics is trying to solve but also the main subject of this thesis.

## 1.3 Early and Late Bilingualism

Why do late bilinguals differ from early (or "real") bilinguals? Linguists supporting the difference claim that there are incredible advantages in learning a second language early in life, as the age of onset of acquisition influences the proficiency reached in a(ny) natural language.

### 1.3.1 Critical Period Hypothesis in First Language Acquisition

This assumption is grounded in the Critical Period Hypothesis (Hurford, 1991, Johnson and Newport, 1989, 1991, Komarova and Nowak, 2001), according to which the human brain is structured such as any language can be acquired, given sufficient stimulus, to a native-like level only in a certain range of time. This period, critical for language, is often considered finished around puberty (or even earlier, around 8 - 9 years of age).

In spite of having been highly debated, the Critical Period Hypothesis has shown to be grounded when cases of feral children came to (scientific) light. One infamous case has been the one of Genie (Curtiss, 1981, Curtiss et al., 1974), an abused child that lived till the age of 14 in linguistically deprived environment and that after years of therapy and psycho- linguistic training never acquired language at a native-like level:

"Through all of the semantic development described above, covering a period of several years, Genie has acquired very little syntax or morphology. There is practically no morphological elaboration in her utterances, such as use of plural or possessive markers or auxiliary forms, and no employment of syntactic devices or operations such as relativization, pronominalization, or movement of constituents as in subject-auxiliary inversion for questions. [..] What results is the stringing together of content words, often with rich and clear meaning but with little grammatical structure ("I like hear music ice cream truck," "Think about Mama love Genie," [..]). Thus she shows a profile of primitive syntactic and morphological ability combined with relatively well-developed semantic ability.[..] Genie and cases like hers may exemplify what kind of language develops with good nonlanguage cognitive abilities but impaired or nonfunctioning language acquisition mechanisms."

Other data in support of the Critical Period Hypothesis come from deaf people that lived for the whole childhood in isolation and without the chance of social interactions: despite the efforts made in teaching them sign language during adolescence, these subjects never became fluent signers (Grimshaw et al., 1998).

### 1.3.2 Maturational Constraints in Second Language Acquisition

Even though adequate evidence is present in support of the validity of the Critical Period Hypothesis in the acquisition of first language, much more debatable is its effectiveness on second language learning.

Cases of high-proficiency reached during adulthood are well known (the so-called "Joseph Conrad Phenomenon", see Scovel, 1969) but unfortunately most of the time not well documented for scientific validity.

On the other side, our everyday experience is familiar with the difficulties encountered by many in learning a foreign language late in (biological) time. Even when the foreign language has been studied for a adequately long period, the marked influence of the native language still stands out in pronunciation (e.g. inflection and accent), in wrong lexical selection (i.e. "false friends") and even production of abstruse grammatical structures, above all when trying to rise speech register.

At the phonological level, several studies confirm the presence of strong maturational constraints that drastically limit not only the production but also the perception of phonemes not present in one's mother tongue. It is quite known that newborns are particularly sensitive to human language and specifically to the one spoken by the mother (DeCasper and Fifer, 1980, Mehler et al., 1988) and they get incredibly quick in detecting the language spoken by the parents among other idioms to the point of completely disregarding all the "sounds" that are not distinctive of meaning for her or his linguistic environment. From that early point on in life, re-acquiring the ability to pronounce properly in another language becomes a hard task.

On the other side, semantics does not seem to be especially influenced by brain development. A person's vocabulary is potentially unlimited (and the only constraint is long term memory) and even late in life it can be enriched by new entries (in first as well as in second language) in the mental lexicon. Moreover, the change in meaning (comprehension task) of a word does not appear particularly challenging in terms of cognitive demand, probably because of the fact that the social transformations influencing the usage of a lexical item are most of the time gradual processes.

### 1.3.3 The Strange Case of Grammar Acquisition

Until recently, grammatical abilities were considered to be semantic-like, that is, they should not be subjected to maturational constraints and consequently they could be theoretically "lifelong learnable". This assumption follows easily from general experience that a high level of proficiency in mastering grammatical structures is possible for late second language learners. Nevertheless, when it comes to judgments of grammaticality (i.e. the ability to instinctively detect well-formed morphosyntactic structures from inadmissible forms) even highly proficient second language speakers do not perform in the same way as native speakers do.

Nowadays, the employment of neuroscientific methods of measurement (such as electroencephalography and functional magnetic resonance imaging), during the performance of language tasks is bringing new insights into the debate. Recent researches show that the age of onset of acquisition (from now on, AoA) appears to have more pronounced effects on grammatical processing and its representation in the brain than on semantic processing (Wartenburger et al., 2003). This finding suggests the presence of strong maturational constraints for the development of syntactic skill in the neural structure and, if this hypothesis reveals to be correct, the acquisition of syntactic abilities of any language would be possible at a native-like level only during the early age of life of an individual.

Several researches have been made in the last years in the attempt to detect neural differences in the way language is processed in the brain by bilinguals and late second language learners, where with *bilingual* is meant subjects that acquired fluently two languages as native tongues from birth and with *second language learners* subjects that learned a second language during puberty or adolescence in a formal setting, as the majority of the last generations do in western countries.

One of the main questions on the topic of the actual difference among bilinguals and late second language learners regards the linguistic proficiency that late second language learners reach at the end-state of acquisition of the second language (Birdsong, 2006). This thesis supports the claim that one of the main differences is in the way grammar is processed in the early and late bilingual brain.

## 1.4 Research Focus: Transfer in Late Bilinguals

Research in applied linguistics identifies the impossibility of suppressing completely one's own native grammar processing network as cause of subsequent incomprehension in the arrival/target language.

In chapter 2, such hypothesis and the theoretical basis behind the project are presented: in particular, the Full Transfer Full Access Hypothesis (Schwartz and Sprouse, 1996) and previous behavioral studies focusing on the phenomenon of transfer in German-English and English-German late bilinguals (Grüter, 2006, Rankin, 2013).

In chapter 3 the multidisciplinarity of the project comes to light through an introduction to the use of electrophysiological techniques for studying the neural correlates of language processing in the human brain. A literature review on previous studies using ERPs and language processing is included in the same chapter.

In chapter 4, the main hypothesis of the study, the paradigm adopted and the set of stimuli selected for this experiment are presented from a linguistic and neurocognitive perspective.

The experiment conducted for this master thesis project is presented in terms of participants, methods and procedure that have been used in chapter 5.

Finally, chapter 6 is dedicated to the statistical analyses of the electrophysiological data and discussion of the findings and their meaning for research in second language acquisition. The last section of chapter 6 deals with implications for further studies on the topic.

In Appendix A, the reader will find the material used for the behavioral and EEG experiment while the abstract of the thesis is given in English and German in Appendix B. Appendix C contains a brief Curriculum Vitae of the author and precedes the whole bibliography in conclusion of the work.

# Chapter 2

# Theoretical Basis of Grammar Transfer

## 2.1 Grammar Transfer in Applied Linguistics

Misunderstandings and misinterpretations happen also to highly proficient second language speakers. When the cause behind such "interpretational mismatch" (between what has been understood and what a native speaker would instead understand) is syntactic in nature, that is, it is not due to lack of vocabulary or misheard parts of the sentence, several researchers agree that a phenomenon in which two grammars compete is occurring.
Competing grammars leads to a language transfer, that is, an application of the parsing system of the native language during the comprehension of a sentence in a second known language.
The following chapter introduces the theoretical background of the project from the hypothesis of grammar transfer in initial state L2 learners to the application in the specific case of interpretational mismatch in proficient German speakers of English.
In order to clarify with a visual aid the difference among similar looking surface structures between English and German, the second section of this chapter is dedicated to a brief syntactic analysis behind ambiguous subject/object WH-questions.

## 2.2 The Full Transfer Hypothesis in Second Language Initial State

In the domain of second language research, one of the main focuses of research tries to explain the initial state of L2 acquisition and how to determine the ending state of the process involved in second language learning.
The Full Transfer Full Access hypothesis (Hoekstra and Schwartz, 1994, Schwartz and Sprouse, 1996) proposes that the phenomenon of an interpretational mismatch between native speakers and second language learners at early stages of acquisition is due to the fact that the entirety of the first language grammar constitutes the second language initial state.
Grüter (2006) has brought empirical evidence in support of such hypothesis testing 17 English-speaking learners of German at the initial state of acquisition with a comprehension-based test. In her study, she claims against the Minimal Trees Hypothesis, according to which the L2 initial state of acquisition consists in a stage lacking of functional categories and previous to the emergence of second language speech. In order to sustain her own claim, Grüter administered her participants with a picture interpretation task where L2 functional properties were manipulated. For such a goal, the ambiguity of subject/object WH-questions in German is perfect: a sentence like (example from Grüter, 2006)

> Was beisst die Katze?
> [what bite-3SG the-FEM cat]

can be interpreted both as a subject question (*What is biting the cat?*) or as an object question (*What is the cat biting?*). Main claim of the author was that the interpretation of these questions involves the presence of functional categories beyond the verb phrase (VP) and that their interpretation depends on a transfer process of functional categories from the native language at the initial state of L2 acquisition.
With her interpretation task, Grüter found evidence that English-speaking learners of German at the initial state interpret direct wh-questions in the present tense prevalently (i.e. 71.2 %) as subject questions (and wh-questions in the perfect tense as object questions with a 97.1% of non-target answer). Such a finding was predicted by the Full

Transfer hypothesis and it is in line with the syntactic order of English subject clause constituents as presented in the next section.

## 2.3 Syntactic Analysis of Ambiguous WH-Questions

In order to understand the differences between the English and German WH-structure and their subsequent interpretations, it is necessary to give a brief background of the differences in construction of subject and object WH-questions in these two germanic languages.

### 2.3.1 On English Subject WH-question

English structure behind the WH-questions has been long debated and several hypotheses have been proposed (Haegeman and Guéron, 1999, Stromswold, 1995 among others). In the next paragraphs an introduction to the general syntactic hypothesis of WH-questions is given to the reader for further comparison with the German variant.
English language has a strict word order Subject – Verb – Object that requires an obligatory and overt movement of WH-elements to the beginning of the clause (i.e. in the complementizer phrase, CP). Do-support is required by lexical (but not modals) verbs to construct interrogative questions, but this does not happen in case of subject WH-questions, where do-insertion would be ungrammatical (except for emphatic stress):

> Which animal chases the dog?
> [Which-NOM animal-NOM chase-3SG the-ACC dog-ACC]
> * Which animal does chase the dog?
> * Does which animal chase the dog?

The corresponding tree representation of the grammatical, direct subject English WH-question is presented in fig. 2.1. In the syntactic tree, the WH-phrase has moved from the VP-shell into the specifier of the CP leaving a trace into the specifier of the inflectional phrase (IP). The lexical verb has moved to the IP to take inflectional features. The head of the complementizer remains empty, on the contrary of what happens in the case of German subject WH-sentences (see fig. 2.2).

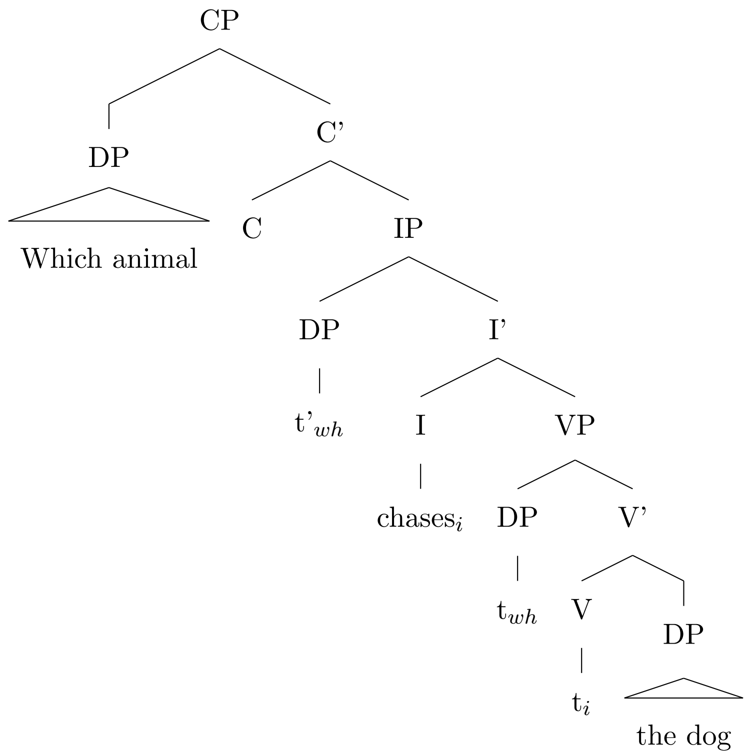



FIGURE 2.1: Syntactic tree representation of the surface structure of a subject WH-question in English. VP subject internal hypothesis is assumed.

WH-questions are unambiguous in English, as the speaker relies on the strict word order and the lack of do-support to distinguish the subject WH-question (e.g. the one in the example above) from the equivalent object WH-question:

> Which animal does the dog chase?
> [Which-ACC animal-ACC do-3SG the-NOM dog-NOM chase]

Note that because there is no explicit case marking in English (few exceptions regard personal and possessive pronouns) the assignment of thematic roles in the sentence is explicitly derived from number agreement and word order.

### 2.3.2 On German Subject WH-question

On the other side, German relies on a relatively loose word order of the type Subject – Object – Verb but it requires to have the inflected verb always in second position (therefore being defined as a *V2 language*). Such parameters are reflected in the construction of all WH-questions, which follow the structure WH-phrase – finite Verb – rest of the clause. In order to understand whether a WH-phrase has a function of subject or object in the sentence, German can count on case marking on the WH-pronouns or the nouns presented in the question:

> Welches Tier jagt den Hund?
> [which-NEUT animal chase-3SG the-MASC-ACC dog-ACC]
> *Which animal chases the dog?*

While the object version of the same question, with case-marking on the masculine determinative, could be:

> Welches Tier jagt der Hund?
> [which-NEUT animal chase-3SG the-MASC-NOM dog-NOM]
> *Which animal does the dog chase?*

Because of its SOV structure, a tree representation of the subject WH-question in German (see fig. 2.2) seems more complex of the English one, but the only real difference is in the left-branching of the VP-shell.
The WH-phrase moves up into the specifier of the CP leaving a trace into the specifier of the inflectional phrase (IP). The lexical verb moves to the IP to take inflectional features and ends in the head of the CP for obtaining prosodic interrogative features and restoring the V2 condition.
Failure in the interpretation of German subject WH-questions takes place when case-marking syncretism happens, e.g. when the noun mentioned in the sentence is neuter or feminine (see the example in section 2.2, *was* does not inflect for case), as case-marking for neuter and feminine genders is not morphologically differentiated for accusative and nominative case.
In such cases, the context helps German native speakers to understand the sentence correctly.

