ERP CORRELATES OF WORD ORDER AND MORPHOSYNTACTIC PHENOMENA IN ADULT NATIVE SPEAKERS AND SECOND LANGUAGE LEARNERS OF ENGLISH

By

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Abstract

ERP CORRELATES TO WORD ORDER AND MORPHOSYNTACTIC PHENOMENA IN ADULT NATIVE SPEAKERS AND L2 LEARNERS OF ENGLISH

by

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This study examined Event-Related Potential (ERP) responses to syntactic and inflectional violations in L2 learners of English (Spanish L1) who differ in proficiency and age of acquisition. L2 groups included high-proficiency early (HPE) learners, acquiring English before age 8, high-proficiency late (HPL) learners, acquiring English after age 8, and low-proficiency (LP) learners. A native English speaking control group was included. ERP responses were recorded over 64 channels while subjects listened to sentences and performed a grammaticality judgment task. Stimuli were present progressive sentences, which included violations of word order (NOT-IS) and verbal inflection (missing *–ING*).

For monolinguals, Word Order (WO) violations elicited an Early Left Anterior Negativity (ELAN) response, which is thought to reflect processes of first-pass structure building based upon word category information. Monolinguals showed a LAN response (250-450 ms), generally associated with morphosyntactic analysis. Negativities in both latency ranges were fronto-centrally distributed. HPE learners showed increased negativity at left fronto-temporal sites in the LAN latency range. HPE learners showed no increased negativity in either latency range to WO violations. Late centro-parietal positivity (P600) is associated with controlled processes of syntactic reanalysis, repair, and integration. P600 effects were observed in Monolinguals. In HPE and HPL groups this effect occurred later (between 700-800 ms). No P600 effect was seen in the LP group.

Inflection violations elicited a LAN followed by later, weaker P600 effects in monolinguals. HPE learners showed increased temporo-parietal negativity that did not reach significance at frontal sites. P600 effects occurred in half of the HPE learners and were absent in HPL and LP groups.

Similar accuracy rates in monolinguals and high-proficiency groups but slower reaction times for HPL learners were found. These results suggest differential processing for syntactic and inflectional violations in monolinguals. While ERP patterns show that processing in later L2 learners differs from native speakers, the underlying grammatical knowledge of word order and verb inflection is the same in both early and late high-proficiency learners and native speakers. These findings suggest maturation effects for processing syntactic and inflectional information, but that access to abstract grammatical knowledge is not affected by age of acquisition.

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Chapter 1: Introduction

1.1 General Overview

The goal of Second Language Acquisition (SLA) Theory is to characterize the process of learning language beyond the first or native language. While it is a relatively new field, much behavioral data has been gathered in the past 20 years which has allowed us to come to an initial characterization of this process. Two questions in particular have been at the forefront of SLA research: 1. How does SLA resemble (and how does it differ from) native language acquisition in the child? and 2. How does the endstate of SLA (ultimate attainment) resemble (and differ from) the endstate of first language acquisition? Much SLA research is based on the hypothesis that the course of acquisition, and therefore the developmental errors attested during acquisition, can be explained in terms of the underlying representation, i.e. the interlanguage grammar, which is thought to differ in some fundamental ways from the representation of the grammar of the adult native speaker (Cook 1989; White, 1989). However, even when investigating the same commonly attested L2 errors, researchers have often come to different conclusions as to the source of these errors. These perspectives will be discussed later in the chapter.

With the development of new non-invasive brain imaging methods, such as fMRI and event-related potential (ERP) recording, it has now become possible to address questions of functional neural organization of language. These methods have only recently been used to investigate the functional organization of language in the context of bilingualism. Here, as in the behavioral SLA studies, different conclusions have been reached about whether first and second languages are processed in similar or in different ways in the brain. The reasons for these different conclusions stem from various methods that have been used to investigate brain activity during language processing. For example, in an fMRI study using covert language production, Kim et al. (1999) found that native and non-native languages were processed in adjacent but distinct areas of the brain in the same subjects. In contrast, Perani et al. (1998) found strong similarities between highly proficient L2 learners and native speakers in a listening task. In two fMRI experiments involving high-proficiency late learners, high-proficiency early learners, and low-proficiency late learners of a second language, they found different areas of activation between L1 and the low-proficiency L2 group, but no significant differences in activation for the L1 compared to either of the high-proficiency L2 groups. On the other hand, evidence that syntactic phenomena are sensitive to age of acquisition was found in Weber-Fox and Neville (1996). This study used ERP methods to examine the timing and distribution of activity associated with processing semantic versus syntactic incongruencies such as violations of subjacency and of phrase structure in English. Their findings indicate that in a reading task, ERP patterns associated with syntactic processing were different in native speakers and L2 learners, even when exposure to English was as early as 4 to 6 years of age.

The current study endeavors to bridge the two approaches to second language representation/organization by correlating behavioral data obtained through psycholinguistic experimental methods with electrophysiological data, focusing on an area of grammatical knowledge which has long been noted to cause considerable difficulty in second language learners, namely, inflectional endings, such as the progressive *–ING* in English, and word order phenomena, such as negative placement. An important aspect of this study is the inclusion of L2 learners from high and low levels of proficiency, as well as early and late ages of acquisition, in order to examine possible differences in processing from both a behavioral and a neurophysiological perspective.

1.2 SLA Background

The question of whether or not the language faculty, specifically the innately determined neural architecture supporting grammar construction, is subject to maturation effects similar to those associated with other types of cognitive processes such as visual perception (Lenneberg, 1967; Eubank and Gregg, 1999; Johnson & Newport, 1989; Neville, 1994; Neville et al., 1992; Pinker, 1994) is a fundamental and controversial question underlying SLA theoretical approaches. It has been central to the debate as to whether L2 acquisition is constrained by principles of Universal Grammar (UG), the biologically endowed system of abstract knowledge that is thought to constrain human language acquisition and thus contribute to in fundamental ways to learnability (Chomsky, 1981; 1995). UG is also attributed to both invariant and variant cross-linguistic properties, generally considered to be manifestations of the underdetermination that characterizes language acquisition in general. Notwithstanding approaches supporting the position that L2 acquisition is either not constrained by UG or only indirectly constrained through the UG principles instantiated in the L1 (Bley-Vroman, 1990; Clahsen & Muysken, 1986; Shachter, 1990), the view adopted here is that L2 acquisition is UG-based. Most relevant to the current study, therefore, is the strong claim derived from the Critical Period Hypothesis (CPH) that exposure to a second language after puberty results in an inability to achieve target-like knowledge of abstract syntactic properties (Johnson & Newport 1989).

The omission of inflectional endings in the written and verbal production of adult learners of a second language is a well-attested phenomenon, as are errors in agreement and word order. Yet there is considerable debate as to the specific source of such errors. Two perspectives have been central in this debate. One view is that errors in surface word order and inflection are the result of a deficit in the mental representation of the L2 learner's grammar. Approaches following from this view maintain that the learner is unable to realize the surface form of verbal inflection, case morphology, or word order because there is a deficit in the underlying syntactic representation.

On one extreme end of the spectrum is the hypothesis that impairment at the representational level is permanent for the L2 learner, in that feature specifications of the L2, often considered to be parameterized, are not available to the learner at all (Tsimpli and Rousseau, 1991; Smith and Tsimpli, 1995; Beck, 1997; Hawkins and Chan, 1997). This approach stems from the long-standing debate involving the CPH, which has generated considerable contradictory evidence (Bialystok & Hakuta, 1994;

Birdsong, 1998; Epstein et al.,1996; Kanno, 1996, 1997; Martohardjono and Gair, 1993; Perez-Leroux & Glass, 1997, 1999).

In early children's L1 acquisition, variability in verb morphology has been attributed to the failure to project a complete syntactic structure, resulting in truncated structures serving as root declarative clauses, rather than the "mature" CP-dominated root matrix clause (Rizzi, 1994; Haegeman, 1995). Under this structure-driven account, variability in verb morphology (e.g. finite versus non-finite forms) is a result of the type of structure projected as a root clause in the developing grammar. This approach has been applied to child L2 acquisition as well (Prévost and White, 1999). Other approaches attribute variability in verb morphology and word order to under-specification of the features (Wexler, 1994 for child grammars), or inert feature strength (Eubank, 1993/1994;1996). Under these accounts, acquisition of feature strength is driven by acquisition of the L2 morphological paradigm, structural impairment being a temporary stage in the acquisition process from which the development of complete functional inventory emerges. Evidence of a mature or maturing inventory is in the realization of the morphological paradigm and in correct word order.

A well-known example of a representational account of adult L2 acquisition, the Minimal Tree Hypothesis (Vainikka & Young-Scholten, 1994; 1996a,b; 1998), maintains that the initial state of the L2 intergrammar lacks functional categories altogether, though headedness and lexical properties are transferred from the L1. Acquisition of the functional categories such as IP and CP and their proper specifications for the L2 is absolutely sequential, driven by L2 input, in particular, morphological elements such as modals and auxiliaries (triggering instantiation of first an underspecified finite phrase (FP), which is eventually fully specified as IP) and –wh elements (ultimately triggering the development of CP). On this account, therefore, evidence of correct verb placement and question formation in L2 production constitutes evidence of the instantiation of IP and CP, respectively. On the other hand, empirical evidence of the presence of functional categories, such as determiners (Grondin and White, 1996), negative markers (Haznadar, 1997) or copula *be* (Lakshmanan, 1993/1994) at early stages of L2 acquisition undermine the principles of this approach.

In contrast to hypotheses which assume a deficit at the representational level, another view considers the possibility that different types of errors belong to different domains of the grammar. Epstein, Flynn and Martohardjono (1996), for example, propose that the faulty realization of verbal inflection is fundamentally different from word order errors. They argue that unlike errors in word order, the omission of inflection is not syntactic in nature, but a function of the mapping that must take place between underlying structural representation and morphophonetic surface form. According to this view, a deficit in this mapping process, rather than a deficit in the underlying syntactic structure of the learner's grammar, is responsible for missing inflection in production. While the inventory of functional categories is hypothesized to be complete in the L2 learner's mental representation, the morphological paradigm itself is not (Haznadar and Schwartz, 1997; Grondin and White, 1996; Lardiere, 1998a,b, 2000; Prévost and White 1999).

Yet another approach that argues against a purely representational explanation of L2 acquisition suggests that the source of surface errors is primarily the result of a deficit in processing, rather than a representational or mapping deficit (Klein and Martohardjono, 1999). Under this approach, the process by which a non-native grammar is constructed, which includes mapping from UG to a language-specific grammar and, crucially, an interaction between performance factors such as parsing and underlying knowledge, are considered the primary causes of differences between the L2 intergrammar and a particular target grammar. This view argues for an important distinction between the relevant properties of the grammar being acquired and the mechanism by which the grammar is restructured, i.e. in the process that leads from one intermediate representation (or knowledge state) to another. It is this latter hypothesis, in the context of the relevant arguments presented thus far, which provides the starting point of the current study, which is mainly concerned with investigating similarities and differences between the neural organization of processing inflection and in word order in the L2.

1.2.1 Theoretical SLA Questions

Verb raising and negation

Under current versions of generative syntactic theory, particular types of word order phenomena are linked to inflection phenomena (Emonds, 1978; Pollock, 1989; Chomsky, 1995). The relationship between word order and inflectional morphology is most transparent in languages like German and French, in which tense-marked verbs

(+finite) and infinitives (-finite) occur in distinct positions in the sentence. In the case of French, +finite verbs appear in front of adverbs and negative markers, but infinitives occur after them, as shown below:

a. Marie ne regarde pas la television.
Marie watches not the television.

a.' *Marie pas regarde la television.
Marie not watches the television.

b. Marie regarde souvent la television.
Marie watches often the television.

b.' *Marie souvent regarde la television.
Marie often watches the television.

c. Marie ne veut pas regarder la television.
Marie wants not to watch the television.

c'.*Marie ne veut regarder pas la television.
Marie wants to watch not the television.

In German, tensed verbs must occur in the second position in the sentence, and -finite verbs occur in sentence final position, as shown below:

d. Maria trinkt oft Kaffee.
Maria drinks often coffee.

d.' *Maria oft trinkt Kaffee.
Maria often drinks coffee.

e. Maria möchte Kaffee trinken.
Maria wants coffee drink-INF.

e.' *Maria möchte trinken Kaffee.
Maria wants drink-INF coffee.

Word order phenomena such as these constitute overt syntactic consequences of the interaction of phrase structure and verb inflection morphology in languages in which thematic verbs undergo movement (Emonds, 1975; Pollock 1989; Chomsky, 1995), illustrating the current view that the building of syntactic structure is driven by the properties of abstract features. Features are minimal units of linguistic information that may be syntactic (Agreement, Tense, NOM Case), semantic (+ animate), or phonological (+ voice). Current proposals hold that verb raising phenomena are based upon the strength or weakness of V-features (verb features) in I, the head of the functional category IP. In French and German, for example, thematic verbs raise from their initial position under VP (Verb Phrase) to a higher position under IP (Inflection

Phrase), so that strong features in I can be checked. In English, on the other hand, V-features in I are weak and cannot support thematic verbs, which are characterized, in part, by their semantic content. As a result, thematic verbs do not raise overtly in English, but instead undergo feature checking via operations of covert "non-visible" movement at Logical Form (LF). Auxilaries, however, are considered semantically "light" verbs (Chomsky, 1993;1995) and can be supported by weak features in I, thus raising to higher functional heads in order for Tense and Agreement features to be checked. The syntactic consequences of auxiliary raising versus non-raising of thematic verbs in English, as compared to raising of both auxiliary and thematic verbs in French, are illustrated in the following word order contrasts, relative to the negative marker or adverb:

f. John is not watching television.
g. John does not watch television.
h. *John watches not television.
i. John ne regarde pas la television.
j. John often watches television.
k. *Jean souvent regarde la television
l. *John watches often television.
m. Jean regarde souvent la television.

As a result of these and related interactions between verb morphology and sentence structure, errors associated with these types of structures in L2 learners' speech, such as the frequent omission of inflectional endings and misplaced verbs, have therefore been ascribed to a faulty representation of the IP node.

In view of this particular theoretical treatment of these phenomena, several interesting question arise with regard to their acquisition by non-native speakers:

First, is the processing of inflectional errors, which results in non-targetlike verb structure, similar to the processing of word order errors, which results in non-target-like sentence structure? Secondly, do non-native speakers process these errors in the same way as native speakers? And finally, if native and non-native processing differs, is there a progression towards native-like processing with increased levels of proficiency and earlier exposure to the L2?

Evidence from production suggests that L2 learners' behavior differs with regard to different types of errors, in spite of the fact that they are associated with the same syntactic phenomenon. In a longitudinal case study of an L2 English speaker who was a native Chinese speaker, Lardiere (1998a,b) shows that two types of morphology, verbal 3rd-person singular -s and pronominal case (he/she; him/her) are treated very differently in L2 acquisition, with the first being frequently omitted, even in very advanced stages of acquisition, while the latter hardly ever result in errors. These findings suggest that there may be a dissociation between different kinds of morphosyntactic information in L2 acquisition.

In addition, syntactic processing has been studied in terms of processing speed and accuracy in judging grammaticality. Juffs and Harrington (1995) show dissociation between accuracy and reaction time in processing complex syntactic structures such as subject extraction in infinitive clauses. The findings of similar accuracy scores in conjunction with slower reaction times in relatively high proficiency L2 learners compared to monolinguals suggests that while syntactic information may be available to L2 learners, the processes by which it is accessed may not be the same as it is in monolinguals.

With respect to the domain of processing in native speakers, brain-imaging studies have also shed some light on the differential treatment of violations, purportedly when different processing tasks are involved. For example, in order to establish both temporal and spatial resolution in a brain imaging study, Meyer, Friederici, and von Cramon (2000) used event-related fMRI methods and found that in addition to bilateral temporal activity associated with auditory sentence processing, the processing of a sentence's syntactic structure elicits greater left frontal activation, while the process of repairing an ungrammatical sentence involves greater bilateral activity, with significantly greater activity in the right inferior frontal operculum and right superior temporal gyrus. The important questions raised by these results are: 1.) To what extent do the increased task demands of syntactic processing in L2 learners of varying proficiency reflect more controlled processes, which are indexed by different patterns of activity in the brain, in terms of timing and distribution? 2.) When during acquisition of a second language do these processes begin to approach the more automatic processing observed in native speakers? 3.) Does age of acquisition play a role in the degree to which these processes become automatic? 4.) Do ERP responses to these processes reflect measurable behavioral changes in development during acquisition?

1.3 ERP Background

A number of ERP studies have examined the timing and distribution of cortical activity associated with syntactic violations versus syntactic ambiguities (Friederici, 1995; Friederici, Hahne, and Mecklinger, 1996, between semantic versus syntactic anomalies (Friederici, Pfeifer, and Hahne, 1993; Hagoort, Brown, and Groothusen, 1993, Neville, Nicol, Barss, Forseter, and Garrett, 1991, or a single specific syntactic phenomenon such as structural reanalysis (Mechlinger, Schriefers, Steinhauer, and Friederici, 1995. Studies focusing on ERP responses to outright syntactic violations have included violations of phrase structure (Friederici et al., 1993; Friederici 1995; Hahne & Friederici, 1999), subjacency and other constraints on wh-movement (Kluender and Kutas, 1998, Neville et al., 1991). Several studies have examined ERP responses to ambiguous or unexpected/non-preferred structures that putatively require processes of reanalysis and repair (Osterhout and Holcomb 1992, 1993; Osterhout, Holcomb, & Swinney, 1994; Gunter, Stowe, and Mulder (1997). Kaan, Gibson, and Holcomb (1998) examined ERP responses elicited by increased difficulty in integration, which specifically did not involve reanalysis. While these studies have produced relatively consistent results, eliciting reliable ERP responses to syntactic incongruities of various kinds, the specific sub-processes underlying the later latency ERP response patterns, namely the P600 effect, are still under investigation. The patterns of results from this corpus of studies have led to the generally held view that purely structural syntactically based violations elicit an early anterior negativity, a later anterior negativity often oriented to the left, and a later positivity in the central posterior region of the scalp.