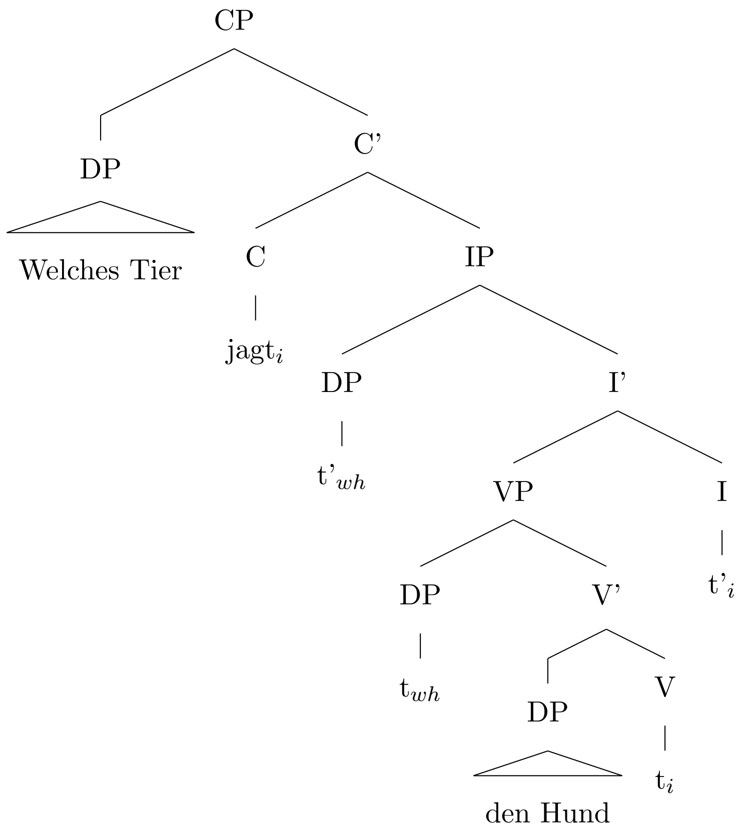



FIGURE 2.2: Syntactic tree representation of the surface structure of a direct subject WH-question in German. VP subject internal hypothesis is assumed.

## 2.4 Competing Grammars in Second Language Acquisition

The phenomenon described by Grüter (2006) has been explained in terms of the different parsing systems of English and German grammar, the first being consistently head-initial while the latter being head-final and having a verb always in second position requirement in main clauses.

While English grammar strictly relies on word order for the interpretation of ambiguous WH-questions, German grammar uses the verbal agreement features or case-marking on nominal constituents to extract semantic meaning from the interrogative question. In the case of ambiguous German sentences (as in "Was beisst die Katze?", mentioned in section 2.2), English speakers consistently opted for a subject interpretation in the present tense and an object interpretation in the perfect tense for the structure WH – Aux – DP – V, as the latter shows the same surface structure of the English object perfect tense question (e.g. “Was hat die Katze gejagt?”, *What has the cat chased?* or *What has chased the cat?*), in comparison to the bimodal distribution of responses within native German speakers. The results obtained suggest that English speakers relied on word-order for interpreting the sentences, while native German speakers' answers suggest their awareness of the questions' ambiguity when case marking cannot disambiguate between subject- and object- question interpretations.

The same phenomenon did not occur in case both L1 and L2 relied on the same parameterization and parsing system: the outcome of a subsequent experiment conducted by Grüter and Conradie (2006) with early stage Afrikaans-speaking learners of German showed no interpretation bias based on word-order structure.

### 2.4.1 Transfer in Second Language End State

The phenomenon of grammar competition is reduced but not completely suppressed at later stages of acquisition and it is the center of the investigation reported in this master thesis.

Rankin (2013) noticed that ”the different underlying syntactic structures of German and English give rise to identical surface linear orders, in particular this is the case in Subject - Verb - Object main clauses, simple tense subject questions and object relative clauses.” In other words, the difficulties encountered by English second language speakers of German at early stage of acquisition affect also German second language speakers of English even at late stage of acquisition.

English provides ambiguous input to a German head-final/V2 grammar because the lack of disambiguating case marking in English causes the German parsing system to produce ambiguous semantic interpretations. In order to shed new light on how German-speaking learners parse English sentences, Rankin has tested 30 German late stage learners of English on their comprehension of English WH- structures that have identical or different surface linear orders between English and German.

Following the Variational Learning hypothesis (Yang, 2010), the distribution of different grammars in a single speaker varies during the course of acquisition and it is constrained by the parametric setting provided by the Universal Grammar (Broselow and Finer, 1991, Yang, 2004).

At late stage of L2 acquisition the learners have acquired the parsing system of L2, by suppressing those features of L1 that are not compatible with the L2 grammar, by resetting those non-target parameters for parsing L2 and by promoting those L1 features that account successfully for L2 phenomena. As in natural selection, it is the environmental feedback that suppresses what is unnecessary and gives a positive reinforcement for L1 features able to parse L2.

In the specific case, when the surface structure of L2 does resemble that of L1, as in case of some types of WH-questions, English structures may still be parsed by proficient German learners of English with a V2/head-final German parser. In particular, perfect tense object WH-questions (WH – Aux – DP – V) and present tense subject WH-question (WH – V – DP) are compatible with a German syntactic parser. In chapter 4 a detailed analysis of the importance of these structures will be given to the reader.

With the administration of a picture interpretation task, Rankin found that advanced German learners of English significantly showed an object interpretation of subject WH-question, while object WH- questions, that cannot be parsed by a V2/head-final parser, had significant target-like interpretations by English learners, comparable to the ones of native speakers (control group, N = 10). This finding supports the idea that grammar transfer can be active even in highly proficient second language speakers and it lays the foundations for the psycholinguistic research project reported here.

# Chapter 3

# Grammar Processing in the Brain

## 3.1 Cognition and Neuroscience

The new frontier of neuroscience consists in using scientific and medical equipment for investigating cognitive faculties that were before only domain of psychology, linguistics and philosophy.

One of the important aspects of neurophysiological measuring techniques is the chance to provide the researcher with methodologies that offer quantifiable measurements during mental and cognitive processing without conscious response of the participant. One of these techniques regards the recording of event-related brain potentials (ERPs), time-locked averaged and filtered records of electrical activity measured with electroencephalography (EEG) and evoked by a particular stimulus. The major assumption about ERPs regards their connection with neural activity as index of a cognitive process occurring in the moment of measurement.

For this reason, EEG is a useful tool for investigating the temporal component of language processing in the brain. In this chapter it is given a description of what ERPs are before entering the main topic: the use of ERPs for studies related to the processing of syntax and semantics in the monolingual and bilingual brain.

## 3.2 Event-Related Potentials and their Neural Basis

ERP components are scalp-recorded neural activity that is generated when a specific cognitive process is performed. The same component can occur at different times and under different conditions, as long as it represents the same cognitive function.
The origin of the signal comes from post-synaptic potentials: when neurotransmitters are released into the synaptic cleft and they bind onto the postsynaptic membrane, ion channels open and cause an instant change in the voltage potential across the membrane. Postsynaptic potentials, mainly located at dendrites, last tens or hundreds of milliseconds, being in such a way able to produce a dipole (see fig. 3.1): current flown outside the membrane generates a net extracellular negativity at the apical dendrites (at resting state a neuron is negatively charged) while the inferior area around the body cell is positively charged. When the dipoles of several spatially aligned millions of neurons (as in the pyramidal cells of the cortex) summate, the resulting voltage can be recorded on the scalp as the sum of a single dipole formed by the averaged orientation of single small dipoles.

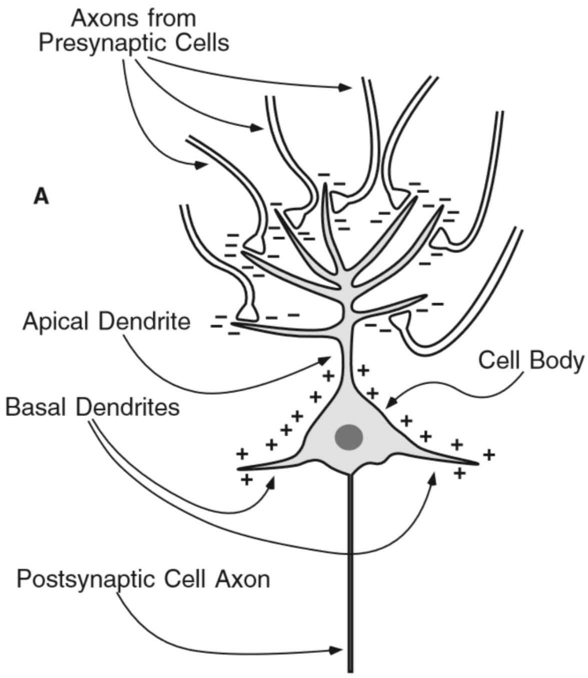



FIGURE 3.1: Representation of a neural dipole created by the difference in potential between apical and inferior part of the neuron.
From: Luck (2014), An introduction to the event-related potential technique.

Because of the fact that an ERP component is a single-brain process that influences the recorded voltage simultaneously at all electrode sites, the spatial resolution of EEG is undefined: potentially, infinite set of dipole configurations could generate a given voltage distribution on the scalp (this is called the *inverse problem* in ERP localization). Nevertheless, some mathematical models have been created to hypothesize the most probable localizations: the BESA (brain electrical source analysis) takes as assumption that the spatio-temporal distribution of voltage can be adequately modelled by a small (less than 10) set of dipoles, each of which has a fixed location and orientation but varies in magnitude. The goal is to find the set of dipoles with the lowest residual variance (i.e. lowest scalp distribution not explained by the model). More valid models come from distributed source approaches, where the goal is to find pattern of activation values for voxels containing many dipoles which produce the observed pattern of voltage on the surface of the scalp. Since many set of voxels could produce the observed distribution (i.e. *problem of nonuniqueness*), a cortically constrained approach, that takes into consideration only cortical voxels and is based on constraining the model through the use of structural MRI image of the subjects' brains, is able to limit the choice of possible explanatory voltage distributions. The voxels need to contain perpendicular dipoles, since those dipoles, that have a magnetic field that exit and does not re-enter (as parallel dipoles do) the head generate highest voltage at the scalp.

Such difficulties are encountered when using a technique, EEG, that is completely not invasive. Intracranial EEG is a valuable version of the same technique that is able to precisely localize neural generators but, being highly expensive and invasive, its employment is limited to clinical diagnosis of abnormal brains.

The main reason to use EEG in cognitive research remains not only its low costs in terms of necessary lab materials, but above all the excellent temporal resolution (in terms of hundreds of milliseconds) that makes it unbeatable (together with the magnetoencephalography, MEG) in analysing the temporal domain of cognitive processes in the human brain.

### 3.2.1 ERP Waveforms

Evoked potentials are averaged segments of EEG data that are time-locked to the stimulus onset. They occur when a certain event happens to the subject and are extracted by raw EEG through filtering and averaging of the signal. Part of the assumption behind

ERP is that everything above 30 Hz is not part of cognitive processes and it is defined as “noise”. (Luck, 2014) A second important assumption is that individual differences of subjects are neutralized by grand averaging a large number of trials (such that there is a high signal -to-noise ratio).

ERP waveforms are expression of several summed latent components. Voltage peak local maximum and components are not the same thing and it is impossible to estimate the time course (also defined as peak latency) of a latent ERP component simply by looking at a single ERP waveform, since there is no obvious relation between shape of a local part of the waveform and underlying components. Differences in peak amplitude do not necessarily correspond with differences in component size as well as differences in peak latency do not necessarily correspond with changes in component timing.

For these reasons, EEG waveforms segments need to be averaged to reduce the noise present in the single waveforms, keeping in mind that averaged ERP waveforms do not represent accurately the individual waveforms (see fig. 3.2): the onset of the averaged waveform represents the earliest onset in the total number of trials, while the offset represents the latest offsets from the individual trials.

Because of this issue, the standard way to quantify ERP waveforms is to refer to the measurement of area amplitude, i.e. the area under the curve in the averaged waveform, since this is equal to the average of the area under single trials curves. Such quantification method has been used for the experiment performed in this master thesis.

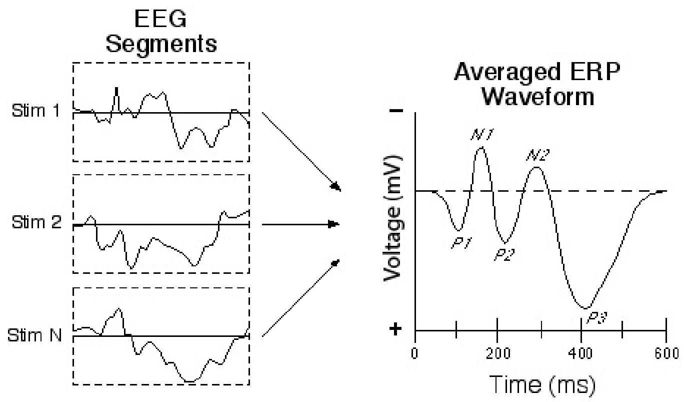



FIGURE 3.2: ERPs are averaged waveforms on a high amount of trials.
From: da Rocha Gesualdi and França (2011), Event-Related Brain Potentials: An Overview.

### 3.2.2 The EEG/ERP System

An EEG system for recording ERP is composed by several parts. It needs at least one computer where a visual EEG recorder and a data analyser are installed, as well as a software where the cognitive task (the "event" of the related potentials) has to be performed by the participant. The electrophysiological signal is recorded from cap-mounted electrodes, usually located following the 10-20 international system: at 50% of the measure between nasion (i.e. the space between the eyes) and inion (a location below the bone on the occipital part of the scalp) the central electrode (called CZ) is placed. From this point, all the other electrodes' position is calculated, considering the region of the head (i.e. frontal, occipital, parietal and temporal) and the distance from CZ. One bipolar electrode is placed above and under the right eye (vertical oculogram) and one is placed on the right and on the left of both eyes (horizontal oculogram) to monitor eye movements during the recording.

Nowadays, EEG amplification systems use differential amplifiers, which amplify difference in voltage between the difference of an active electrode (placed at the desired site on the scalp) and a ground electrode (placed on subject's head or body) and the difference of a reference electrode and the ground electrode. The reference electrode can be located on different locations, as far as the position is as electrically neutral as possible (e.g. on the tip of the nose, on the two mastoid bones, on the centre of the head or by using a common average reference, based on the assumption that the averaged sum of activity of all electrodes is zero.) The ground electrode is necessary because of the necessity to remove the noise caused by ground circuit electromagnetism.

The EEG signal, after having been collected and amplified, is digitalized through an analog-to-digit converter, that transforms EEG voltage fluctuations into numerical representations.

### 3.2.3 Noise and Filters in the EEG Signal

It is defined as "noise" that part of EEG recorded electrical activity that comes from non EEG biological signals and electrical sources. Since the frequency range of EEG connected with cognitive activity is between 0.01 and 30 hz, everything below or above this range is considered noise.

Possible noise source is the impedance of skin (the resistance of skin does not allow for the electrical signal to pass clearly from the scalp to the electrodes), that can be reduced through common mode rejection (i.e. the ability of an amplifier to subtract away environmental noise accurately) and with a mechanical cleaning (done by the researcher with alcohol and abrasive paste) of the skin surface of the subject. Skin potentials, i.e. the tonic electrical potentials between surface and deep layers of the skin, produce slow shifts in voltage in the EEG signal that can be subtracted by high-pass filters, that is, digital and analogic filters that attenuates low frequencies (usually under 0.01 hz). If slow voltage shifts are not kept at the minimum, they may cause the amplifier to saturate, resulting in "blocking" (i.e. a flat EEG signal).

Other sources of noise are eye blinks, eye movements and environmental noise given by AC current or electronic tools present in the laboratory (e.g. monitors) during recording. A notch filter (at 50 hz in Europe) is used to remove noise caused by electrical power lines. For the other mentioned sources, as well as for sweating (that increases skin impedance) and muscular movements produced by the subject, low-pass filters are used to attenuate the high frequency of the noise.

Since noise decrease as a function of the square root of the number of trials in the average, increasing the number of trials has a positive effect on signal-to-noise ratio. On the other side, this procedure increases the possibility to incur in the phenomenon of *habituation* that is the reduction of mean amplitude of ERPs component due to the recurrent presence of the same stimuli repeated for a long period of time. A good experimental setup has to find a compromise between reduction of noise and increase of habituation, either increasing the number of subjects or reducing noise sources.