In the context of studies examining syntactic and morphosyntactic processing, relatively few have specifically compared ERP responses to violations of word-order (e.g. **John not is walking*) and inflection (e.g. **John is not walk*) using naturally spoken language (Friederici et al., 1993; Friederici et al., 1996; Osterhout et al., 1993; Hagoort & Brown, 2000). A number of studies examining morphosyntactic phenomena involving various manipulations of inflectional information, have produced inconsistent results (Gunter et al., 1997; Coulson, King, and Kutas, 1998; Münte, Matzke, and Johannes, 1997; Osterhout and Mobley, 1995; Kaan et al., 1998; Hagoort & Brown, 2000; Müller, Hahne, Fujii, and Friederici, 2003).

1.3.1 ERP Studies Investigating Inflection

Studies investigating ERP responses to inflection violations vary greatly in the types of inflectional information manipulated, and very few involve auditory stimuli. In one of the rare studies using auditory sentence stimuli to compare syntactic and inflectional processing, Friederici et al. (1993) examined responses to phrase structure violations and inflectional violations in monolingual German speakers, as examples 1.) and 2.) illustrate:

1.) phrase structure violation: *Das bekannte Lied wurde vom gesungen
*The well-known song was [by the] sung.

2.) inflection violation: *Das bekannte Leid wurde vom Tenor singen
* The well-known song was [by the] tenor sing.

In response to phrase structure errors, they found an early negativity peaking at about

180 ms, maximal over left anterior electrode sites (early left anterior negativity, ELAN), and a later negativity at approximately 400 ms that was largest over bilateral frontal sites (left anterior negativity, LAN). In response to morphosyntactic errors they observed an anterior negativity peaking at about 400 ms followed by weak late positivity over parietal sites (P600).

Using the same types of sentences in a visual study, Gunter and Friederici (1999) found a broadly distributed negativity elicited by inflectional violations and a more narrowly distributed negativity elicited by word-category violations. They suggest that topographical differences may be associated with different types of verb inflection errors. However, these questions have not been studied in detail. As this study focused on the "N400 and P600" responses, it did not include a planned comparison in the early 150-250 ms latency range; therefore no ELAN was reported.

Gunter et al. (1997) found negativities at 150 and 350 ms, as well as a P600 effect in ERPs elicited by inflectional errors in Dutch. These errors were realized as an incorrectly inflected verb and are structurally similar to those used in Friederici et al., (1993) and subsequently in Friederici (1999), in which they were considered inflection violations. However, they are considered "syntactic" in Gunter et al. (1997) (compare sentence number 2.) with sentence 3.) below).

3.) *De vuile matten werden door de hulp **kloppen / geklopt.*

*The dirty doormats were by the housekeeper **beat / beaten.*

One question that remains from the results of these three studies is to what extent the anterior negativities elicited by word-category and verb inflection violations reflect the same or similar underlying processes. A second question involves the extent to which these negativities are related to those elicited by morphosyntactic violations involving agreement.

A number of studies have investigated ERPs to morphosyntactic violations in the form of subject-verb agreement mismatches (Kutas & Hillyard, 1983; Coulson, King and Kutas, M., 1998; Osterhoust & Mobley, 1995; Hagoort et al., 1993; Gunter, Stowe, & Mulder, 1997; Penke, Weyerts, Gross, Zander, Münte, Clahsen, 1997; Kaan et al., 1998. Coulson et al. (1998) examined ERPs elicited by two types of inflectional violations. Their experimental materials manipulated pronoun case in English (*The plane took *we/us to paradise and back*) and subject-verb agreement *(he *mow/mows the lawn*) in English. They found that pronoun violations elicited a left anterior negativity, and verb agreement violations elicited a negativity with a predominantly centro-parietal distribution, slightly larger on the right. These results are particularly provocative in light of the seemingly dissociative behavioral results in SLA reported above. Gunter, Friederici, & Schriefers (2000) classify the LAN as "syntactic in nature", based upon the range of studies in which it has been observed in ERP responses to different kinds of morphosyntactic violations. The question remains, however, as to whether the functional nature of the processes that fall into the category of "morphosyntactic" can be further delineated.

Taken together, topographic differences in ERPs suggest that different types of inflectional violations reflect differential processing, and further, that the processing of inflectional information may not be a single unified process. In addition, studies investigating early automatic processes involving structure building

(ELAN) and later processes believed to involve reanalysis and repair (P600) have prompted relatively direct and uncontroversial claims about the underlying processes which are reflected in the ERP patterns associated with them. This is not the case with respect to the underlying processes involved in the mid-latency range, excluding investigations of the N400 response to semantic incongruity. Further study of inflection violations in the auditory modality is needed in order to further explore the extent to which anterior negativities and later centro-parietal positivities are correlated with specific types of inflectional processing. In addition, it is important to determine whether such findings can be correlated with behavioral data.

1.3.2 ERP Studies Investigating L2

There have been only a handful of ERP studies to date involving native and nonnative speakers. Weber-Fox and Neville (1996) included L2 learners who varied in age of acquisition across five groups: 1-3, 4-6, 7-10, 11-13, >16 years. Extensive proficiency testing was performed, in addition to self-ratings for a variety of skills. The same visually presented stimuli as Neville et al. (1991) were used in this study, which included semantic, phrase structure, specificity constraint, and subjacency violations, as illustrated in the following examples.

a) Semantic: The scientist criticized Max's event of the theorem.
b) Phrase structure: The scientist criticized Max's of proof the theorem.
c) Specificity constraint: What did the scientist criticize Max's proof of?
d) Subjacency constraint: What was a proof of criticized by the scientist?

Participants were adult Chinese learners of English as a second language. It is important to note that the group exposed to English at the youngest age (1-3) was, for the most part, living in households in which Chinese and English were used equally. Therefore, their manner of acquisition was more or less simultaneous for the two languages, as opposed to the other groups, who learned Chinese first and English second.

This investigation found that phrase structure violations elicited a LAN for early learners (1-3, 4-6) only. No early anterior negativity was found for any group. P600 effects were found for early learners as well as the more intermediate 7-10 group, but not for later learners (11-13, >16). Monolingual data were taken from a previous study (Neville et al., 1991). For this group a variable ELAN was observed in ERPs to phrase structure violations, as well as LAN and P600 effects.

Another study involving L2 learners is Hahne (2001). This is an auditory study examining ERPs to semantic and syntactic (word category) violations in monolingual German speakers and native speakers of Russian learning German as a second language. Though specific age-of-acquisition information is not provided, the report suggests that L2 learners are later learners. In addition, no proficiency testing is reported. Self-rating only is used, with participants reporting 3.6 in auditory comprehension, 3.7 in reading, 2.9 in speaking, and 3.3 in writing (from a 1-4 point scale, with 1=hardly any knowledge and 4=very good). Accuracy scores on the grammaticality judgment were reported as an 8% error rate.

The findings from this study indicate that there was no early anterior negativity for the L2 group in the phrase structure violations. However a slightly larger N2 pattern (one of the obligatory components of a response to an auditory stimulus) is observed at anterior electrodes for correct sentences in this group, compared to the monolingual group. A small P600 effect is reported in the L2 group, peaking about 150 ms later than the positivity observed in the monolingual group. The monolingual group also shows an early anterior negativity in the 100-250 ms latency range. No mid-latency LAN is reported, as the study examines only the semantic N400 effect in the 400-700 ms time window.

In a similar study, Hahne and Friederici (2001) report that lower proficiency Japanese learners of German did not show a P600 effect. All of the L2 learners in this study were exposed to German after age 18. Their most significant finding is an absence of a difference between correct and incorrect sentences in the L2 group, in comparison to a significant difference between the ERP responses to grammatical and ungrammatical sentences in the L1 group. For the L2 group, the correct sentences elicited more positive ERPs, greater on the right, and including anterior sites.

These findings highlight the need for further investigation of ERP patterns in L2 learners of varying proficiency levels and ages of acquisition. Weber-Fox and Neville (1996) compare the progression in decreased proficiency and accuracy for processing different types of syntactic violations, ranging from the earliest to the latest ages of acquisition; however, the interpretation of findings is focused on the relationship between ERP effects and age of acquisition, with proficiency as a secondary variable. The Hahne (2001) and Hahne & Friederici (2001) studies include only one L2 group each, with no normed testing for proficiency at all. Therefore, there were obvious limitations in terms of claims that could be made about effects of proficiency or age of acquisition on the functional organization of syntactic processing. The findings across the two studies suggest that at least later cognitive processing reflected in the P600 are affected by proficiency, as the Japanese learners of German had lower accuracy scores (20% error rate) than the Russian learners (8%). The current study set out to address these questions directly.

Chapter 2: Research Questions and Hypotheses

The current study investigates differences in the processing of linguistic information associated with word order and inflection in native speakers and second-language learners using multi-channel electrophysiological recordings. This aim will be achieved by examining ERP correlates to processes that have posed problems for second-language acquisition theory based upon behavioral measures alone. A further aim is to examine ERP patterns in native speakers, specifically those associated with syntactic and inflectional processing. Given the disparate results found across studies examining syntactic and morphosyntactic processing, a central objective of the current study is to delineate more clearly the timing and distribution of underlying processes involving phrase structure and inflection.

ERPs were recorded while participants listened to sentences in English, in order to examine the spatio-temporal characteristics of cortical activity associated with the processing of word order and inflection, respectively, and the extent to which these characteristics vary according to proficiency level and age of L2 acquisition. A grammaticality judgment task was included in order to determine whether behavioral and electrophysiology measures correlated with each other. The following research questions, hypotheses and predictions provide the basis for the current investigation.