### 3.2.4 EEG Sampling Rate

EEG is converted into voltage at a sequence of discrete time points. A sampling period is defined as the time window in which EEG is recorded and the sampling rate relates to the maximum frequency recorded per second. The Nyquist Theorem affirms that EEG signal information can be captured digitally as long as the sampling rate is at least twice (or even three times) as great as the highest frequency of the signal. For this reason, the presence of online low-pass filters in EEG amplifiers influences the sampling rate which in fact depends on the cut-off frequency in low-pass filters. Lower filter frequency in low-pass filters would be advisable for rejecting as much noise as possible, but this results in a lower sampling rate and, as a consequence, less temporal precision. For

this reason, it is required to apply further offline low-pass filters during the extraction of ERP from the raw EEG. A reasonable online low-pass filter cut-off value is around 80-100 hz (equivalent to a sampling rate of 250 hz).
If the signal contains frequencies more than twice higher than the digitalization rate, these high frequencies will appear as low frequencies in the digitized data, provoking a distortion of the signal (a phenomenon called *aliasing*).
All these notions and precautions have to be kept in mind when designing an ERP experiment, in order not to draw conclusions from the recorded noise instead of the recorded neural activity.

### 3.2.5 EEG Extraction Procedure

Once obtained the raw data, offline filters are applied to all channels to reduce noise (usually with a cut-off of at least 30 hz for low-pass filters) in the EEG signal. At this point, EEG data is segmented into "chunks" locked to the onset of the presented stimulus or to the response of the subjects. Each of these segments corresponds to one trial of the experiment.
Through the process of ocular correction, eye movements (whose voltage gradient becomes more positive at sites that eyes have move towards, creating characteristic saccades in the signal) and eye blinks (whose response is opposite in polarity for sites above and below the eye) are removed, both using algorithms that compare the specific value of voltage deflections in the signal to a given threshold and visually inspecting critical portions of EEG data. A correlated process is the one of artifact rejection, in which the influence of artifacts is estimated by algorithms and correction procedures, either automatic or manual, are applied in order to exclude contaminated segments.
Once all the trials have been cleaned by noise and eventual artifacts, the segments are averaged all together and a baseline correction is applied (a procedure that corrects the period antecedent to the stimulus, usually from -200 ms to 0 ms, such that the sum of the signal in that time window is equal to zero, in order to have an estimate of the noise before the stimulus onset and to correct all the trials such that they have 0 mv as reference). Using baseline correction not only makes the trials comparable one with another, but it shows also possible overlap with the response from preceding trials.

The whole procedure is repeated for all the subjects, till a grand-average, i.e. an average of the averaged ERPs for each participant, is applied to make visible subtle ERP components in the EEG signal.

### 3.2.6 ERPs Application: Famous Components

ERP have found their application across all the modalities: they have been found in the visual, auditory, motor, linguistic and sensory dimensions (examples of the latter are the Somatosensory Evoked Potentials (SEP), elicited by several sensory stimuli, as mechanical impacts to fingertip and air puffs). The name of ERP component is given either because of their ordinal position of temporal appearance in the EEG signal (e.g. N1, P1 as shown in fig. 3.2), or by their latency in terms of milliseconds (e.g. P300) from the onset of the stimulus. The "P" stands for a component with a positive curve (plotted downward), while "N" for a negative component (plotted upward).
Among famous ERP components, P300 and MMN (mismatch negativity) are both evoked when using an oddball paradigm (i.e. when the subject is presented with a series of standard stimuli and a rare deviant stimulus), above all in the auditory dimension. The first occurs while the subject is vigilant, while the second happens in case the subject does not have to pay attention to the stimuli. Another auditory ERP is the Brainstem Auditory Evoked Potential (BAEP), a group of several components reflecting activity in the auditory nerve and in the brainstem, used to monitor the functioning of the auditory system in babies.
Centre of the debate around the timing of language dimensions, Early Left Anterior Negativity (ELAN) is a negative peak around 200 ms post-stimulus evoked by violations of noun agreement or phrase structure. The most important syntactic related component is P600, elicited by grammatical violations both in auditory and visual presented stimuli. Finally, N400 is a component evoked by an inappropriate stimulus in an expected context and, being often used in word association tasks, it has been defined as index of attempts to access and integrate meaning into current context evoked by potentially meaningful stimuli. This semantic related component is also crossmodal (as it has been found both with visual and auditory stimuli).
The following section presents a review of recent literature about language research on grammatical processing in the brain with the use of EEG technique through the extraction of meaningful language-related ERP components.

## 3.3 ERPs and Syntactic Processing

ERPs have revealed to be a powerful tool for analyzing the time-scale of the neural correlates of semantic and syntactic processing and, as a consequence of that, a wide literature has been written on the topic. In the following section an introduction on syntactic components in ERP research is given to the reader.

### 3.3.1 On P600, LAN and ELAN

The major finding connected with syntactic processing in ERP research has been the so-called component P600 (see fig. 3.3), a late bilateral centroparietal positivity that peaks around 600 ms after a syntactic anomaly is detected in the stimulus (Ainsworth-Darnell et al., 1998, Osterhout and Holcomb, 1992, 1995).
The majority of the studies show also another effect, that is a left anterior negativity (LAN) around 200 – 300 ms preceding the P600 component for those violations concerning word category errors and agreement violations (Friederici et al., 1996). Left anterior negativity has been interpreted as index of detection of the morphosyntactic error while the P600 component would reflect processes of syntactic reanalysis (Rossi et al., 2005). This biphasic pattern has been seen also in research concerning metric stress patterns during auditory syntactic processing (Schmidt-Kassow and Kotz, 2009), with the only

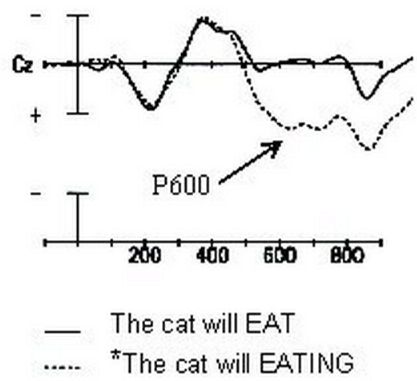



FIGURE 3.3: P600 Component. From: Cognitive Neuroscience of Language Lab, Lee Osterhout, Dept of Psychology, University of Washington, n.d., Web 7/08/2014, http://faculty.washington.edu/

difference that metric cues are processed at an early stage (evoking an early left anterior negativity, ELAN). An ELAN effect has been also observed in occurrence of phrase structure violation (Hahne and Friederici, 2002) and even morphological violation of word stem and inflectional violations (Rodriguez-Fornells et al., 2001) leading to suppose that the latency of left anterior negativity is related to the function of the violation type: ELAN for phrase structure violations and LAN for agreement violations (Friederici and Kotz, 2003). An interesting finding on the LAN effect behavior comes from simultaneous processing of (visually presented) language and (auditory presented) music: music-syntactically irregular chords elicit early right anterior negativity (ERAN) that reduces the contemporary LAN of syntactically incorrect sentences, suggesting that processing of musical syntax interacts with the processing of linguistic syntax (Koelsch et al., 2005).

As far as it concerns the functional interpretation of P600, it has been considered mainly as index of syntactic processes connected with reanalysis and repair of syntactic violations. Differences in the distribution of LAN and P600 have been attributed to variation in the syntactic structure involved in the violation. While number agreement violations elicit posterior distribution of P600, person agreement violations show a frontally distributed P600 in the early phase (Mancini et al., 2011) and experiments on the combined interaction between semantic incongruence and morphosyntactic violations observe a left lateralization of LAN and N400 (see the following paragraph for a reference) in contrast with a more pronounced P600 in the posterior areas of the right hemisphere (Palolahti et al., 2005).

The latency of ELAN/LAN and the co-occurrence of P600 have been of great impact for the formulation of syntactic processing models in interaction with the semantic interface. Examples are the extended Argument Dependency Model (eADM), based on the occurrence of a so-called "semantic P600" effect due to implausible thematic role assignment of an argument to the sentence (Bornkessel-Schlesewsky and Schlesewsky, 2008) and the model proposed by (Friederici and Kotz, 2003) that integrates in a unique time-scale process ELAN, P600 and the N400 component. The literature on N400 is even huger than P600 and, for the sake of brevity, in this context it will be sufficient to say that N400 is associated to semantic incongruences and it reflects the attempt to access and integrate meaning evoked by potentially meaningful stimuli into current context.

Friederici's model of auditory language comprehension assumes three functionally and temporally separable phases: firstly, after initial acoustic and phonological analysis, a stage of initial syntactic processes of local structure building, reflected in ELAN. In second place, lexical-semantic and thematic processes following evidence from N400 studies and processes of thematic role assignment based on morphosyntactic information related to agreement relations as expressed by LAN effect. And thirdly, late processes of syntactic revision and integration, correlated to the P600 component. This model, supported also by fMRI studies on the anatomical localization of syntactic and semantic processing, is generally referred to as "syntactic first" because of the emphasis on ELAN as first index of syntactic analysis in the brain.

### 3.3.2 Semantic P600: An Alternative Hypothesis

Up to this point, studies regarding person, verb agreement and phrase structure violations have been mentioned to support the presence of P600 effect as correlate of processes of syntactic reanalysis. Particularly critical views on the origins of P600 come from studies based on violations of the tense of the verb, to which the next paragraph is dedicated.

Sentences in which the main verb varies for grammaticality, i.e. for tense violation vs. no tense violation, have been primarily investigated with ERPs in English. Syntactically anomalous sentences read by participants in a verb tense violation task elicited "a late positive shift with an onset around 500 msec and a duration of several hundred msec" (Osterhout and Nicol, 1999). What it will be now called a P600 was also elicited by agrammatical sentences for regular verbs, while in the case of irregular verbs the P600 component was evoked earlier in time only for high-frequency forms (Allen et al., 2003). Proof in favor of distinct neurocognitive processes for the processing of regular and irregular verbs has been recently (Newman et al., 2007) provided through a task in which participants read English sentences with either correct or agrammatical past tense inflection both for regular and irregular verbs and with syntactic phrase structure or lexical violations. Only violations of regular past tense and phrase structure elicited LAN (in contrast with the ELAN found by Friederici and Kotz, 2003).

As far as it regards the P600 component, it was maximal on right parietal regions for regular, irregular and phrase structure violations. This finding suggests a dependence from rule-governed combination processing for regular verbs (a compositional process similar to the one of phrase construction) while irregular verbs, that behaves like lexical tokens in their ERP response, would depend on processes of lexical memorization.

As previously mentioned, the presence of P600 with irregular verbs has been explained as index of aspects of controlled syntactic processing (reanalysis and integration) of both phrase structure and morphosyntax. This is coherent with studies on morphological manipulations such as the one from Hagoort (2003), where syntactic violations consisting of a mismatch in grammatical gender or number of the definite article and the noun elicited a P600, whose size was not affected by additional combined semantic violation in the sentence, suggesting, in the author view, that "in absence of syntactic ambiguity, the assignment of syntactic structure is independent of semantic context".

On the other side, the fact that violations of verb tense (in the specific case, use of present indicative form in sentences requiring past tense due to the presence of temporal adverbs) elicit LAN has been studied not only as a syntactic-based process, but also as a result of semantic analysis active in the attempt to establish temporal reference in the sentence (Baggio, 2008, Bos et al., 2013). One of the main claim of Baggio (2008) regards the fact that studies in which no temporal adverbs (such as in the cases of Allen et al., 2003, Osterhout and Nicol, 1999) have been used cannot be defined as related to actual "tense violations", because of the failure in anchoring the verb to a temporal reference in the sentence. In any case, a study that specifies time reference realized as temporal adverbs (Steinhauer and Ullman, 2002), while investigating tense violations, evoked both LAN (considered by the authors as index of morphosyntactic processing) and the P600 component.

This brief overview of recent ERPs studies with focus on tense violations reveals how problematic the same definition of a "tense violation" is. While a difference in suffixes carrying tense information (e.g. "-ed" morpheme in regular English verbs) has been sufficient to consider the evoked potentials as indexes of morphosyntactic processes in former studies, latter studies sustain the necessity of semantic information conveyed by a temporal reference to evoke a genuine tense violation (e.g. in the sentence "Yesterday I paints the car"). This last hypothesis reevaluates the P600 component as index of semantic processing (Baggio, 2004, Kuperberg, 2007), quite a different conclusion from the one based on the independence of syntactic structure assignment from semantics in the context of morphosyntactic violations (Hagoort, 2003). From the comparison between these studies it is possible to say that there is at the moment no certain agreement on a unique nature of P600, and this component could be index of more than one cognitive process.

Besides the P600 problematic origin, the cognitive index correlated with LAN effect is still debated: it has been elicited by case, number and gender agreement violations (Hahne and Friederici, 2002), phrase structure violations (Newman et al., 2007) and tense violations (Baggio, 2008); the latter interpreted by the author as reflecting the failure in tense agreement check between the adverb and the verb. In this view, processing of temporal reference is not only part of semantic processing but is also a preliminary stage of syntactic structure building. The hypothesis that the brain accesses and evaluates semantic information already around 200 – 300 ms (i.e. eliciting LAN effect) after word onset is overtly in contrast with the model proposed by Friederici and Kotz (2003) and it is therefore mentioned as "semantic first".
Such an overview has been given for sake of correctness and clarity on the current issue concerning (E)LAN and P600 as language-related components. This project does not enter into the debate of the nature of these components and for the whole discussion of the following experiment it has always been assumed the "syntactic first" model as well as the syntactic origin of P600.

### 3.3.3 The Brain on Late Bilinguals

In the previous sections the importance of ERP components for temporal detection of cognitive processes as well as their sensitivity to violations concerning different language dimensions has been presented. While the studies mentioned before focused on understanding language functions on the monolingual brain, the focus of this thesis is to connect such psycholinguistic findings with the research in second language acquisition and, in particular, with the linguistic phenomenon of syntactic transfer in late bilinguals. That morpho-syntactic similarities between first and second language can influence the processing of second language has been a hot topic in the last years of research in second language acquisition. In particular, it has been proved that in case of crosslinguistically similar constructions there is no difference in brain activity evoked by ERPs or localized with fMRI studies (Tolentino and Tokowicz, 2011).
A very recent groundbreaking ERP study on the effects of structural distance between first and second language speakers (Bañón et al., 2014) found that English advanced learners of Spanish showed the same evoked-related potentials (a P600 component) for number and gender violations as Spanish native speakers, even if there is no gender agreement in their native language, English. This results support the Full Transfer Full

Access Hypothesis (see chapter 2), suggesting that syntactic novel features (i.e. gender) can be processed by second language speakers in a native-like way.

Such a finding adds to the evidence provided by previous ERP studies on second language learners (Bond et al., 2011) regarding the possibility by adult learners to exhibit native-like processing features of grammar structures not present in their first language, suggesting that they are able to use the parsing system of the second language.

In the next chapter, such discoveries will be taken in account for the paradigm design and the main hypothesis of the experiment conducted on late German-English bilinguals.

# Chapter 4

# The Experiment: Paradigm and Hypotheses

## 4.1 A Narrow Literature

At the time this research proposal has been written, the specific literature on the neurophysiological correlates of the syntactic processing of WH- questions is surprisingly narrow.

A seminal study on the topic comes from German native speakers (Fiebach et al., 2002), where 24 participants were recorder when processing case-unambiguous indirect subject/object WH-questions. As a result, a left anterior negativity similar to LAN was observed for object questions with long distance between WH-filler and its gap, furthermore a positive-going ERP effect between 600 and 750ms (i.e. P600 component) was observed for short and long object WH-questions at the position of the second noun phrase. No significant differences between ERPs elicited by subject and object WH-fillers at the position of the question word have been found.

P600 has also been considered as a marker of the difficulty of syntactic integration processes and as reflecting the amount of resources required for such processes, on the basis that integration is more difficult in grammatical, long distance WH-questions (Kaan et al., 2000).