2.1 ERPs to Word Order and Inflection Violations in Monolinguals

We investigated whether violations of Word Order and Inflection elicit brain potentials that reflect different processes in adult monolingual speakers of English. This question is based on observed differences in ERP responses to syntactic and morphosyntactic violations (Friederici et al., 1993, Gunter, 1997; Gunter and Friederici, 1999). However, a complicating factor is a lack of converging results associated with morphosyntactic processing (Gunter & Friederici, 1999; Hagoort & Brown, 2000; Hagoort et al., 1993; Hinojosa et al., 2003). Therefore, since more consistent results associated with P600 effects elicited by both Word Order and Inflection violations are available to date, we expected that both phrase structure and verb inflection violations would elicit this effect. Based upon previous findings of early anterior negativities elicited by phrase structure violations, Word Order violations were expected to elicit similar ERP patterns. We reserved prediction with respect to whether or not similar ERP responses would be elicited by violations of verb inflection, due to the inconsistent results across studies involving inflection violations. Despite some degree of divergence with respect to the topographical distribution of mid-latency negativities, we predicted that phrase structure violations would elicit left anterior negativities in the 250-450 ms latency range and that negativities in the same latency range, but not necessarily with the same distribution, would be elicited by violations of verb inflection.

2.2 ERPs to Word Order and Inflection Violations in L2 Learners

We investigated whether the timing and distribution of ERP responses to violations of Word Order and Inflection presented in the non-native language reflect proficiency level and age of acquisition. This question reflects the hypothesis in SLA theory, extending from Pollock (1989) and Chomsky (1991,1993), that Word Order and inflectional errors are closely associated in terms of the function of the IP node and the relevant feature encoding that belongs to it (Wexler, 1994; Rizzi, 1993/1994; Borer & Rorbacher, 1997; Phillips, 1995 for child L1; Vainikka & Young-Scholten, 1994;1996; Eubank, 1993/1994; 1996; Prévost & White, 2000; Eubank et al., 1997 for L2). As discussed above, much debate has revolved around various approaches to explaining the nature of the interaction between verb raising and inflectional feature properties and in particular, the implications for both L1 and L2 language acquisition. Therefore, this is an important place to examine how the acquisition of underlying knowledge of word order and the paradigmatic knowledge of morphological properties can be assessed. In conjunction with taking new approaches to measuring extremely subtle linguistic processes, the promise of answering these stubborn questions lies in extending the methods of inquiry and hypothesis testing into the fields of electrophysiology and functional imaging, which utilize fine-grained temporal information and rapidly developing techniques of event-related magnetic resonance imaging, respectively, to compare cortical processing of different types of linguistic information. As these new methods have emerged, so have intriguing results, though these have yet to converge substantially, resulting in challenges for hypothesis testing.

As noted above, Perani et al. (1998) found that regions of cortical activation during comprehension in high-proficiency-level L2 learners are similar to native speakers. Based upon this finding and the fMRI data from Kim et al. (1997) in which overlapping areas of activation were found for early L2 learners but not for late learners, we expected to see similar ERP responses in early L2 learners and monolingual speakers, i.e. early anterior negativities, mid-latency negativities, and

P600 effects elicited by Word Order violations, and anterior negativity in the 250-450 ms latency range and P600 effects for inflectional violations.

Evidence from imaging studies and ERP studies involving later L2 learners is lacking, and what exists is inconsistent. Perani et al. (1998) also found differences in areas of activation in the L2 for low proficiency learners and high-proficiency later learners compared to their L1. In addition, Kim et al. (1997) found non-overlapping areas of activation in the left inferior frontal gyrus (Broca's area) during covert language production in later L2 learners compared to early L2 learners. ERP results from Hahne (2001) and Hahne & Friederici (2001) indicate that ERP patterns for late L2 learners of lower proficiency differ from the established patterns observed in previous studies for native speakers. Respectively, they found increased negativity elicited by grammatical sentences, and no P600 effect and increased positivity in processing grammatical sentences compared to ungrammatical sentences. This lead us to predict substantial differences in ERP patterns among low proficiency L2 learners compared to native speakers. However, it does not provide strong grounds upon which to base predictions for high proficiency late learners. This problem is highlighted by an additional source of ERP data. Weber-Fox and Neville (1996) found differences in ERP correlates of syntactic processing for quite early L2 learners (ages 4-6) compared to native speakers. Thus, taken together, these results do not lead to clear predictions for later learners of high proficiency.

Lardiere (2000) proposes that there is a Critical Period effect on mapping from abstract features to morphological form. Generalizing from this hypothesis, we attribute maturation effects to the domain of processing as a locus of impairment. We therefore predict differences in ERP correlates of the processing of phrase structure and verbal inflection in late L2 learners compared to monolinguals and early learners.

2.3 Behavioral Measures: Accuracy and Reaction Time

We investigate whether, across proficiency levels and ages of acquisition, differences in processing, as reflected in a behavioral task, correlate with ERP responses. We examine whether ERPs, as an on-line measure of processing, correlate with behavioral measures such as accuracy and reaction time, determined in a concurrently performed grammaticality judgment task. We expect to find differences between accuracy and reaction time, based upon Juffs et al. (1995), who found similar accuracy rates but slower reaction times in high proficiency L2 learners. This dissociation was taken as evidence that advanced L2 learners have access to the same underlying grammatical knowledge as monolinguals (in the context of parsing relative clauses), though processing, (i.e. the manner of accessing and using that knowledge) is different. For this reason, we hypothesize that late learners of high proficiency have access to the same knowledge as native speakers, but that they access it differently. We thus expect to see differences in ERP responses associated with these processing differences.

While the hypothesis adopted here is consistent with Lardiere's mapping deficit hypothesis, it differs in two fundamental ways. First, the current study attempts to correlate temporal differences in on-line syntactic processing with reaction time[1] and accuracy in a grammaticality judgment task. Secondly, Lardiere's argument is aimed,

[1] Reaction time, relative to ERP recording, is not strictly an online measure.

at least in part, at explaining "permanent" or fossilized divergent patterns in production of morphosyntactic elements, in relation to and possibly autonomous from underlying syntactic computation. In the case of the current study, however, we propose that while ultimate attainment of certain aspects of overt or "spelled out" morphophonetic form may not diverge from the target language, measurable aspects of underlying processes (i.e. ERP correlates), which may reflect computational operations (at the representation level) or cross-system mapping from representation to morphophonetic form (or both), may diverge from those of native-speakers in the same linguistic contexts.

Chapter 3: Methodology

3.1 Research Design

On-line measures of comprehension/perception such as ERPs eliminate the kinds of performance errors associated with production, which potentially obscure the learner's underlying knowledge. In particular, since measuring production of inflectional morphology is not a reliable method of determining underlying structural representation in L2 acquisition, given potentially independent courses of development for Word Order and Inflection and the possibility that missing or variable inflection is a result of post- or extra-syntactic factors (Lardiere, 1998a,b), using ERP data will enable us to investigate syntactic knowledge without relying on production, and thus obtain a more accurate measure of underlying processes involved in comprehension. In addition, using auditory stimuli rather than visually presented stimuli eliminates reading-specific factors that are extrinsic to auditory comprehension.

3.2 Syntactic and Inflectional Properties

While English is limited in terms of properties associated with verb inflection, Word Order is particularly salient, and the use of lexical and inflectional markers in positive and negative progressive constructions provide a means with which to study how surface morphology in the form of lexical markers such as auxilary *be* or verb inflection such as progressive *–ING* marking are processed. Three types of violation were presented to participants, one phrase structure violation and two types of inflection violation. For the purposes of the current study, which are discussed below, only one of the two types of morphosyntactic errors associated with progressive constructions were included in the analysis. Analysis of ERP responses to a missing auxiliary, which is a lexical form of inflection, will be carried out at a later date.

Experimental sentences include phrase structure (word order) error in which a negative marker appears before an auxiliary:

a.*John not is eating pizza in a restaurant.

Experimental materials also include Inflection violations realized by the incorrect application of a verbal suffix, is a bound morpheme attached to the verb, as shown in b. and c. When progressive aspect is signaled by the presence of auxiliary *be*, its dependent counterpart, the *-ING* affix, is obligatory, and lack of this affix clearly violates the morphosyntactic requirement.

b. Now John is eating pizza in the kitchen.
c. *Now John is eat pizza in the kitchen.

A total of eight single-syllable verbs were used in the current experiment, four of which are regular (call, watch, play, wait) and four of which are irregular (send, leave, read, eat). Though only present progressive constructions were used, regular and irregular verbs were balanced across all experimental sentences in case of possible differences in processing based upon verb type (Jaeger, Lockwood, Kemmerer, Van Valin, Murphy, and Khalak) [2].

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[2] Due to time constraints, analysis of verb type has been reserved for future investigation, in which we will examine ERP responses to missing auxiliaries (*free* inflectional morphemes) and missing *-ING* (*bound* inflectional morpheme). So in addition to Word Order sentences, both types of inflection violation were included in the current experimental sentence set. Reports of effects of verb type, if found, will be forthcoming.

3.2.1 Cross Linguistic Contrasts

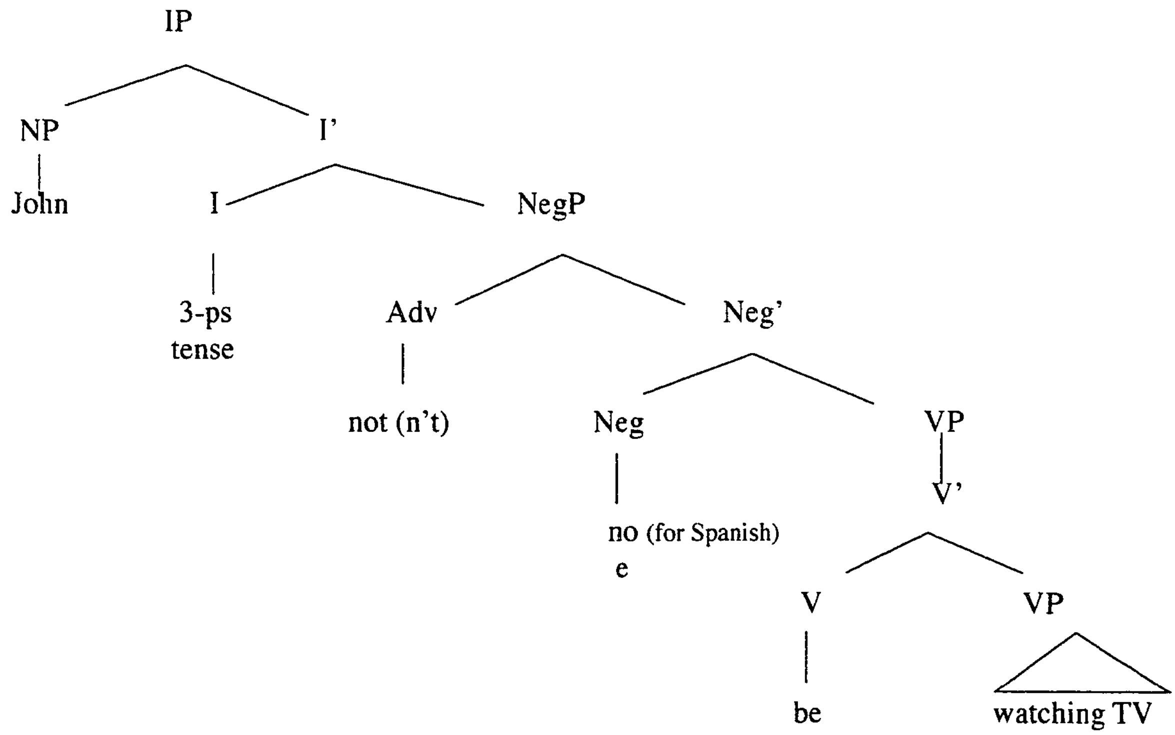
The current experiment examines how the same types of inflectional and word-order properties are processed in L2 learners of English whose native language is Spanish. In the absence of a current and straightforward account of auxiliary raising in English, we refer to earlier accounts of auxiliary raising in English and French (Pollock, 1989; Chomsky, 1991), in addition to accounts that include Spanish (Suñer, 1994; Hawkins, 2001), for the purpose of describing the relevant contrast between English and Spanish word order, illustrated in examples d. and e. below.

d. No estamos hablando. *We not are speaking.
No hemos hablado. *We not have spoken.

e. We are not speaking *Estamos no hablando.
We have not spoken *Hemos no hablado.

Both English and Spanish progressive constructions require both a lexical element, in the form of auxiliary *be/estar*, and an inflectional ending on the verb (*–ing/ando*). In addition to learning the correct verb inflectional paradigm in L2 English, Spanish-speaking learners of English must learn that there is a difference in word order in negative progressive sentences in the target language. Initial accounts of verb raising in Romance versus English (Pollock, 1989) focused on the observation that thematic verbs do not raise in English, unlike French. Conversely, in English auxiliary verbs, which are considered semantically light, purportedly raise to INFL, as evidenced by the order shown above.

According to Hawkins (2001), extending from Pollock (1989), differences in auxiliary-neg order in Spanish (or French) and English are attributed to parametric differences in the structure of Neg Phrase in the two languages. In the case of English, the auxiliary verb raises to check inflection in I, via head-to-head movement across not/n't, which is generated in Spec NegP. This operation results in the order Aux-Neg. In Spanish or French, on the other hand, the negative marker no/ne is the head of NegP and cliticizes to the auxiliary verb in the process of auxiliary raising. This results in the order Neg-Aux. In French and Spanish, in contrast to English, strong features in I attract both thematic and semantically "light" auxiliary verbs, whereas in English, weak features in I are unable to support thematic verbs, resulting in auxiliary verbs appearing above Neg in surface order and thematic verbs remaining in situ, appearing after Neg. The basic underlying structure upon which this account is based is shown below[3].



[3] This particular analysis is not crucial to the objectives of or the claims generated by this study, nor are the specific configurations of functional projections under IP.

3.2.2 Functional Categories

Though a standard current and unified theoretical account of auxiliary raising and negation in English and Spanish is not available, the general hypothesis that morphosyntactic properties are determined by operations of feature checking under IP, and more specifically, that features associated with functional categories are the locus for cross-linguistic variation in word order (Chomsky, 1993), is relatively uncontroversial. By extension, the nature of these properties is particularly relevant to long-standing questions regarding L2 acquisition of functional categories. And hence, the interaction of inflectional morphology and syntactic structure is of particular interest to the study of the mechanisms underlying this type of processing.

In designing this study, which focuses specifically on these relationships, it was important to minimize interaction of different types of linguistic information involved in longer distance syntactic relations and higher-level semantic integration. Therefore, the progressive inflectional ending *–ING* was chosen for manipulation of verbal morphology. In progressive constructions, the participle is directly associated with (i.e. selected by) the auxiliary *be*, rather than a lexical category or an argument requiring the checking of Case features, for example. The auxiliary and participle were kept as syntactically local as possible, with a single intervening constituent, the function word, *not*[4]. Consequently, the violation is local to the auxiliary-participle relation in both Word Order and Inflection conditions. Differences in the timing and distribution of ERPs to violations of Word Order, on one hand, and Inflection on the other, would suggest that, in a narrow sense,

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[4] There is some disagreement about the status of *not*, i.e. whether it is a function word or an adverb. For the purposes of this discussion, it has the characteristics of a function word, in that it is a closed-class morpheme, which is phonologically weak (often reduced to n't), and lacks the specific conceptual content of lexical categories (Hawkins, 2001).

the underlying processes making use of morphosyntactic and structural information are not homogeneous.

3.3 Participants

A total of 40 subjects with normal hearing were tested. Four were excluded from the study due to a poor signal-to-noise ratio, leaving a total of 36 participants, 18 of whom were male, and 18 female. Four participants were left handed and two reported a family history of left handedness. Two of the left handed participants were male and two were female.

Four adult linguistic groups participated in the experiment. Ten monolingual speakers of English and 26 second-language learners of English whose native language is Spanish were tested. The L2 learners were divided into three groups: 9 low-proficiency learners of English, 8 high-proficiency learners who were exposed to English before 8 years of age, and 8 high-proficiency learners who were exposed to English after 8 years of age. Mean ages of each group at the time of testing were 32.7 for Monolinguals, 25.7 years for High Proficiency Early learners, 28.6 years for High Proficiency Late learners and 31.3 years for Low Proficiency learners. All participants were between 18 and 47. Proficiency in English was determined by scores on the Michigan Test of English Proficiency. Participants in both High Proficiency groups scored above 78% correct (mean for HPE: 90.3; mean for HPL: 88.9). The mean score for the Low Proficiency group was 51%.

3.4 Materials

A total of 288 experimental sentences and 60 filler sentences were digitally recorded and edited using ProTools 5.0.1. Each word in the sentence was followed by a 50-ms pause in order to minimize overlap of obligatory responses to critical words in the experimental sentences. 48 sentences contained a word order error, 48 sentences contained an inflectional error of missing inflection, and 48 sentences contained an inflection error of missing auxiliary. 144 correct sentences were presented. 60 correct filler sentences were presented. Incorrect sentences include one of the following types of sentences:

1. Word Order (Neg-Aux placement) *John not is eating pizza in the kitchen.
2. Inflection (deletion of verbal suffix) *Now John is eat pizza in the kitchen.
3. Inflection (deletion of auxiliary) *Now John eating pizza in the kitchen.

The average length of each sentence was 4 seconds, with a 2-second interval between sentences. During the response time subjects were instructed to press one button which corresponds to whether the sentence is correct and another one for incorrect. The order of presentation of the sentences was pseudorandomized. Location of buttons (right or left) for correct and incorrect sentence judgments was counterbalanced. Sentences were presented in blocks of 29, including 24 experimental sentences and 5 filler sentences. Twelve blocks lasting 3 minutes each were presented.

3.5 Task

Subjects were seated in comfortable chair. A response box was positioned on a removable tray in front of them. They were instructed to listen to each sentence carefully and decide if it was a good or bad sentence. They were instructed to wait until the end of the sentence before pressing the buttons corresponding to good or bad, and to make a response, even if they were not sure. A bilingual research assistant was present at all times, explaining all procedures and answering any questions in Spanish if the subject was more comfortable using Spanish. This was more often the case with the low proficiency learners than with the high-proficiency learners. Once the experiment was in progress, however, efforts were made to communicate in English as much as possible, in order to keep language switching to a minimum.

3.6 General Electrophysiological Methods

3.6.1 ERP Procedures

All experiments took place in a 9' x 10' ft soundproof, electrically shielded booth. Test stimuli were presented over free field, through speakers located one meter in front and behind the participant's head. Sound level measured one meter from speakers was 59 dB.