While such studies focused on well-formed sentences, a follow-up study on the processing

of ungrammatical WH- questions has been conducted on 24 Chinese Mandarin speakers, revealing a P600 effect on grammatical violations of long distance WH- questions compared to declarative control sentences (Xiang et al., 2014).
A recent fMRI study conducted on Japanese native speakers (Kambara et al., 2013), confirmed a significant difference in the brain activation occurring during the processing of grammatical versus ungrammatical and semantically anomalous WH-question sentences.
An interesting finding on the topic of subject/object wh-questions comes from a recent study on 13 children with specific language impairment (Epstein et al., 2013). As main assumption, LAN was used as a marker for atypical processing of wh-questions, since this left anterior negativity has been previously linked to great working memory processes connected with maintaining in memory dislocated object in wh-questions. As a result, typically developing children showed anterior positivity to object relative to subject questions compared to a non-significant effect in the SLI group, that revealed very poor comprehension of wh-questions. The expected LAN effect was instead elicited in the adult control group.
Until now it has been showed evidence of syntactic components evoked in native speakers when grammatical violations occur (see chapter 3) as well as syntactic components specifically evoked by WH-questions. Because of the lack of dedicated literature on the effects of morpho-syntactic violations in wh-questions on second language speakers in ERP research, this study has been configured as an experimental project, i.e. a psycholinguistic pilot for further extended research on the neural correlates underlying the processing of grammaticality violations of interrogative questions in proficient second language learners of English in conjunction with native language transfer.

## 4.2 Research Hypothesis

Main object of the study is the neural processing of direct subject/object English WH-questions by highly proficient German learners of English (see chapter 2 for a theoretical introduction to the topic).
On one side, behavioral studies have shown a mismatch in the interpretation of ambiguous WH-questions between native speakers and proficient learners of English. From a theoretical perspective, these non-target interpretations have been considered proof in

support of the Full Transfer Full Access hypothesis, i.e. the transfer of functional structures from the first (L1) to the second language (L2), and of the Variational Learning hypothesis, i.e. the possibility to rely on a native language syntactic parser when L1 parameters successfully parse the L2 structure. On the other side, neurophysiological studies (see chapter 3) in monolinguals and bilinguals have found neural correlates that have been interpreted as indexes of syntactic processing of reanalysis and repair of syntactic violations and integration effort of ungrammatical constituents (P600), as well as indexes of noun-verb agreement violations and working memory load (ELAN and LAN).

### 4.2.1 Aim of the Study

Main hypothesis of the study regards the processing of syntactic violations by late stage English learners. While grammatical WH-questions should evoke no significant effect connected with syntactic and agreement violations (i.e. ELAN/LAN and P600), ungrammatical variations of subject/object structures of WH-questions should show a different pattern of response connected with the possibility for these sentences to be parsed or not by German grammar.

For the purpose of this experiment it has been decided to investigate the neural correlates elicited by two types of English structures, either compatible or not with a German parser. As previously discussed in chapter 2, present tense subject WH question (WH – V – DP) and perfect tense object WH questions (WH – Aux – DP –V) can be parsed by a German grammar while the complementary present tense object WH questions (WH – do insertion - DP - V) and perfect tense subject WH questions (WH – Aux – V - DP) show features, such as word order and "do" insertion, which are not allowed by a German parser, therefore suggesting that the learner must rely on a L2 parser to analyze the sentences.

Four conditions are object of the experiment: two target conditions consisting of ungrammatical WH-questions that can either be parsed ("Compatible" with a German parsing system in fig. 4.1) or not ("Incompatible" in fig. 4.1) by German grammar and two control conditions consisting in the grammatical equivalents of the four interrogative structures mentioned above.

| | **Grammatical** | **Ungrammatical** |
|---|---|---|
| **Compatible** | WH - V – DP<br>*(Which animal chases the dog?)* | *WH - V – DP<br>*(Which animal chase the dog?)* |
| | WH - Aux - DP – V<br>*(Which animal has the dog chased?)* | *WH - Aux - DP – V<br>*(Which animal have the dog chased?)* |
| **Incompatible** | WH - do - DP – V<br>*(Which animal does the dog chase?)* | *WH - do - DP – V<br>*(Which animal do the dog chase?)* |
| | WH - Aux - V – DP<br>*(Which animal has chased the dog?)* | *WH - Aux - V – DP<br>*(Which animal have chased the dog?)* |

FIGURE 4.1: Scheme representing the four conditions used in the experiment design: each condition is given by the intersection of two factors. Examples of sentences used in the task are in italic.

### 4.2.2 Predictions and Expected Results

Based on the previous assumptions, it is predicted that the ungrammatical versions of the four types of WH-questions focus of the study should elicit correlates of syntactic violations identifiable with the P600 component and, possibly, an (early) left anterior negativity (ELAN - LAN). Such an hypothesis is sustained on the basis that grammatical violations require a higher effort for neural processes of syntactic integration in the second language parsing system.

What is more interesting is the second prediction of the study, i.e. that, among the ungrammatical target conditions, those sentences that are not compatible with a German parser are more likely going to show a higher P600 amplitude that the ones that can be successfully parsed by L1 grammar, even if ungrammatical in English language. This prediction is made on the assumption that a lower effort in syntactic processes of reanalysis in second language comprehension (that is, a lower amplitude in P600) is connected with the selection of the first language parsing system (i.e. German), because of the subject relying on noun-verb agreement instead of the English word order system. Such a condition is possible in advance second language speakers only when the grammatical structure of L1 and L2 is similar (as in the case of English and German present tense subject and perfect tense object WH questions).

## 4.3 Selection of Stimuli

The inner core of the stimulus list (12 items) derives from the material used by a previous behavioral study in applied linguistics to L2 research made by Rankin (2013).
In order to standardize the stimuli at a level of psycholinguistic validity, it has been decided to use always the same structure, consisting of the WH-question "Which animal" for singular and "Which animals" for plural referents followed by a verb, an auxiliary or a do-insertion depending on the condition (see fig. 4.1).
The sentences' components (e.g. nouns and verbs selection) have been manually randomized in the process of sentences construction during their design in a *Office Excel 14.0* (Microsoft Corporation) sheet in order to avoid repeated specular constructions with the only difference of the animal involved in the question. All sentences have been standardized for length, same syntactic structure and frequency of verbs and conjunctions, maintaining similarity among the critical items but using different lexical material. Four high-frequency verbs have been used in order to diminish possible misunderstandings in the comprehension of the sentences: *to hunt, to chase, to follow, to catch.* During the experiment procedure, it has been clarified to the participants that those verbs have been used as absolute synonyms in the whole task. It has been assured that the participants know that the past perfect of the verb "to catch" is the irregular "to have *caught*".
Nine high-frequency animals have been selected either as subject or object of the WH-questions in their singular and plural variant: lion(s), elephant(s), dog(s), cat(s), fox(es), bird(s), cow(s), bear(s) and horse(s).
A single animal used as subject or object in four types of sentences repeated twice in their either grammatical or ungrammatical version with either a plural or singular referent gives rise to 2 x 4 x 2 x 2 = 32 unique sentences for the experiment, that means 8 unique sentences for each condition.
Because of the fact that in EEG research is fundamental to keep noise derived from other cognitive activities as low as possible as well as the environmental noise and given that a 5-10% of trials can be possibly rejected during filter analyses due to the interference of artifacts of various nature (as slow voltage shifts for high skin resistance, eye blinks or other sudden movements of the participant), the number of trials to be used in the experiment is a "hot topic" in every ERP design. Using a reduced number of trials avoids the phenomenon of habituation in front of the same stimulus repeated over and over again and it can be particularly useful in paradigms focusing on the N400 effect of

unexpected semantically related stimuli.

Since the research experiment here reported focus on P600 and because of the fact that noise decrease as a function of the square root of the number of trials in the average (see chapter 3), meaning that increasing the number of trials has a positive effect on signal-to-noise ratio, it has been decided to opt for a paradigm design consisting of 72 unique stimuli for each condition (that is not a particularly high quantity of trials for an ERP study but it has the benefit to be not too tedious and tiresome for the subjects), equivalent to the above-mentioned 32 unique sentences x 9 animals for a total of 288 unique sentences used as experiment material.

Among the 288 stimuli used for the ERP experiment, 64 sentences have been extracted keeping constant the amount of sentences for each condition, the frequency of animals and verbs used and have been randomized for the design of the extended behavioral version of the experiment, subsequently called "Tom's Task" in honor of the original creator of the task (see chapter 5 for further explanations).

By courtesy of Tom Rankin it has also been possible to use the same cartoon pictures of animals for the EEG and the extended behavioral task that he used for its own study. The pictures have been standardized in size and rearranged in order to form "triptyques" composed by three animals or couple of animals chasing each other. The object or subject of the action mentioned in the 288 questions have always been the median animal presented in the picture (see fig. 4.2).

In the following chapter, the necessity of a behavioral pilot will be explained to the reader as well as the way in which the stimuli have been presented to the participants during the EEG recording.

For the complete list of the stimuli used in the EEG experiment, see Appendix A.

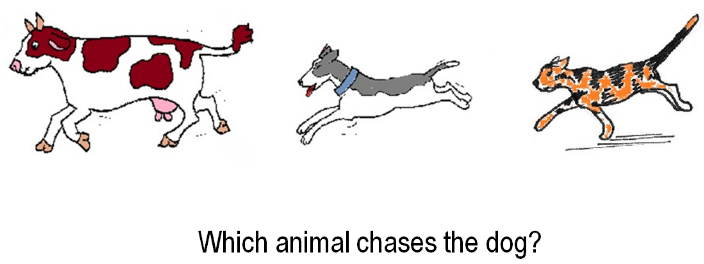



Figure 4.2: Example of cartoon picture used in the task. In both the behavioral and the EEG experiment the question temporally preceded the chasing scene.

# Chapter 5

# The Experiment: Methods and Procedure

## 5.1 Preface: A Behavioral Pilot

Because of the huge implementation in terms of stimuli selection and standardization procedure, presence of ungrammatical counterparts of the WH-questions and manipulation of the animal pictures compare to the material used in the original study (Rankin, 2013), a behavioral pilot has been planned to confirm the original findings in terms of comprehension mismatch in the interpretation of ambiguous interrogative sentences by native and second language speakers of English and to confirm the individual difference in syntactic aptitude and parsing strategy in L2 English speakers.

In order to maintain the comprehension-oriented meaning of the original task, each sentence has been followed by an interpretation picture task in the online experiment. Such an interpretation picture task serves the goal to check for the interpretation mismatch previously found in behavioral research.

The behavioral task has been administered by three Bachelor students in Linguistics and English Studies at the University of Vienna (Alex Hellewell, Theresa Kritsch and Marc-Paul Ibitz) as part of a proseminar project on the "Individual Differences in Grammar Sensitivity in L2 English Speakers as Measured by a Grammar Task" supervised by Prof. Susanne Reiterer.

28 (of which 18 females) German native speakers with late age of onset of acquisition for

English (AoA higher than 8 years of age) have been tested for their level of proficiency of English through the administration of the Modern Language Aptitude Test part IV for grammar sensitivity (MLAT IV), a standardized test that examines the knowledge of syntax, principles, parameters and supra-segmental awareness of the subjects. Subsequently, these advanced learners of English have participated individually to the online "Tom's Task" (see chapter 4 for further explanation on the design), consisting of 64 WH-questions, each of them presented on a monitor and followed by a picture displaying a chasing scene as the one presented in fig. 4.2.

After the presentation of each picture, the participant's feedback was requested through an interactive page for the selection of the considered correct answer (e.g. which of the two possible animals or couples of animals is the one involved in the action described by the previous sentence).

Furthermore, a control group of 11 English native speakers (5 females) with no previous knowledge of German (to avoid possible language interferences) have been tested with MLAT IV and the online Tom's Task for comparing the scores obtained by first and second language speakers of English. The results of the behavioral pilot relevant for this study are briefly presented, together with the findings of the EEG experiment, in chapter 6.

## 5.2 Participants of the Study

Initially, the participants of the behavioral pilot were planned to take part also in the EEG experiment. Due to the low response rate obtained by later contacts established with those participants, the experiment has been delayed in time and a new pool of participants has been found.

The participants of the EEG experiment have been 15 right-handed German native speakers (of which 5 females), with an age ranging from 19 to 35 and a mean age of $25.8 \pm 3.9$, highly motivated in participating in a cognitive psychology research project. All the subjects have a medium-high level of education (minimum: secondary school leaving certificate), cognitively unimpaired and with no previous history of neurological or psychiatric disorders.

Most important criterion for selection was English age of acquisition (higher than 8 years of age) and a high level of English proficiency. The participants have been asked

to fill out an informed consent form (see appendix A), the Edinburgh right-handedness questionnaire and a general questionnaire on their language background.
Furthermore, it has been asked to the participants if they had already been tested with a formal test for English proficiency (such as IELTS or TOEFL) and, in case of negative answer, they have been required to fill in a reduced version of TOEFL (Test of English as a Foreign Language). All the participants showed high or very high level of English proficiency in the English test (mean score: $20 \pm 2.9$ out of 25).

## 5.3 Research Methods

The neurophysiological technique chosen for the experiment is EEG. The electrophysiological signal evoked by relevant stimuli has been recorded from 35 cap-mounted centro-parietal electrodes located following the 10-10 international system (see fig. 5.1). The selection of the electrodes used for the experiment have been based on previous research on syntactic related ERPs component (centro-parietal for P600, left anterior for ELAN and LAN). An extra electrode above and below the right eye monitored vertical eye movements (*vertical hoculogram*) while electrodes marked with numbers 61 and 51 in fig. 5.1 monitored horizontal eye movements (*horizontal hoculogram*). Ground electrode has been placed on the nasion. Electrodes have been referenced to an electrode placed over the right mastoid bone, electrical activity on the left mastoid has also been recorded to check for experimental effect detectable on mastoids.
The electrode impedance has been kept below 4 k$\Omega$ throughout the experiment using an online impedance controller system on the recording monitor. The sampling rate has been 500 Hz with a low pass filter at 70 Hz and a high pass filter at 0.01 Hz.

## 5.4 Experimental Procedure

Each participant has taken part in an experimental session for the duration of around 2 hours of preparation and approximately 45 minutes of EEG recording.
During the preparation phase, the participant has been administered with the tests and questionnaires mentioned in section 5.1 while measurements of her/his head (nasion to inion, A1, i.e. left ear lobe, to A2, i.e. right ear lobe, and circumference) have been taken. Such measurements are necessary for the selection of the right cap size as well as for an

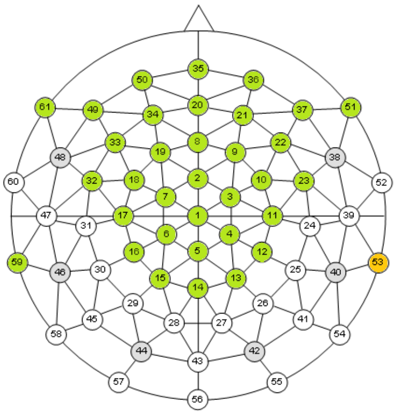



FIGURE 5.1: Scheme of electrodes localization on the scalp. (EasyCap ® System, 61 electrodes). Reference electrode on right mastoid (marked in orange).

exact placement of the electrodes on the scalp. Reduction of skin impedance has been assured via cleaning of the skin with alcohol and subsequent injection of each electrode with neurogel for facilitating electrical conductance between the scalp and the electrodes. Eventual bubbles have been removed with a sterile needle while the impedance have been reduced below 4 kΩ with an analogical impedance controller device.

After the preparation procedure, the participant has been guided into a Faraday cage (a room shielded from electromagnetic activity) where she/he has taken a sit in front of the monitor for the experimental task. All the instructions have been given to the participant in English from the first encounter. In particular, it has been explained that the aim of the experiment is not to judge the answer given to each question, but to investigate the neural activity connected with the comprehension of read sentences. Before starting the experiment, it has been asked to the participant about any further necessity (e.g. a glass of water, clearer explanations, what to do in case of sudden emergency).

The participant has been monitored during all the experimental task through a video camera and eventual communication has been established through a speaker system.

## 5.5 Materials and Task Design

ERPs time-locked at the onset of the stimulus (i.e. the noun-verb agreement mismatch) have been recorded while the participants read a total of 288 visually presented and randomized sentences (see chapter 4 for stimuli selection). Each WH-question has been followed by an interpretation picture (of the type presented in fig. 4.2) to which the participant had to provide answer by manual response on the keyboard.

The response was given by pressing the right arrow if the correct answer was the animal on the right and left arrow for the animal on the left of the picture. Space bar could be pressed in case the sentence had no possible answer (e.g. in case of ungrammatical sentences).

Because of the nature of ERPs, it is necessary to establish clearly the onset of the target stimulus, i.e. the part of the sentence where the grammatical violation is realized. For this reason, it is not possible to present the sentence as a whole but instead the approach adopted has been to present several sentence constituents on temporally consequent slides (as proposed by Tanner et al., 2013). Such a design allows to precisely time when the trigger has to be sent from the software where the experimental task runs to the EEG recording device. Such a trigger is essential for segmenting the EEG raw data in ERPs and for recognizing to which condition each trial is related (since the stimuli are randomly presented).

Because of the large amount of trials and in the attempt to maintain a reading speed similar to the one of a singularly presented sentenced, each slide has been presented for 600 ms and it has been preceded by a fixation cross (duration: 200 ms) in black on a white background. Aim of the fixation cross is to avoid sudden ocular movements at the moment of stimulus presentation. Each sentence constituent has been preceded and followed by a 200 ms inter stimulus interval except for the critical constituent (the one connected with the trigger onset, labelled as "Target3" in fig. 5.2), followed by a 400 ms inter stimulus interval (the 200 ms difference is too small to be detected by the human eye). Such a length is necessary in order to restrain the evoked ERP to the processing occurring during the detection of the syntactic violation and subsequent reanalysis and to allow the ERP component to emerge without overlaps with the neural activity evoked by the following sentence constituent.

In order to clarify the task design, let's make an example: if the trial sentence is the ungrammatical "Which animal chase the dog?", the first appearing slide would contain the word "Which" ("Target 1" in fig. 5.2), the second "animal" and the target slide, the one where the lack of agreement between noun and verb is realized and the trigger is sent to the recorder, is the third slide ("Target 3", as mentioned before).

Sentence-ending constituents (i.e. "Target 4") appeared with a question mark, followed by an inter stimulus interval of 1000 ms and a picture depicting the animals involved in

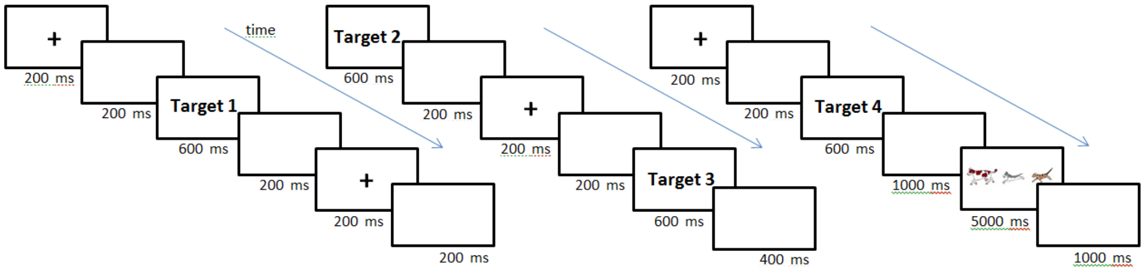



FIGURE 5.2: Representation of the task design. Each slide was presented individually. The timeline is marked in blue.

the event for 5000 ms. In this time window the subjects were asked to press the correct button on the keyboard corresponding to the answer of the previous read question.
A final inter stimulus interval slide with a duration of 1000 ms visually concluded each trial. As a consequence, the total time lenght of each trial has been set at 13.8 seconds, that could be reduced in case the participant pressed the answer button in an interval of time smaller than 5000 ms.
Every 20 trials a break has been programmed, such that the participant could stretch, blink, drink water and, if necessary, communicate with the researchers. The length of the break was limitless and the experimental task resumed only by pressing space bar when the subject felt ready. Such precautions have been taken in order to reduce the test stress and to assure a safe environment for the participant. The breaks have also been useful to keep the participants vigilant through oral communication via the speakers, in order to reduce the amount of alpha waves (that produce noise in the cognitive-related EEG signal), connected with boredom, tiredness and drowsiness.
In the following and final chapter, the EEG analyses for ERPs extraction performed on the data and consequent statistical analyses are presented from the viewpoint of psycholinguistic research in second language acquisition.

# Chapter 6

# Grammar Transfer: Data Analysis and Findings

## 6.1 Behavioral Experiment: Findings

The experimental pilot conducted before the EEG project (see chapter 5 for a description) has been useful for testing the efficacy of Tom's Task, composed by 64 selected and randomized WH-questions among the 288 prepared as stimuli for the EEG task. Before presenting the results of the EEG experiment, an overview of the findings coming from the pilot is presented here.

English native speakers and advanced German speakers of English have been behaviorally tested for understanding their level of comprehension in the interpretation or grammatical and ungrammatical subject/object direct WH-questions. A scoring system has been designed such that each question answered correctly (i.e. with a target interpretation) was equivalent to a point in a scale system of maximum 64 points, divided in two subscores (called "G-score" and "T-score" in the pilot) of 32 points each depending on the level of compatibility of the sentences with German grammar. Wrong answers (not target-like) resulted in no points assigned.

The whole test was timed and consisted of three slides (question - picture - answer sheet) accessible for a total of 8 seconds. The whole test's duration was 26 minutes.

As presented in fig. 6.1, advanced German speakers of English scored at similar levels of English native speakers only in case the grammatical or ungrammatical sentences

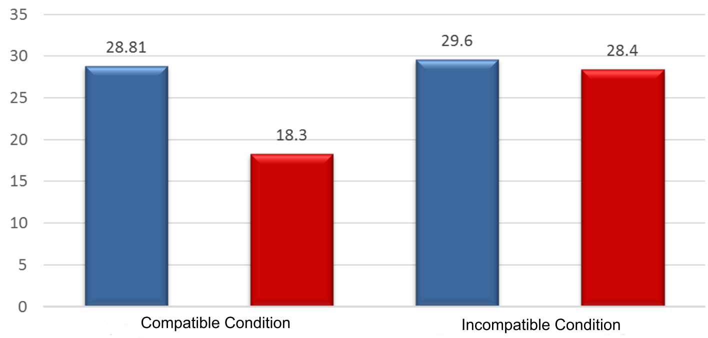



FIGURE 6.1: Tom's Task average scores. English native speakers (in blue) performed equally well in both conditions, while German native speakers (in red) show a lower performance in case of sentences compatible with German grammar.

presented were incompatible with a German parsing system (T-test: $p < .005$). On the other side, they scored significantly lower than English native speakers (T-test: $p < .05$) in case the sentences were compatible with a German syntactic structure. Such a result supposes that in case questions are answered according to their word order, as in English, the answer is target-like. Answering English ungrammatical sentences with an agreement strategy (as in German) leads to a low score due to non-target like answers. All in all, the Tom's Task pilot revealed to be a success. Not only the stimuli have revealed to be adequate for the phenomenon under analysis, but also the grammar transfer due to the competing German - English parsing system in L2 speakers of English took place and its effects are evident in the resulting scores.

## 6.2 EEG Data Analysis and ERPs Extraction

Before introducing the results of the ERP study, it is necessary to give some attention to a crucial step of EEG research: the offline analysis of data and the ERPs extraction procedure.

As previously discussed in chapter 3, a complex data filtering procedure is necessary to extract ERPs from the raw EEG data and to "clean the signal" from unwanted noise. Using a software specific for visual EEG data analysis, all electrodes' channels for each of the 15 recordings (except for vertical and horizontal hoculogram) have been filtered with a high-pass filter at 0.1 Hz and a low-pass filter at 30 Hz, slope 24, to remove any not-cognitive related electrical activity.

Taking advantage of the markers set on the EEG data by the trigger sent when the target stimulus appeared during the recordings, a segmentation procedure allows to subdivide the continuous flow of EEG data in segments, time-locked at the stimulus onset and divided per condition, in a time window starting 200 ms before the stimulus and ending at 1000 ms post stimulus.

Such 288 segments have been afterwards analyzed for ocular correction through a semi-automatic algorithm for the detection of eye blinks and eye movements. By means of visual inspection of segments marked by an artifact rejection procedure, carried out on vertical hoculogram before and afterwards on all the other channels, any segment distorted by noise due to blinks or muscular activity has been removed. Due probably to a systematic malfunction of a few electrodes on one of the caps used for the recordings, five channels (F3, C3, CP1, P1 and Pz) showed generalized low activity in case of six participants. Such channels have been removed from analyses, as they could have contaminated the averaging results lowering the mean area amplitude of functioning channels.

At this point in time mastoid channels have been filtered with a low-pass filter at 15Hz and all the other electrodes have been re-referenced to the average activity of both mastoids in order to reduce abnormal amplitude given by the relative distance of each electrode from a single mastoid reference.

Artifact-free segments, extracted from target stimuli, have been averaged over trials in each experimental condition for each participant. A final baseline correction procedure using the 200 ms pre-stimulus interval assured the same "0" point for the onset of each ERP waveform. A grand-average among participants for each condition has been finally performed for visual inspection of the eventual emergence of ERP components. A clear P600 component is marked in the grey area in fig. 6.2.

For other grand-averaged ERPs waveforms on relevant electrodes, see appendix A.

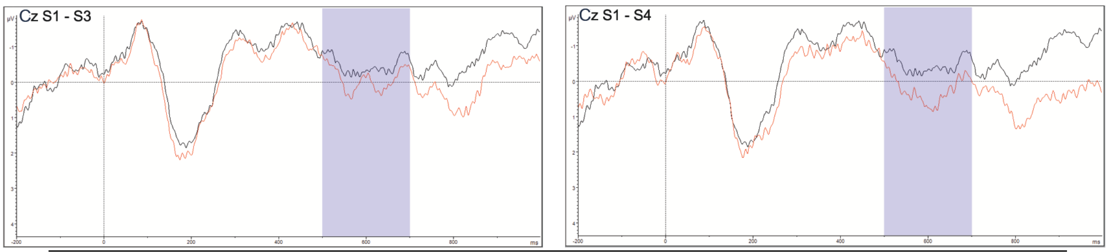



FIGURE 6.2: Grand-averaged ERP waveform on Cz. Control condition is in black. Mean area amplitude of ungrammatical incompatible condition (red waveform on the right) is visually larger than in case of the ungrammatical compatible (red on the left).

## 6.3 Inferential Statistics of ERPs Data

Input for statistical analyses have been the mean area amplitude values of ERP waveforms for each conditions in three crucial time windows: 150-250, 350-450 and 500-700 ms. Based on the visual inspection of the grand-average, the statistical analyses here reported are based on those electrodes in which the difference between conditions have shown partially significant or significant results.

A 2x2 factorial design (grammatical, ungrammatical x compatible, incompatible) has been used for testing the equality of means in relevant centro-parietal electrodes among participants on the software for statistical analysis *SPSS 19.0* (IBM Corporation). The adopted tests have been One-Way ANOVA, used when a single factor (i.e. mean are amplitude, measured in voltage) shows several levels and multiple observations (in this case, the four conditions), and Two-Way Repeated Measures ANOVA, used when the same indipendent sample is tested under different conditions and each trial represents the measurement of the same characteristic (i.e. mean area amplitude) under a different condition.

All the following statistical analyses have been performed on mean area amplitude in the previously mentioned three target time intervals. Here only the significant results, belonging uniquely to the time window 500 - 700 ms, have been reported. No significant results came from the analyses of the other selected time windows.

First of all, One-way ANOVA results have been consistently not significant on all the electrodes under analysis. The only exception regards the mean amplitude difference between condition S1 (grammatical compatible) and S4 (ungrammatical incompatible) where it is possible to see a tendency: on electrodes **P2**, **CP4**, **FC1** and **FC2** mean amplitude difference between S1 and S4 is 1.6 $\mu$V (higher than any other condition) and significance level are smaller ($p \leq 0.2$).

Repeated Measures ANOVA revealed much more interesting results. In the following paragraph, an extended inferential analysis is given for electrode **FCz**, that showed to be the visually most appealing one as far as it concerns syntactic related components (see fig. 6.3). The same procedure described for FCz has been adopted for every recorded electrode. Any statistically interesting finding on other relevant electrodes is reported in a shortened variant, in order to make clear the most relevant aspects of the analysis.

A repeated measures ANOVA correction on electrode FCz (sphericity assumed, Mauchly's

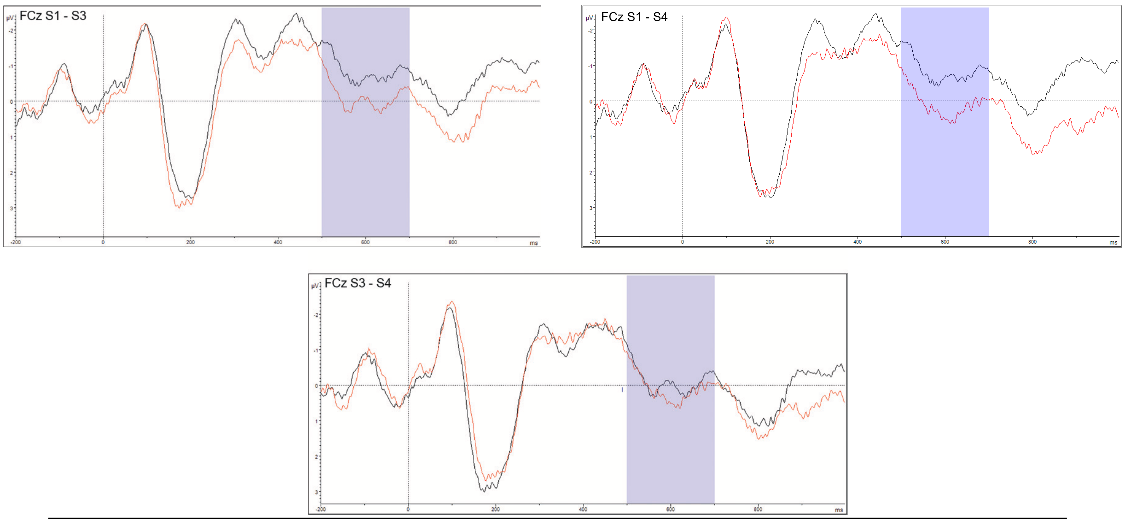



FIGURE 6.3: Grand-averaged ERP waveform on FCz. Control condition is in black. P600 in ungrammatical incompatible condition (red waveform on the up right) is visually larger than in ungrammatical compatible (red on the up left). In the picture below, a comparison between the two ungrammatical conditions (compatible in black).

sphericity test: $p > .05$) determined that the mean voltage area amplitude differed statistically significantly between grammaticality conditions ($F(1, 14) = 7.8$, $p < .05$). Post hoc tests using Bonferroni correction revealed that among the grammaticality factor, grammatical sentences elicited a more negative oriented mean area amplitude compared to ungrammatical ones ($0.15 \pm 0.33$ $\mu$V vs $0.95 \pm 0.56$ $\mu$V, respectively) which was statistically significant ($p = .014$). However, it is not possible to say the same for the comparison among the compatibility factor ($F(1,14) = 3.8$, $p > .05$), whose elicited mean area amplitude between compatible and incompatible sentences ($0.16 \pm 0.47$ $\mu$V vs $0.94 \pm 0.66$ $\mu$V, respectively) revealed to be slightly not significant ($p = .072$) even if similar in trend to the differences in the mean encountered in the grammaticality condition. Furthermore, no significant interaction ($p = .920$) has been found between compatibility and grammaticality as factors.