3.6.2 Stimulus Delivery

All stimuli are delivered using Eprime with Biological Add-on. This software is custom-designed, to be used with the Geodesic Net Station. This software controls the timing of stimulus delivery and sends information concerning the timing of the events to the Netstation G4-Mac computer.

3.6.3 Electrode Placement

ERPs were recorded using a sixty-five electrode Geodesic net. The vertex served as the reference during data collection and a right posterior-inferior site as the ground.

Eye-movements were monitored from two frontal and two infra-orbital electrode sites. Impedances were maintained below 60 kOhms. This value is acceptable with the high-impedance Geodesic amplifies (input impedance 200 Mohms) when data are collected in an electrically shielded room (Ferree, et al., 2001, Picton, et al., 2000).

3.6.4 Data Recording

The EEG was amplified 10K with a bandpass of 0.1 to 50 Hz, using Geodesic amplifiers. NetStation 3.01 system (on a G4 Mac) in continuous mode was used to acquire the data at a sampling rate of 200 Hz per channel for later off-line processing.

3.6.5 Post-Acquisition Data Analysis

The EEG was low-pass filtered at 30 Hz, corrected for eye blinks, and segmented into epochs of 900 ms. Any epoch containing electrophysiological activity exceeding +/- 70 μV was rejected. ERP averages were calculated for target stimuli. Channels that were bad (artifact or zero-variance) on more than 10% of the trials were replaced using spherical spline interpolation. Data was re-referenced to an average reference for statistical analyses. Topographic maps were constructed from voltage values at 64 electrode sites for grammatical and ungrammatical sentences. In addition, topographical maps were created based upon subtraction waves, which were derived from amplitudes for ungrammatical – grammatical sentences.

3.6.6 Statistical Analysis

ANOVAS were performed based on planned comparisons for specific electrode sites in each of three latency ranges. For early anterior modulations, analyses were performed in the 100-250 ms window, at right and left frontal electrodes 13, 62 in the Geodesic system. These correspond with positions approximately halfway between F3 and F5 on the left and F4 and F6 on the right, in the 10-20 system. Analyses for the 250-450 ms latency range were performed at the same frontal sites, including central sites 4, , 30, 34, and 38, corresponding to Fz, Cpz, Pz, and Oz in the 10-20 system. Lateral sites 28 and 46, corresponding roughly to midway between P3 and P5 on the left and P4 and P6 on the right were included in comparisons for this latency range. In addition, temporo-parietal sites 21, 25, 53 and 50, corresponding to C5, CP5, C6, and CP6, respectively, were included in these planned comparisons. In the 500-800 ms latency range, centro-parietal sites 30, 34, 38, and lateral posterior sites 28 and 46 were included. Post hoc analyses were performed to examine group comparisons based upon initial analyses.

Chapter 4: Electrophysiology Results

4.1 Word Order Condition

4.1.1 Early Anterior Negativity

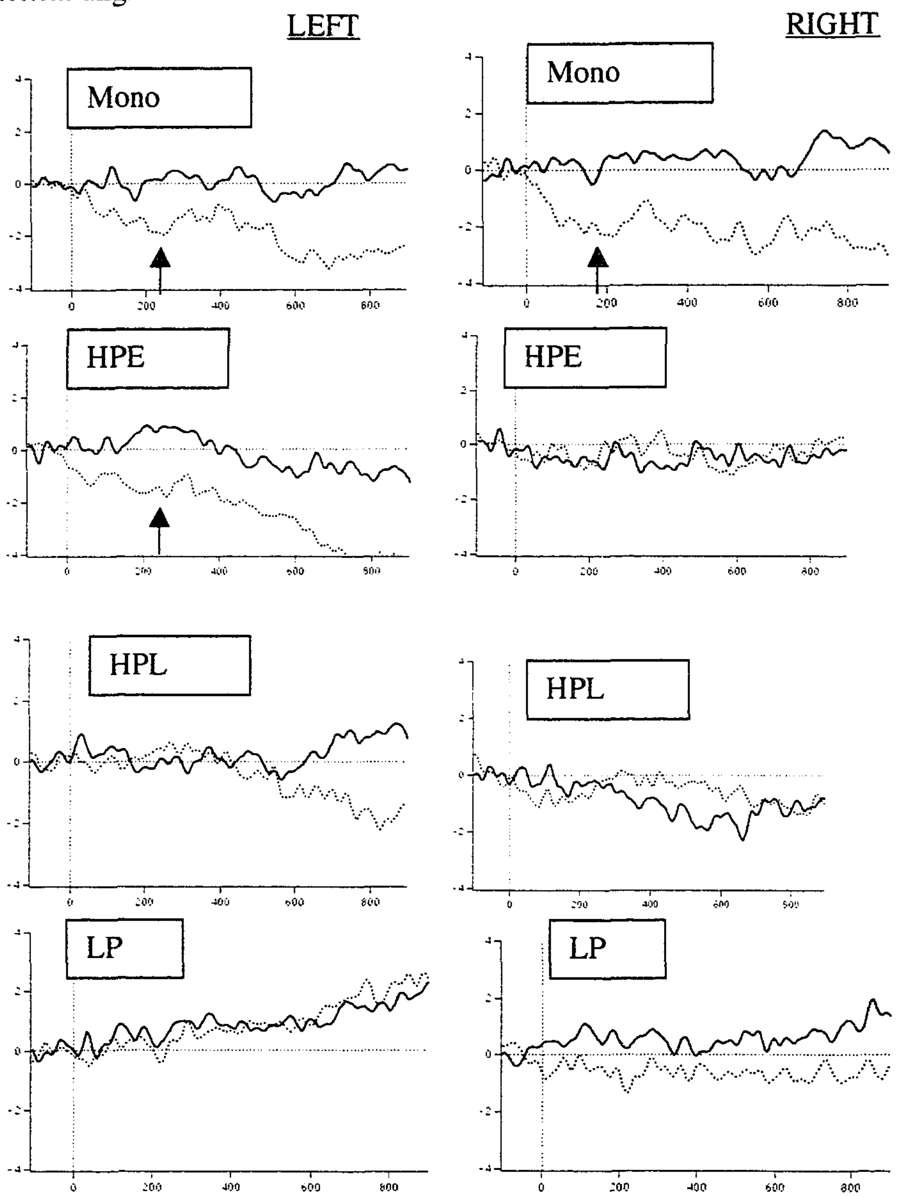
ANOVAs were performed at frontal electrode sites 13 and 62, which correspond most closely to F3/5 and F4/6 in the 10-20 system. Analyses examining condition (grammatical, ungrammatical) by electrode site 13 (F3/5) and 62 (F4/6) by time, including three 50-ms windows (100-150, 151-200, 201-250) were performed for each group separately. Grand means of the ERPs to the negative marker *not* in grammatical and ungrammatical sentences for all groups are shown in Figure 1.

Monolingual: A hemisphere by time by condition interaction is found for the 100-250 ms time window (F(1,9)=5.062, p=.05). Repeated measures ANOVAs for hemisphere by condition were performed at each of three 50-ms subintervals for the frontal sites reveals an effect of condition in all three intervals: 100-150ms (F (1, 9)=9.0, p=.009); 151-200 ms (F (1,9)= 16.255, p=.003); 201-250 ms (F(1,9)=6.383, p=.032). Mean amplitudes at the three 50-ms time intervals for the left and right frontal electrode sites are shown in Table 1.

High Proficiency Early: An ANOVA comparing hemisphere by condition by time for the100-250 ms window reveals an interaction of hemisphere by condition by time (F (2, 14=4.407, p=.033) as well as a main effect of hemisphere (F(1, 7)=6.54, p=.035). Follow up analyses examining hemisphere by condition at frontal sites 13 and 62 for each subinterval reveal a hemisphere by condition

Figure 1. ERPs to grammatical sentences and Word Order violations at right and left frontal sites 13(F3/5) and 62(F4/6)

______ grammatical
.... ungrammatical



Mono=Monolingual
HPE=High Proficiency Early
HPL=High Proficiency Late
LP=Low Proficiency

±4 μV
-100-900 ms

Table 1. Subtracted Mean Amplitudes (100-250 ms). All Groups

Ungrammatical – Grammatical

	LEFT F3 (13)			RIGHT F4 (62)		
Time in ms	100-150	151-200	201-250	100-150	151-200	201-250
Mono	-1.3	-1.11	-1.98	0.27	-0.57	1.37
HPE	-1.16	-2.04	-2.38	0.02	0.4	0.01
HPL	-0.44	0.21	0.4	0.25	-0.02	-0.41
LP	-0.39	-0.24	-0.44	0.88	0.74	1.04

Mono=Monolingual
HPE=High Proficiency Early
HPL=High Proficiency Late
LP=Low Proficiency

interaction in the 151-200 ms interval ($F(1,7)=6.845$, $p=.035$). No interaction is found in the 201-250 ms interval ($F(1,7)=4.177$, $p=.080$). Separate analyses for right and left frontal electrodes reveal a significant main effect of condition at the left site 13 (F3/5) in the 201-250 ms interval $p=.05$). There is no significant difference in amplitude from 100-250 ms at right frontal sites for this group.