Besides FCz, grammaticality has revealed to have a significant main effect on electrodes **FC1** ($F(1,14) = 5.2$, $p < .05$), **FC2** ($F(1,14) = 6.1$, $p < .05$) and **C4** ($F(1,14) = 7.8$, $p < .05$), and to show a significant tendency on electrodes **Cz** ($F(1,14) = 3.8$, $p < .08$), **CP4** ($F(1,14) = 4.6$, $p < .06$), **CP2** ($F(1,14) = 3.2$, $p < .1$). Compatibility has revealed to have a significant main effect on **CP4** ($F(1,14) = 5.5$, $p < .05$), **CP2** ($F(1,14) = 5.3$, $p < .05$) and to show a significant tendency on electrodes **Cz** ($F(1,14) = 3.8$, $p < .08$), **CPz** ($F(1,14) = 4.3$, $p < .06$), **P2** ($F(1,14) = 4.3$, $p < .06$), **FC1** ($F(1,14) = 3.2$, $p < .1$), **FC2** ($F(1,14) = 4.0$, $p < .07$) and **C4** ($F(1,14) = 3.8$, $p < .08$).

No significant interaction has been found between compatibility and grammaticality as factors in any of the above mentioned electrode positions.

## 6.4 Discussion of Results and Implications

In the previous section the procedures necessary to extract ERPs from raw EEG data, through segmentation, artifact rejection and filtering, have been explained to the reader. An overview of the statistical analyses performed on the ERP data has shown that nine electrodes gave partial or completely significant results for the study in the time window of 500 - 700 ms.

The findings coming from Two-way Repeated Measures ANOVA show that both grammaticality and compatibility have a main effect on the mean area amplitude of ERPs (see fig. 6.4 for FCz) and, as independent factors, they influence the voltage amplitude of neural components (presence of significant p values). The fact that no electrodes have shown significance levels for both factors at the same time seem to be more a specific issue of the experiment design than a generalized phenomenon. Such a claim is sustained by the fact that the same electrodes that showed high significance levels for a factor (e.g. FC1, FC2, C4 for grammaticality), showed almost significance levels for the other factor (e.g. FC1, FC2, C4 for compatibility) and viceversa.

It is interesting to notice that there is no interaction between compatibility and grammaticality, which behave as independent factors without sorting any influence one on the other. Such a systematic finding is reasonable, as the similarity of a syntactic structure

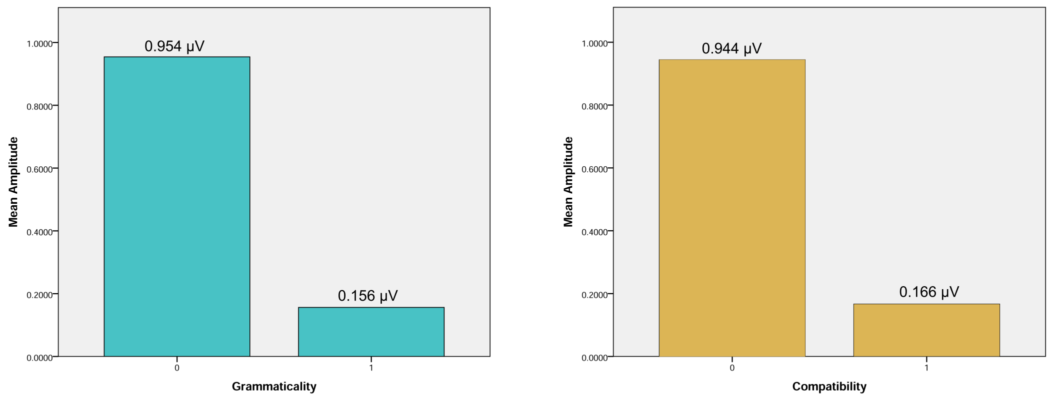



FIGURE 6.4: The mean area amplitude of ERPs waveform depends on the degree of grammaticality and compatibility of the stimulus. Ungrammatical and incompatible stimuli have a higher and more positive mean amplitude (measures in $\mu$V).

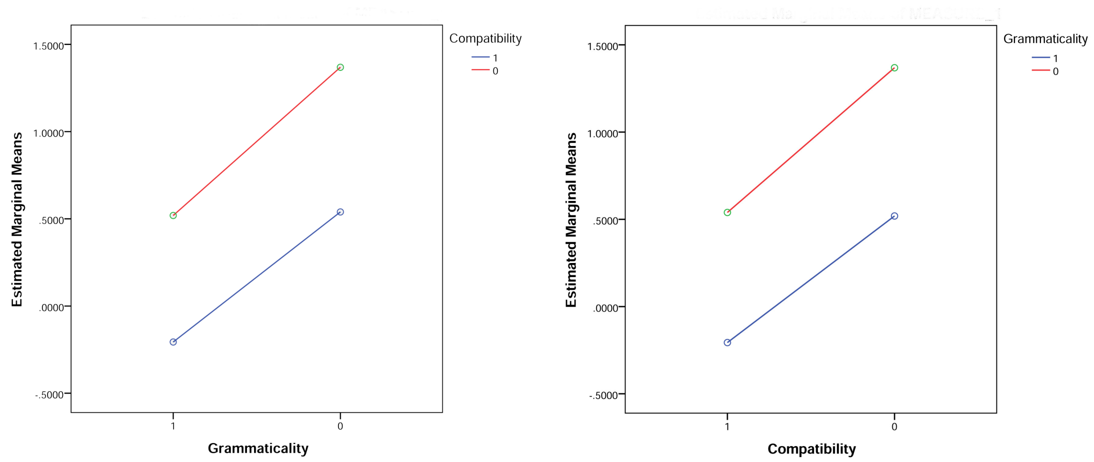



FIGURE 6.5: Grammaticality and compatibility show a similar but not interacting behavior. Ungrammatical and incompatible stimuli have a more positive mean of area amplitude than their grammatical and compatible counterparts.

between two languages is not correlated with the grammaticality of the structure itself. A clear distinction among these two not interacting factors is visible in the two parallel lines represented for FCz in fig. 6.5.

The positive tendency showed by ungrammatical and incompatible stimuli is congruent with a P600 effect (consistent with the area marked grey in the grand-average ERP waveforms of fig. 6.2 and 6.3), that is, a positive waveform that peaks at around 600 ms, i.e. in the time window under analysis.

The lack of significant results or tendencies in both the other time windows (150-250 ms and 350 - 450 ms) excludes the presence of any ELAN, LAN or N400 effect in the stimuli used for the experiment. Unfortunately, the necessity to reject the data recorded from electrodes Pz, P1 and CP1, because of their low activity become evident at the moment of EEG data analysis (as mentioned in section 6.2), has deprived the project from three essential channels in syntactic-related research.

Nevertheless, other centro-parietal electrodes have shown the expected P600 component in presence of the two ungrammatical conditions, i.e. during syntactic violations of agreement between noun and verb in the WH-questions. In particular, the unique result coming from One-Way ANOVA shows a tendency for which the mean amplitude difference between control condition (i.e. grammatical compatible sentence, with a negative mean area amplitude) and target condition (i.e. ungrammatical incompatible with a largely positive mean area amplitude) is consistent.

The results of the study can be summarized by the representation of the differences

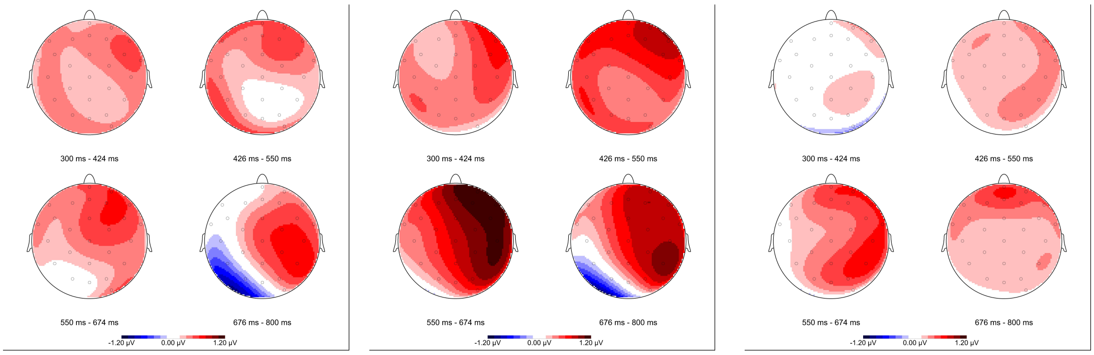



FIGURE 6.6: Difference in voltage distribution on the scalp among conditions. On the left and in the middle, positive voltage due to ungrammaticality compared to control. On the right, difference in compatibility between ungrammatical conditions.

in voltage distribution of grand-averaged ERPs between conditions as in fig. 6.6. Ungrammatical interrogative sentences evoke a P600 component (as the deeper shades of red particularly show in the 550 ms - 674 ms time window) mainly located in the right centro-parietal hemisphere. Such a finding is coherent with previous literature on ERP research on grammatical violations in WH-questions in native and advanced second language speakers (Fiebach et al., 2002, Kaan et al., 2000, Xiang et al., 2014). No ELAN or LAN component has been detected, suggesting that 2L speakers could not present the same great working memory effort due to dislocated objects in WH-questions that other studies found (Epstein et al., 2013, Fiebach et al., 2002).

The second and more relevant finding is the presence of a positive voltage distribution connected with the degree of compatibility: ungrammatical but compatible stimuli evoke a lower positive response compared to ungrammatical incompatible stimuli (difference between the more positive incompatible condition and the lower voltage of the compatible condition is given on the right in fig. 6.6).

### 6.4.1 Considerations for Future Research

The positive voltage distribution evoked by the ungrammatical incompatible condition sustains the main hypothesis of this master thesis research project: in those cases where no interference from a competing grammar system is possible, i.e. when the syntactic structure is not present in the native language, German advanced speakers of English have to rely on their English parsing system. In such a case the neurophysiological response of L2 speakers is similar to the one of native speakers (presence of a consistent P600 evoked by the necessity of performing a process of syntactic reanalysis of the sentence where the violation occurred). On the other side, when the ungrammatical WH-question can be analysed by a German parsing system, even highly proficient L2 speakers of English tend to analyze the sentence with their German parser, consequently reducing the P600 effect due to the (English) ungrammaticality (phenomenon of *grammar transfer*).

Even if the results are only partially significant, it is possible to see a clear tendency in the degree of positivity connected with ungrammatical and incompatible stimuli. Such a study has been configured as a pilot in a field of research still unexplored, that is the meeting area between cognitive psychology and theoretical linguistics. The goal of the study, finding evidence of the neural correlates in support of grammar transfer, has been reached, but there is space for improvements.

First of all, future studies on the topic of language transfer in late bilinguals should consider a higher number of participants to reach statistical levels of significance and not to suffer excessively from the rejection of corrupted data. Furthermore, a ground-breaking study should consider to have a control group, consisting of English native speakers, in order to compare the degree of similarity of event-related potentials between L1 and L2 speakers in case of ungrammatical incompatible WH-questions.

Till now, theoretical linguistics is a quite auto-referential field that has been supported by the evidence collected by experts in applied linguistics. It is time, with the help of techniques coming from the raising field of neuroscience and the methods of cognitive psychology, to shed new light on language phenomena and their complex processes in the human brain.

# Appendix A

# Experiment Material

# List of Stimuli

| WH sing | WH plur | Aux | V | DP sing | DP plur | V | Condition |
|---|---|---|---|---|---|---|---|
| Which animal | | | chases | the dog | | | 1 |
| Which animal | | | hunts | | the dogs | | 1 |
| | Which animals | | follow | the dog | | | 1 |
| | Which animals | | catch | | the dogs | | 1 |
| Which animal | | has | | the dog | | chased | 1 |
| Which animal | | have | | | the dogs | hunted | 1 |
| | Which animals | has | | the dog | | followed | 1 |
| | Which animals | have | | | the dogs | caught | 1 |
| Which animal | | | follows | the cat | | | 1 |
| Which animal | | | catches | | the cats | | 1 |
| | Which animals | | chase | the cat | | | 1 |
| | Which animals | | hunt | | the cats | | 1 |
| Which animal | | has | | the cat | | followed | 1 |
| Which animal | | have | | | the cats | caught | 1 |
| | Which animals | has | | the cat | | chased | 1 |
| | Which animals | have | | | the cats | hunted | 1 |
| Which animal | | | hunts | the fox | | | 1 |
| Which animal | | | follows | | the foxes | | 1 |
| | Which animals | | catch | the fox | | | 1 |
| | Which animals | | chase | | the foxes | | 1 |
| Which animal | | has | | the fox | | hunted | 1 |
| Which animal | | have | | | the foxes | followed | 1 |
| | Which animals | has | | the fox | | caught | 1 |
| | Which animals | have | | | the foxes | chased | 1 |
| Which animal | | | catches | the bird | | | 1 |
| Which animal | | | chases | | the birds | | 1 |
| | Which animals | | hunt | the bird | | | 1 |
| | Which animals | | follow | | the birds | | 1 |
| Which animal | | has | | the bird | | caught | 1 |
| Which animal | | have | | | the birds | chased | 1 |
| | Which animals | has | | the bird | | hunted | 1 |
| | Which animals | have | | | the birds | followed | 1 |
| Which animal | | | chases | the elephant | | | 1 |
| Which animal | | | catches | | the elephants | | 1 |
| | Which animals | | follow | the elephant | | | 1 |
| | Which animals | | hunt | | the elephants | | 1 |

| **WH sing** | **WH plur** | **Aux** | **V** | **DP sing** | **DP plur** | **V** | **Condition** |
|---|---|---|---|---|---|---|---|
| Which animal | | has | | the elephant | | chased | 1 |
| Which animal | | have | | | the elephants | caught | 1 |
| | Which animals | has | | the elephant | | followed | 1 |
| | Which animals | have | | | the elephants | hunted | 1 |
| Which animal | | | follows | the cow | | | 1 |
| Which animal | | | chases | | the cows | | 1 |
| | Which animals | | catch | the cow | | | 1 |
| | Which animals | | hunt | | the cows | | 1 |
| Which animal | | has | | the cow | | followed | 1 |
| Which animal | | have | | | the cows | chased | 1 |
| | Which animals | has | | the cow | | caught | 1 |
| | Which animals | have | | | the cows | hunted | 1 |
| Which animal | | | hunts | the bear | | | 1 |
| Which animal | | | catches | | the bears | | 1 |
| | Which animals | | follow | the bear | | | 1 |
| | Which animals | | chase | | the bears | | 1 |
| Which animal | | has | | the bear | | hunted | 1 |
| Which animal | | have | | | the bears | caught | 1 |
| | Which animals | has | | the bear | | followed | 1 |
| | Which animals | have | | | the bears | chased | 1 |
| Which animal | | | catches | the horse | | | 1 |
| Which animal | | | hunts | | the horses | | 1 |
| | Which animals | | chase | the horse | | | 1 |
| | Which animals | | follow | | the horses | | 1 |
| Which animal | | has | | the horse | | caught | 1 |
| Which animal | | have | | | the horses | hunted | 1 |
| | Which animals | has | | the horse | | chased | 1 |
| | Which animals | have | | | the horses | followed | 1 |
| Which animal | | | chases | the lion | | | 1 |
| Which animal | | | follows | | the lions | | 1 |
| | Which animals | | hunt | the lion | | | 1 |
| | Which animals | | catch | | the lions | | 1 |
| Which animal | | has | | the lion | | chased | 1 |
| Which animal | | have | | | the lions | followed | 1 |
| | Which animals | has | | the lion | | hunted | 1 |
| | Which animals | have | | | the lions | caught | 1 |

| WH sing | WH plur | Aux | V | DP sing | DP plur | V | Condition |
|---|---|---|---|---|---|---|---|
| Which animal | | does | | the dog | | chase | 2 |
| Which animal | | do | | | the dogs | hunt | 2 |
| | Which animals | does | | the dog | | follow | 2 |
| | Which animals | do | | | the dogs | catch | 2 |
| Which animal | | has | chased | the dog | | | 2 |
| Which animal | | has | hunted | | the dogs | | 2 |
| | Which animals | have | followed | the dog | | | 2 |
| | Which animals | have | caught | | the dogs | | 2 |
| Which animal | | does | | the cat | | follow | 2 |
| Which animal | | do | | | the cats | catch | 2 |
| | Which animals | does | | the cat | | chase | 2 |
| | Which animals | do | | | the cats | hunt | 2 |
| Which animal | | has | followed | the cat | | | 2 |
| Which animal | | has | caught | | the cats | | 2 |
| | Which animals | have | chased | the cat | | | 2 |
| | Which animals | have | hunted | | the cats | | 2 |
| Which animal | | does | | the fox | | hunt | 2 |
| Which animal | | do | | | the foxes | follow | 2 |
| | Which animals | does | | the fox | | catch | 2 |
| | Which animals | do | | | the foxes | chase | 2 |
| Which animal | | has | hunted | the fox | | | 2 |
| Which animal | | has | followed | | the foxes | | 2 |
| | Which animals | have | caught | the fox | | | 2 |
| | Which animals | have | chased | | the foxes | | 2 |
| Which animal | | does | | the bird | | catch | 2 |
| Which animal | | do | | | the birds | chase | 2 |
| | Which animals | does | | the bird | | hunt | 2 |
| | Which animals | do | | | the birds | follow | 2 |
| Which animal | | has | caught | the bird | | | 2 |
| Which animal | | has | chased | | the birds | | 2 |
| | Which animals | have | hunted | the bird | | | 2 |
| | Which animals | have | followed | | the birds | | 2 |
| Which animal | | does | | the elephant | | chase | 2 |
| Which animal | | do | | | the elephants | catch | 2 |
| | Which animals | does | | the elephant | | follow | 2 |
| | Which animals | do | | | the elephants | hunt | 2 |

| **WH sing** | **WH plur** | **Aux** | **V** | **DP sing** | **DP plur** | **V** | **Condition** |
|---|---|---|---|---|---|---|---|
| Which animal | | has | chased | the elephant | | | 2 |
| Which animal | | has | caught | | the elephants | | 2 |
| | Which animals | have | followed | the elephant | | | 2 |
| | Which animals | have | hunted | | the elephants | | 2 |
| Which animal | | does | | the cow | | chase | 2 |
| Which animal | | do | | | the cows | follow | 2 |
| | Which animals | does | | the cow | | hunt | 2 |
| | Which animals | do | | | the cows | catch | 2 |
| Which animal | | has | chased | the cow | | | 2 |
| Which animal | | has | followed | | the cows | | 2 |
| | Which animals | have | hunted | the cow | | | 2 |
| | Which animals | have | caught | | the cows | | 2 |
| Which animal | | does | | the bear | | catch | 2 |
| Which animal | | do | | | the bears | hunt | 2 |
| | Which animals | does | | the bear | | chase | 2 |
| | Which animals | do | | | the bears | follow | 2 |
| Which animal | | has | caught | the bear | | | 2 |
| Which animal | | has | hunted | | the bears | | 2 |
| | Which animals | have | chased | the bear | | | 2 |
| | Which animals | have | followed | | the bears | | 2 |
| Which animal | | does | | the horse | | hunt | 2 |
| Which animal | | do | | | the horses | catch | 2 |
| | Which animals | does | | the horse | | follow | 2 |
| | Which animals | do | | | the horses | chase | 2 |
| Which animal | | has | hunted | the horse | | | 2 |
| Which animal | | has | caught | | the horses | | 2 |
| | Which animals | have | followed | the horse | | | 2 |
| | Which animals | have | chased | | the horses | | 2 |
| Which animal | | does | | the lion | | follow | 2 |
| Which animal | | do | | | the lions | chase | 2 |
| | Which animals | does | | the lion | | catch | 2 |
| | Which animals | do | | | the lions | hunt | 2 |
| Which animal | | has | followed | the lion | | | 2 |
| Which animal | | has | chased | | the lions | | 2 |
| | Which animals | have | caught | the lion | | | 2 |
| | Which animals | have | hunted | | the lions | | 2 |

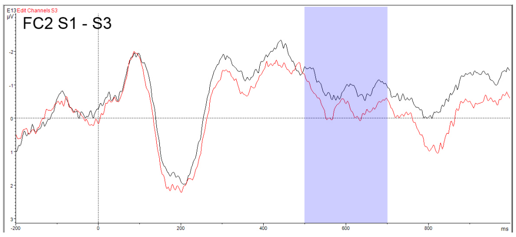
| WH sing | WH plur | Aux | V | DP sing | DP plur | V | Condition |
|---|---|---|---|---|---|---|---|
| Which animal | | | chase | the dog | | | 3 |
| Which animal | | | follow | | the dogs | | 3 |
| | Which animals | | hunts | the dog | | | 3 |
| | Which animals | | catches | | the dogs | | 3 |
| Which animal | | have | | the dog | | chased | 3 |
| Which animal | | has | | | the dogs | followed | 3 |
| | Which animals | have | | the dog | | hunted | 3 |
| | Which animals | has | | | the dogs | caught | 3 |
| Which animal | | | catch | the cat | | | 3 |
| Which animal | | | hunt | | the cats | | 3 |
| | Which animals | | chases | the cat | | | 3 |
| | Which animals | | follows | | the cats | | 3 |
| Which animal | | have | | the cat | | caught | 3 |
| Which animal | | has | | | the cats | hunted | 3 |
| | Which animals | have | | the cat | | chased | 3 |
| | Which animals | has | | | the cats | followed | 3 |
| Which animal | | | hunt | the fox | | | 3 |
| Which animal | | | catch | | the foxes | | 3 |
| | Which animals | | follows | the fox | | | 3 |
| | Which animals | | chases | | the foxes | | 3 |
| Which animal | | have | | the fox | | hunted | 3 |
| Which animal | | has | | | the foxes | caught | 3 |
| | Which animals | have | | the fox | | followed | 3 |
| | Which animals | has | | | the foxes | chased | 3 |
| Which animal | | | follow | the bird | | | 3 |
| Which animal | | | chase | | the birds | | 3 |
| | Which animals | | catches | the bird | | | 3 |
| | Which animals | | hunts | | the birds | | 3 |
| Which animal | | have | | the bird | | followed | 3 |
| Which animal | | has | | | the birds | chased | 3 |
| | Which animals | have | | the bird | | caught | 3 |
| | Which animals | has | | | the birds | hunted | 3 |
| Which animal | | | catch | the elephant | | | 3 |
| Which animal | | | chase | | the elephants | | 3 |
| | Which animals | | hunts | the elephant | | | 3 |
| | Which animals | | follows | | the elephants | | 3 |

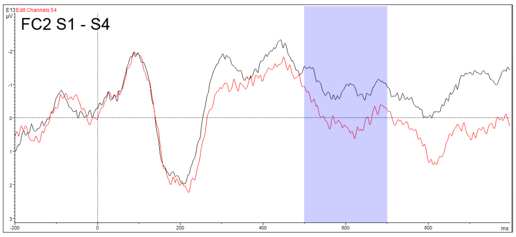
| WH sing | WH plur | Aux | V | DP sing | DP plur | V | Condition |
|---|---|---|---|---|---|---|---|
| Which animal | | have | | the elephant | | caught | 3 |
| Which animal | | has | | | the elephants | chased | 3 |
| | Which animals | have | | the elephant | | hunted | 3 |
| | Which animals | has | | | the elephants | followed | 3 |
| Which animal | | | chase | the cow | | | 3 |
| Which animal | | | catch | | the cows | | 3 |
| | Which animals | | follows | the cow | | | 3 |
| | Which animals | | hunts | | the cows | | 3 |
| Which animal | | have | | the cow | | chased | 3 |
| Which animal | | has | | | the cows | caught | 3 |
| | Which animals | have | | the cow | | followed | 3 |
| | Which animals | has | | | the cows | hunted | 3 |
| Which animal | | | hunt | the bear | | | 3 |
| Which animal | | | follow | | the bears | | 3 |
| | Which animals | | catches | the bear | | | 3 |
| | Which animals | | chases | | the bears | | 3 |
| Which animal | | have | | the bear | | hunted | 3 |
| Which animal | | has | | | the bears | followed | 3 |
| | Which animals | have | | the bear | | caught | 3 |
| | Which animals | has | | | the bears | chased | 3 |
| Which animal | | | follow | the horse | | | 3 |
| Which animal | | | catch | | the horses | | 3 |
| | Which animals | | chases | the horse | | | 3 |
| | Which animals | | hunts | | the horses | | 3 |
| Which animal | | have | | the horse | | followed | 3 |
| Which animal | | has | | | the horses | caught | 3 |
| | Which animals | have | | the horse | | chased | 3 |
| | Which animals | has | | | the horses | hunted | 3 |
| Which animal | | | chase | the lion | | | 3 |
| Which animal | | | hunt | | the lions | | 3 |
| | Which animals | | follows | the lion | | | 3 |
| | Which animals | | catches | | the lions | | 3 |
| Which animal | | have | | the lion | | chased | 3 |
| Which animal | | has | | | the lions | hunted | 3 |
| | Which animals | have | | the lion | | followed | 3 |
| | Which animals | has | | | the lions | caught | 3 |

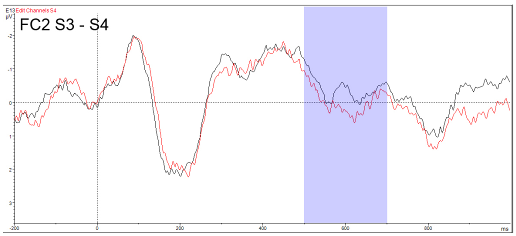
| WH sing | WH plur | Aux | V | DP sing | DP plur | V | Condition |
|---|---|---|---|---|---|---|---|
| Which animal | | do | | the dog | | chase | 4 |
| Which animal | | does | | | the dogs | catch | 4 |
| | Which animals | do | | the dog | | follow | 4 |
| | Which animals | does | | | the dogs | hunt | 4 |
| Which animal | | have | chased | the dog | | | 4 |
| Which animal | | have | caught | | the dogs | | 4 |
| | Which animals | has | followed | the dog | | | 4 |
| | Which animals | has | hunted | | the dogs | | 4 |
| Which animal | | do | | the cat | | follow | 4 |
| Which animal | | does | | | the cats | chase | 4 |
| | Which animals | do | | the cat | | catch | 4 |
| | Which animals | does | | | the cats | hunt | 4 |
| Which animal | | have | followed | the cat | | | 4 |
| Which animal | | have | chased | | the cats | | 4 |
| | Which animals | has | caught | the cat | | | 4 |
| | Which animals | has | hunted | | the cats | | 4 |
| Which animal | | do | | the fox | | catch | 4 |
| Which animal | | does | | | the foxes | hunt | 4 |
| | Which animals | do | | the fox | | chase | 4 |
| | Which animals | does | | | the foxes | follow | 4 |
| Which animal | | have | caught | the fox | | | 4 |
| Which animal | | have | hunted | | the foxes | | 4 |
| | Which animals | has | chased | the fox | | | 4 |
| | Which animals | has | followed | | the foxes | | 4 |
| Which animal | | do | | the bird | | hunt | 4 |
| Which animal | | does | | | the birds | catch | 4 |
| | Which animals | do | | the bird | | follow | 4 |
| | Which animals | does | | | the birds | chase | 4 |
| Which animal | | have | hunted | the bird | | | 4 |
| Which animal | | have | caught | | the birds | | 4 |
| | Which animals | has | followed | the bird | | | 4 |
| | Which animals | has | chased | | the birds | | 4 |
| Which animal | | do | | the elephant | | chase | 4 |
| Which animal | | does | | | the elephants | follow | 4 |
| | Which animals | do | | the elephant | | hunt | 4 |
| | Which animals | does | | | the elephants | catch | 4 |

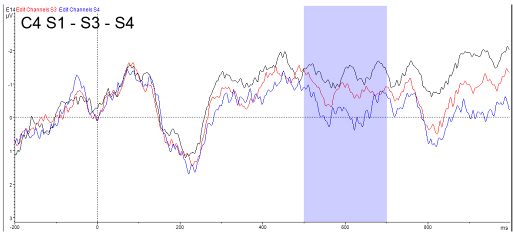
| WH sing | WH plur | Aux | V | DP sing | DP plur | V | Condition |
|---|---|---|---|---|---|---|---|
| Which animal | | have | chased | the elephant | | | 4 |
| Which animal | | have | followed | | the elephants | | 4 |
| | Which animals | has | hunted | the elephant | | | 4 |
| | Which animals | has | caught | | the elephants | | 4 |
| Which animal | | do | | the cow | | chase | 4 |
| Which animal | | does | | | the cows | hunt | 4 |
| | Which animals | do | | the cow | | follow | 4 |
| | Which animals | does | | | the cows | catch | 4 |
| Which animal | | have | chased | the cow | | | 4 |
| Which animal | | have | hunted | | the cows | | 4 |
| | Which animals | has | followed | the cow | | | 4 |
| | Which animals | has | caught | | the cows | | 4 |
| Which animal | | do | | the bear | | follow | 4 |
| Which animal | | does | | | the bears | catch | 4 |
| | Which animals | do | | the bear | | chase | 4 |
| | Which animals | does | | | the bears | hunt | 4 |
| Which animal | | have | followed | the bear | | | 4 |
| Which animal | | have | caught | | the bears | | 4 |
| | Which animals | has | chased | the bear | | | 4 |
| | Which animals | has | hunted | | the bears | | 4 |
| Which animal | | do | | the horse | | hunt | 4 |
| Which animal | | does | | | the horses | follow | 4 |
| | Which animals | do | | the horse | | catch | 4 |
| | Which animals | does | | | the horses | chase | 4 |
| Which animal | | have | hunted | the horse | | | 4 |
| Which animal | | have | followed | | the horses | | 4 |
| | Which animals | has | caught | the horse | | | 4 |
| | Which animals | has | chased | | the horses | | 4 |
| Which animal | | do | | the lion | | catch | 4 |
| Which animal | | does | | | the lions | chase | 4 |
| | Which animals | do | | the lion | | hunt | 4 |
| | Which animals | does | | | the lions | follow | 4 |
| Which animal | | have | caught | the lion | | | 4 |
| Which animal | | have | chased | | the lions | | 4 |
| | Which animals | has | hunted | the lion | | | 4 |
| | Which animals | has | followed | | the lions | | 4 |