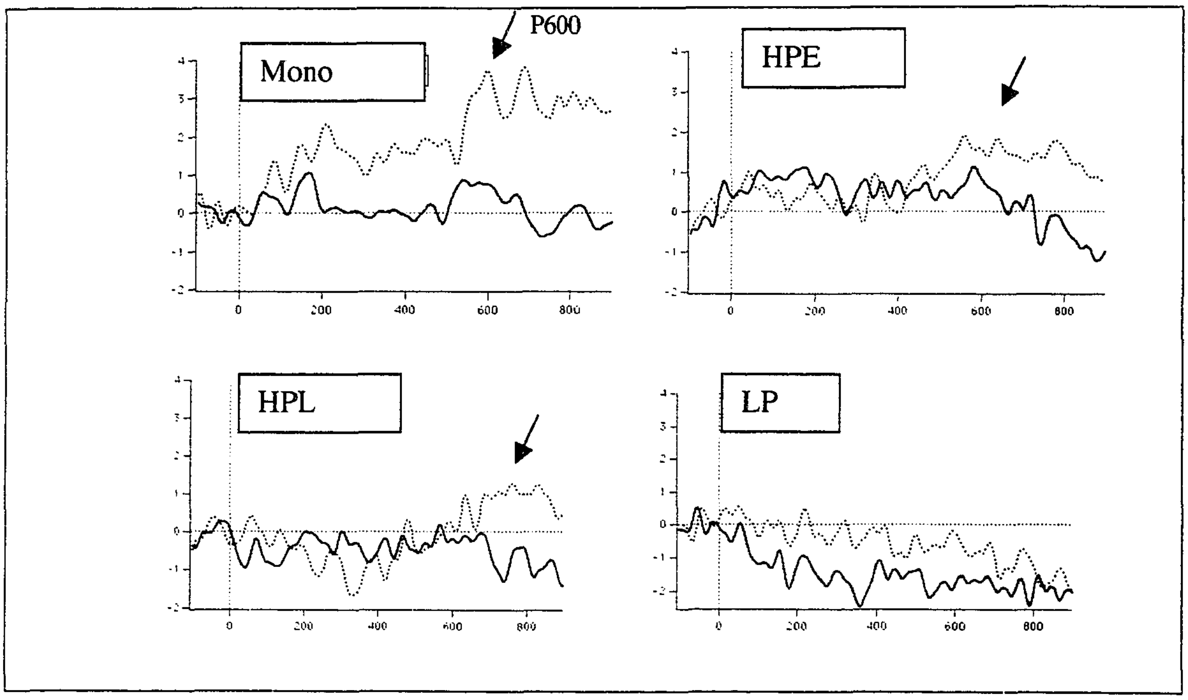
High Proficiency Late: No main effects of condition or interactions including condition at frontal sites in the 100-250 ms time interval are found.

Low Proficiency: No main effects of condition or interactions with condition are found. Figure 1 shows that ERPs to grammatical and ungrammatical sentences are nearly identical across the entire epoch for Low Proficiency learners.

In sum, responses to ungrammatical Word Order sentences are more negative at lateral frontal sites for Monolinguals and at left frontal sites for HPE learners in the early 100-250 ms latency range. HPL and LP learners show no significant differences at anterior sites in the ungrammatical condition compared to the grammatical condition in this latency range.

Figure 2. Grand mean ERPs for grammatical and ungrammatical sentences at 38(Pz)
Word Order Condition

_______ grammatical
.... ungrammatical



Mono=Monolingual
HPE=High Proficiency Early
HPL=High Proficiency Late
LP=Low Proficiency

-2-4 μV
-100-900 ms

4.1.2 Anterior Negativity (250-450 ms)

ANOVAs examining hemisphere, condition, and time were performed at frontal electrodes 13(F3/5) and 62(F4/6) and at superior temporo-parietal sites 21, 53, 25, and 50, which correspond most closely to C5 and C6 and CP5 and CP6, respectively, in the 10-20 system. Including these sites in the analysis was based upon evidence from previous studies that negativities in the 250-450 latency range vary in topography, from a more temporo-parietal distribution (Neville et al., 1991) to a more fronto-central (Coulson et al, 1998; Osterhout & Mobley, 1995; Gunter et al., 1997; Penke et al., 1997) or left frontal distribution (Rösler et al., 1993; King and Kutas, 1995). The anterior negativity can be seen in ERPs at frontal sites between 250 and 450 ms in Figure 1.

Monolingual: Main effects of condition are found at site 13 (F3/5) and site (F/4/6) 62, $F(1,9)=19.3$, $p=.002$, as well as at 21(C5) and 53(C6) ($F(1, 9)=5.418$, $p=.013$ in the monolingual group. Figure 1 shows a negativity in the ungrammatical condition compared to the grammatical condition at frontal sites in the 250-450 ms time interval. There were no significant effects at fronto-central site Fz.

High Proficiency Early: Mean amplitudes and Standard Deviations for 13(F3/5) and 62(F4/6) are shown in Tables 2 and 3. Increased negativity at left electrode sites is confirmed by a hemisphere by condition interaction found at frontal sites 13 and 62 ($F(1,7)=5.629$, $p=.049$).

Table 2. Mean Amplitudes (250-450 ms) F3 (13) Left Frontal Site

	Grammatical				Ungrammatical			
Time	250-300	301-350	351-400	401-450	250-300	301-350	351-400	401-450
MONO								
	0.4	0.22	-0.12	0.27	-1.60	-1.61	-1.42	-1.37
SD	1.21	1.43	2.14	2.14	2.36	2.23	1.88	1.98
HPE								
	0.81	0.61	0.19	0.00	-1.47	-1.37	-1.58	-2.02
SD	1.30	1.12	1.329	1.35	2.70	2.72	2.82	2.82
HPL								
	0.393	0.15	0.409	0.14	-0.02	0.36	0.00	0.00
SD	2.15	2.17	2.061	2.04	2.21	1.67	1.81	1.814
LP								
	0.93	0.97	0.92	0.83	0.59	0.54	0.68	0.72
SD	2.27	2.13	2.16	2.33	3.13	3.06	3.44	3.23

Table 3. Mean Amplitudes (250-450 ms) F4 (62) Right Frontal Site

	Grammatical				Ungrammatical			
Time	250-300	301-350	351-400	401-450	250-300	301-350	351-400	401-450
MONO								
mean	0.45	0.47	0.43	0.49	-1.52	-1.66	-1.73	-1.72
sd	1.01	1.26	1.00	1.28	0.80	1.21	1.01	1.1
HPE								
mean	-0.26	-0.69	-0.77	-0.84	-0.03	-0.01	-1.53	-0.227
sd	1.19	1.52	1.69	1.91	1.08	1.15	1.45	1.49
HPL								
mean	-0.41	-0.46	-0.73	-0.87	-0.03	-0.26	-0.38	-0.65
sd	2.23	2.62	2.58	2.63	1.27	1.54	1.0	1.1
LP								
mean	0.76	0.32	0.32	0.18	-0.42	-0.58	-0.67	-0.55
sd	1.64	1.64	2.37	2.41	2.03	2.08	2.31	2.45

Mono=Monolingual
HPE=High Proficiency Early
HPL=High Proficiency Late
LP=Low Proficiency

High Proficiency Late: An analysis for hemisphere and condition performed at frontal sites 13(F3/5) and 62(F4/6) reveals no significant effects including condition.

Low Proficiency: This group shows no interactions or main effects involving condition.

Group Comparisons: Post hoc analyses of Monolingual versus HPE groups and HPE versus HPL groups, respectively, were performed. Results for the Monolingual versus HPE comparison across the 250-450 ms time interval, show a condition by group interaction at the right frontal site 62(F4/6) ($F(1,16)=11.208$, $p=.004$), reflecting the bilateral nature of the frontal activity observed in the Monolingual group, compared to the left-oriented activity in the HPE group. No condition by group interaction is found at the left frontal site 13(F3/5) in the 250-450 ms time window. The analysis comparing the HPE and HPL groups reveals no interaction of group and condition at frontal sites, though a group by condition interaction is found at site 13(F3/5) ($F(1,15)=5.284$, $p=.036$).

In sum, ERPs for monolinguals in the 250-450 ms range show greater negativity in response to ungrammatical compared to grammatical sentences at lateral frontal sites. HPE learners show greater negativity for ungrammatical than grammatical sentences only at left anterior sites. No such effects of condition are seen in the HPL or low proficiency group.

4.1.3 Late Positivity

ANOVAs were preformed at Pz (34), Pz (38), P3 (28), P4 (46) for six 50-ms time intervals between 500 and 800 ms. Grand Mean ERPs to grammatical and ungrammatical sentences at Pz(38) for all groups are shown in Figure 2. Posterior electrodes 28 and 46, which correspond most closely to P3 and P4 in the 10-20 system, and central sites 30, 34, and 38, which correspond most closely with Cpz, Pz, and Oz in the 10-20 system, were included in the analysis.