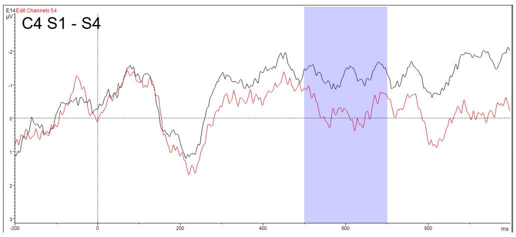
## Grand-Averaged ERPs

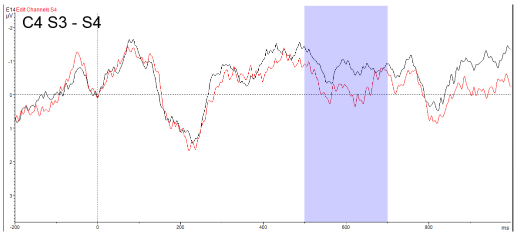


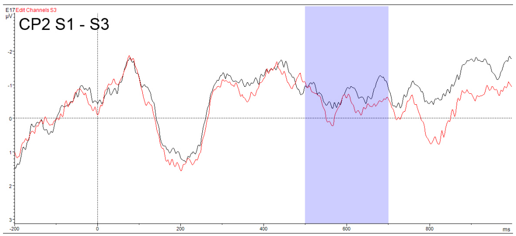



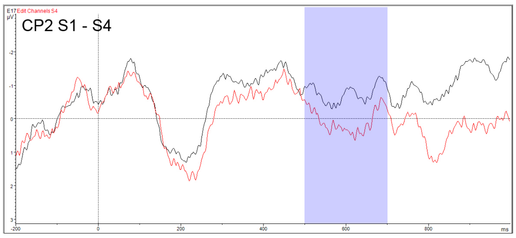



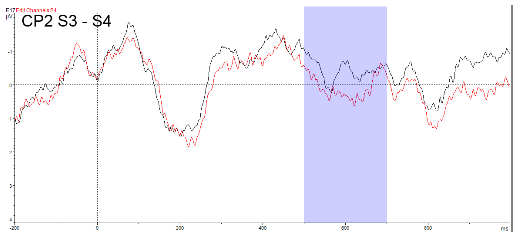



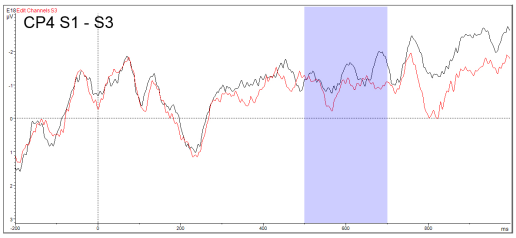



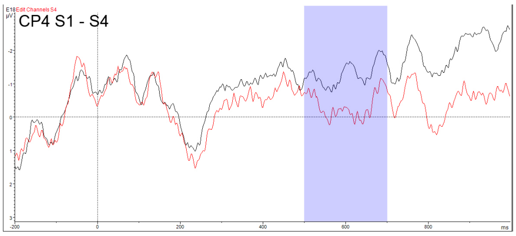

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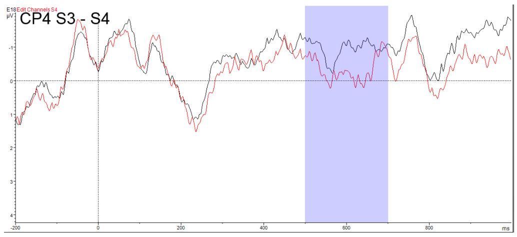
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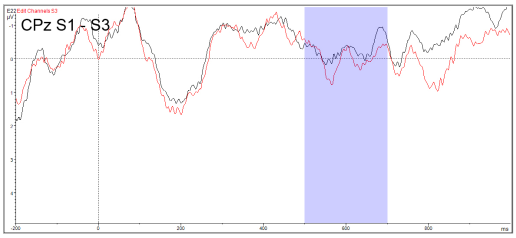
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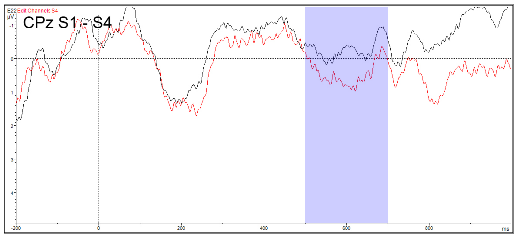
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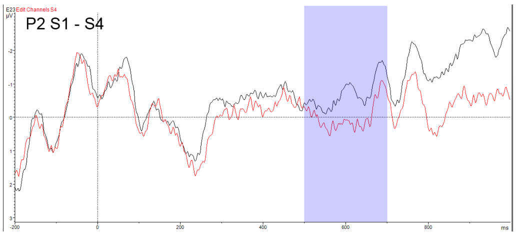
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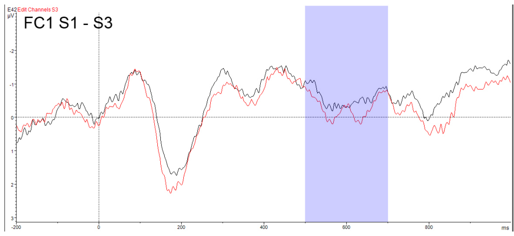
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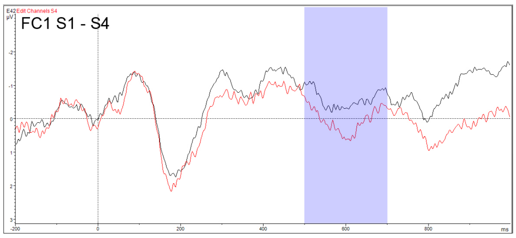
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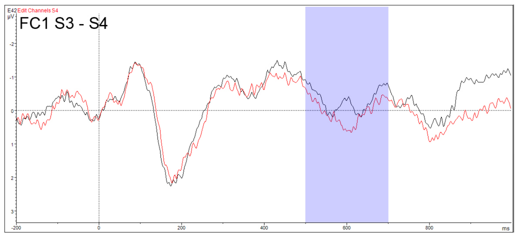
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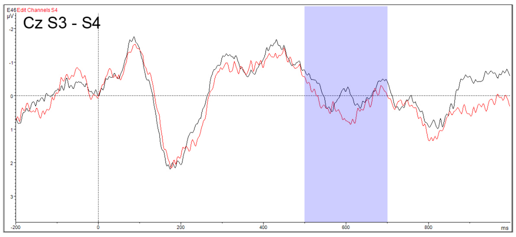
Cz S3 - S4

## Informed Consent

universität wien

MEi:CogSci Middle European Interdisciplinary Master Programme in Cognitive Science

**Department of Psychology, EEG Scan Unit**
**University of Vienna**

### INFORMED CONSENT FORM
### FOR RESEARCH PARTICIPANTS

The aim of this form is to facilitate informed consent by communicating with participants in a language that they can understand.

**Purpose of the Study.** The purpose of this study is to investigate the brain activity correlated with the comprehension and interpretation of English questions by German native speakers.

**What will the study involve?** The study involves an EEG (Electroencephalogramm) experiment.
You will wear a special hat covered with 62 electrodes.
Additional 5 electrodes will be put around your eyes. The application of the electrodes might cause small skin irritation or you might feel a small scratch on the head. EEG is not invasive and you will not explore further pain. The application is furthermore without any short-term or long-term risk for your health.
The participation is voluntary. The whole procedure will be explained beforehand of the experiment.
At any time of the experiment there is the option to withdraw your participation. Furthermore you have the option to withdraw your consent to the process of data analyzes (even if you agreed to participate in the beginning).

**Will your participation in the study be kept confidential?** Yes! Your name will be substitute with a code and the data will be randomized. There will be no connection to your personal information.

**What will happen to the information which you give?** The data will be kept confidential for the duration of the study and for further ongoing data collection and data analyzes.

**What will happen to the results?** The results will be presented in lectures within the Middle-European Cognitive Science Programme network. They will be seen by the researcher's supervisors and research colleagues within the department of Psychology and Philosophy. This study is part of a master thesis project and it could eventually be published in a research paper.

**What are the possible disadvantages of taking part?** There are no disadvantages of participating in this study.

**Any further queries?** If you need any further information, you can contact the researcher under the following address:

stellaserena.grosso@gmail.com
+43 676 6465612

universität wien

MEi:CogSci Middle European Interdisciplinary Master Programme in Cognitive Science

# Informed Consent Form

Name: ________________________________________________________________

Age: _____

Gender: F M

Native Language(s): ________________________________________________________________

E-mail (for further contact, if necessary): _______________________________________________________

**I** ___________________________________________ agree to participate in Stella Grosso's research study.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that anonymity will be ensured in the write-up by disguising my identity.

I understand that disguised extracts from my interview may be quoted in the thesis and any subsequent publications if I give permission below:

Signature _____________________________________ Date __________________

## Appendix B

# Abstract

UNIVERSITY OF VIENNA

Master of Science in Cognitive Science

# *Abstract*

**Which animal chases the dog? Neural correlates of syntactic transfer in German - English late bilinguals: an ERP study**

Stella Serena Grosso

Recent research in the field of second language acquisition found evidence of a systematic interpretational mismatch in the comprehension of English subject interrogative sentences between German learners of English and native speakers. The phenomenon does not disappear with increased levels of proficiency, supporting the Full Transfer Full Access hypothesis: because of the identical surface linear order between English and German subject questions, second language learners of English tend to rely on the parsing system of their first language for sentence comprehension, leading to non-target interpretations.

In the following study, 15 German highly proficient speakers of English have undertaken an English interpretation task while being recorded with electroencephalography, in the attempt to find evidence of neural correlates underlying the processing of grammaticality violations of interrogative questions in conjunction with grammar transfer.

ERPs (event-related potentials) have revealed a higher P600 component (connected with neural processes of reanalysis of syntactic violations) for ungrammatical sentences that are not compatible with a German parsing system compared to compatible and grammatical interrogative sentences. Statistical analysis confirmed that both grammaticality and compatibility as independent factors influence the amplitude of neural components associated with syntactic reanalysis.

Those findings support the hypothesis that highly proficient German speakers process grammar violations in a way similar to native speakers (as confirmed by the presence of P600), except when there is the possibility to switch to their native parsing system. In that case, the neural effort for processes of reanalysis of English syntactic violations is reduced by the activation of a competing grammar system.

UNIVERSITÄT WIEN

Master of Science in Cognitive Science

# *Abstract*

**Welches Tier jagt den Hund? Neuronale Korrelate syntaktischen Transfers in Deutsch-Englischen Spätbilingualen: eine ERP-Studie**

Stella Serena Grosso

Aktuelle Forschungen im Bereich des Zweitspracherwerbs konnten eine systematische Interpretationsinkongruenz im Verständnis von englischen Subjekt-Fragesätzen zwischen deutschsprachigen Englischlernenden und L1-Englischsprachigen belegen. Das Phänomen verschwindet nicht mit wachsendem Kenntnisstand der L2-Lernenden, was die Full Transfer Full Access Hypothese unterstützt: Aufgrund der identischen, linearen Oberflächenstruktur zwischen englischen und deutschen Subjektfragen tendieren Deutschsprachige mit L2 Englisch dazu, sich für die Interpretation solcher Sätze auf das Syntaxsystem ihrer Erstsprache zu verlassen und dadurch die Sätze nicht nach den tatsächlichen Syntaxregeln des Englischen zu entschlüsseln.
In der folgenden Studie hatten 15 TeilnehmerInnen mit L1 Deutsch und einer hohen L2-Kompetenz in Englisch eine englischsprachige Interpretationsaufgabe zu lösen, während ihre Gehirnaktivität mit Hilfe von Elektroenzephalographie gemessen wurde. Das Ziel der Studie war, Indizien für neuronale Korrelate zu finden, die der Verarbeitung von grammatikalischen Verstößen bei Interrogativfragen in Verbindung mit einem Grammatiktransfer zwischen Erst- und Zweitsprache zugrunde liegen. EKPs ("Ereigniskorrelierte Potentiale" oder engl. "Event-Related Potentials", ERP) konnten nachweisen, dass bei agrammatischen Sätzen, die nicht mit dem deutschsprachigen Syntaxsystem übereinstimmen, ein höherer P600 Komponent (steht im Zusammenhang mit Vorgängen bei der Reanalyse von Syntaxverletzungen) auftritt als bei Sätzen, die im deutschsprachigen System kompatibel sind, oder bei grammatischen Sätzen. Statistische Analysen bestätigten, dass sowohl Grammatikalität als auch Kompatibilität unabhängige Faktoren darstellen, welche die Amplitude der neuronalen Komponenten, die mit der syntaktischen Reanalyse assoziiert werden, beeinflussen.

Diese Ergebnisse stützen die Hypothese, dass L1-Deutschsprachige mit einer hohen L2-Kompetenz in Englisch Grammatikverstöße in einer ähnlichen Weise wie L1 Sprecher verarbeiten (bestätigt durch die Präsenz des P600-Komponenten), ausgenommen es besteht die Möglichkeit auf das Syntaxsystem der Erstsprache zurückzugreifen. In einem solchen Fall wird der neuronale Aufwand für den Prozess der Reanalyse der englischen Syntaxverletzungen durch die Aktivierung des konkurrierenden Grammatiksystems reduziert.

Appendix C

# Curriculum Vitae

# STELLA SERENA GROSSO

## INTEREST

Gain fundamental experience for developing further research in the field of Cognitive Neuroscience of Language.

## WORK EXPERIENCE

*11/2011-06/2012* **Italian Language Assistant**

*Amity Institute, USA*

Teaching Italian Language and Culture as intern in an experimental program for early bilingualism in North-American children

Employer: B. Franklin Magnet School, 1610 Lake Street, Glendale (CA), United States of America

*07/2011-08/2011* **Italian Language Teacher**

*Italian Cultural Center, Moscow*

Teaching Italian grammar and culture in a Russian Institute for Italian Studies

Employer: Ital'janskij Centr Kultury, 20 Butyrskij Val, Moscow, Russian Federation

## EDUCATION

*10/2012-09/2014* **Joint M.Sc. in Cognitive Science**

*University of Vienna, Austria*

Thesis: *Which Animal Chases the Dog? Neural Correlates of Syntactic Transfer in German-English late Bilinguals: An ERP Study*

Description: This thesis is the result of an experimental attempt to find support of the Grammar Transfer hypothesis within the field of Cognitive Neuroscience. The study explores the presence of neurophysiological correlates of syntactic transfer in German speakers while comprehending English sentences.

Advisors: Ass. Prof. Susanne Reiterer & Prof. Marijan Palmovic

Final Grade: -

*08/2008-10/2011* **B.A. in Science of Language**

*"Ca' Foscari" University Venice, Italy*

Thesis: *Russian Possessor - A DP Analysis in a Comparative View*

Description: This thesis focused on an innovative theoretical description of Russian genitive case following the generative framework.

Advisors: Prof. Iliana Krapova

Final Grade: 110 cum Laude / 110

## PUBLICATIONS

*June 2014* **Which animal chases the dog? Neural Correlates of Language Transfer in German - English late Bilinguals**

Grosso, S.S. (2014) in Proceedings of the MEi:CogSci Conference 2014, Jagiellonian University, Kraków on 12 June to 14 June. Comenius University in Bratislava. (ISBN: 978-80-223-3622-2)

*June 2013* **Language Aptitude: Evidence from Audio-vocal Speech Imitation and Grammar Sensitivity**

Grosso, S.S. (2013) in Proceedings of the MEi:CogSci Conference 2013, Eötvös Loránd University, Budapest on 20 June to 22 June. Comenius University in Bratislava. (ISBN: 978-80-223-3436-5)

## PRESENTATIONS

*July 2014* **Neural Correlates of Syntactic Transfer in German - English late Bilinguals: An EEG Study**

Grosso, S.S., Rankin, T., Reiterer, S. (2014) Poster presented at "Language, MUSIC and the Brain" Workshop on July 2, 2014, Vienna, Austria.

## LINGUISTIC SKILLS

*Mothertongue* Italian

| | Listening | Reading | Spoken Production | Spoken Interaction | Writing |
|---|---|---|---|---|---|
| *English* | C1* | C1 | C1 | C1 | C1 |
| *Russian* | B1 | B1 | A2 | A2 | B1 |
| *German* | B1 | A2 | A2 | A2 | B1 |

*Following the European Framework for Language Proficiency

*Certificates* IELTS Certificate (Academic) General Score: 7.5 / 9

## COMPUTER SKILLS

*Word Processors* Office Word, LaTeX, OpenOffice

*Data Analysis* SPSS, Office Excel

*Experiment Setup* PYTHON, E-Prime, Brain Products EEG Visual Recorder and EEG Analyzer

*Digital Processing* Adobe Photoshop, Adobe Illustrator

*Multimedia* Office Power Point, Prezi

## TECHNICAL SKILLS

*EEG Research* 2/1014 - 07/2014 · Conduction of psycholinguistic EEG Project at the Psychology Department of Vienna University with ERP (event related potential) technique.

10/1013 - 02/2014 · Conduction of EEG Project on Visual Perception at the Educational and Rehabilitation Department of Zagreb University with ERP technique.

*Education* Experience as language assistant and teacher to adults (Moscow, 2011) and children (Glendale, 2011-2012). Private tuition teacher.

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