Monolingual: The monolingual group shows a significant effect of condition at central posterior sites 34(CPz) ($F(1,9)=15.306$, $p=.004$) and at 38(Pz) ($F(1,9)=26.407$, $p=.001$) in response to ungrammatical sentences compared to grammatical sentences across the entire 500-800 ms time interval. They also show an interaction of condition by time at left superior posterior site 28(P3) ($F(5, 45)=3.547$, $p=.009$). A main effect of condition is found at 46(P4) ($F(5,45)=2.92$, $p=.023$). To further examine the condition by time interaction at 28 (P3), comparisons were performed for each of six 50-ms time intervals between 500 and 800 ms. A main effect of condition is also observed at right posterior site P4 in four consecutive subintervals: 601-650ms ($F(1,9)=5.392$, $p=.045$); 651-700ms ($F(1,9)=5.276$, $p=.040$); 701-750ms ($F(1,9)=8.778$, $p=.016$); 751-800ms ($F(1,9)=7.70$, $p=.022$). A main effect of condition is found at left posterior site 28(P3) in the 701-750 ms interval ($F(1,9)=6.921$, $p=.027$) and in the 751-800 ms interval ($F(1,9)=10.721$, $p=.010$).

High Proficiency Early: The HPE group shows a condition by time interaction at site (34) Pz ($F(5,35)=3.143$, $p=.019$). A main effect of condition is found at posterior sites 28(P3) and 46(P4) ($F(1,7)=7.340$, $p=.030$).

High Proficiency Late: A condition by time effect is found at site 34 (Pz) for the 300 ms latency range ($F(5,40)=7.086$, $p= .000$) and at site 38(Pz) ($F(5,40)=5.508$, $p=.001$). A condition by time interaction is found at these sites as well ($F(5,40)=2.982$, $p=.022$). Analyses at 50 ms subintervals reveal a main effect of condition at Pz(34) in the 701-750 ms window ($F(1,8)=10.295$, $p=.012$) and an effect of condition in the 751-800 ms window ($F(1,8)=5.043$, $p=.05$).

Low Proficiency: No significant interactions or main effects involving condition are observed for the LP group.

Group Comparisons: Figure 3 shows a graph of mean amplitudes for sentences at 38(Pz) for each group in each of the six 50-ms. The greatest difference in mean amplitude between ERPs to grammatical and ungrammatical sentences is in the monolingual group. This chart also shows that while the LP group's responses to ungrammatical sentences are more positive in general than their responses to grammatical sentences, there is little change in amplitude for either condition across the 300-ms interval, compared to the other groups. Subtracted mean amplitudes for grammatical and ungrammatical for all groups are depicted in Figure 4, showing a linear increase in amplitude for the Monolingual group as well as increased positivity across the 300 ms time interval for the HPE and HPL groups.

Figure 3. Mean amplitudes 500-800 ms for grammatical and ungrammatical sentences

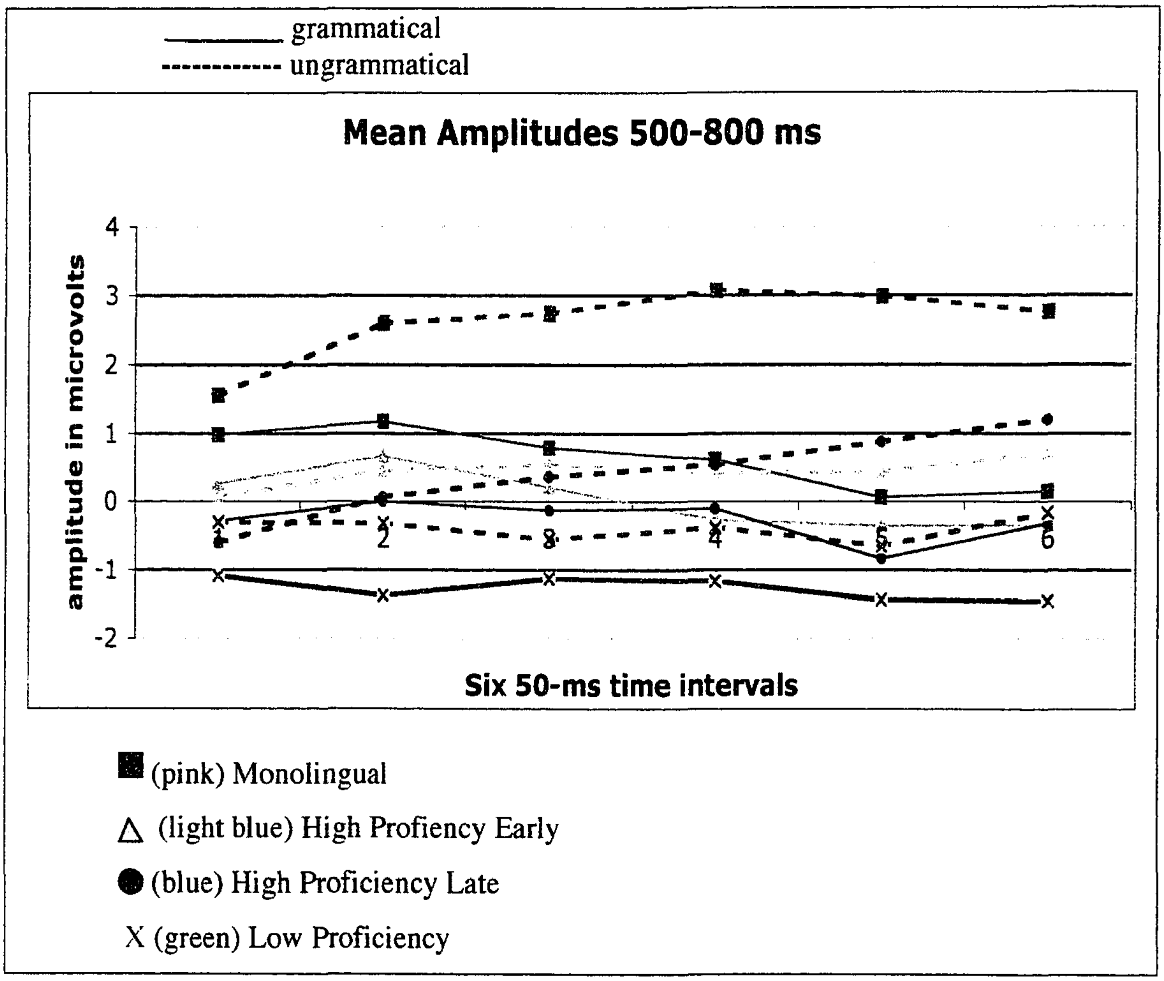
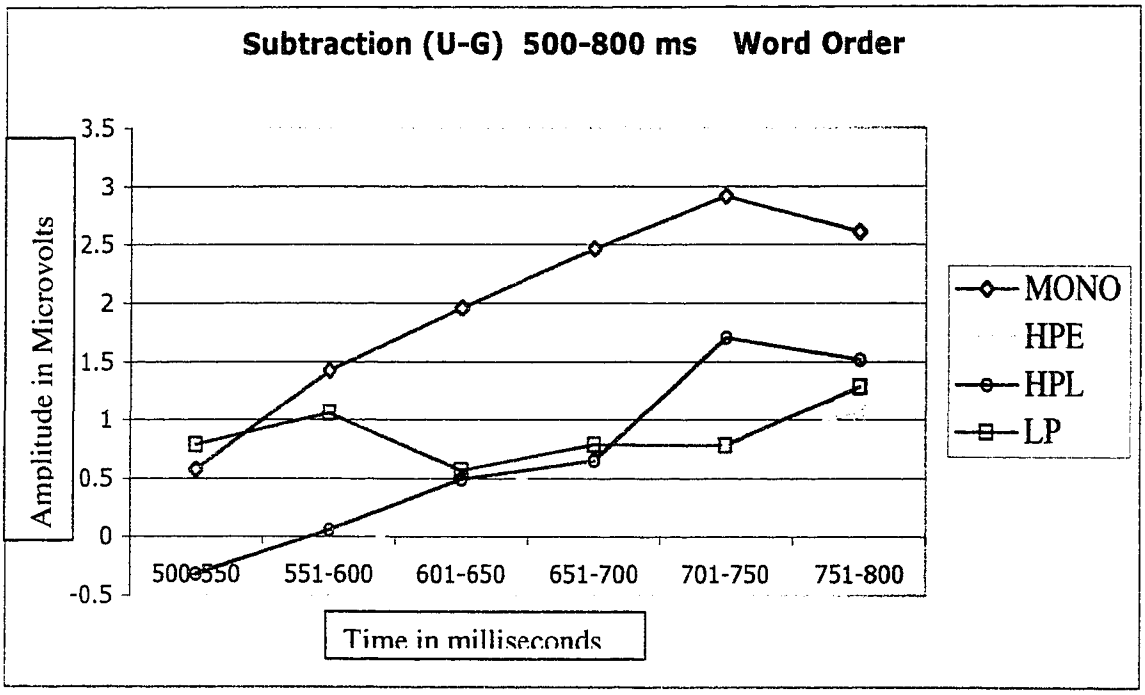


Figure 4. Subtraction values for 38 (Pz) Word Order Condition



U=ungrammatical
G=grammatical

Mono=Monolingual
HPE=High Proficiency Early
HPL=High Proficiency Late
LP=Low Proficiency

ANOVAs performed for 38(Pz) at each sub-interval show a significant group by condition interaction. Group comparisons at 38(Pz) for each of the six 50-ms time intervals show no effect of group at any time interval. Only main effects of condition from 550-800 ms were found: 551-600 ms ($F(1, 35)=4.171$, $p=.049$), 601-650 ms $F(1, 35)=5.332$, $p=.028$); 651-700 ms ($F(1,35)=10.944$, $p=.002$); 701-750 ms ($F(1, 35) = 20.520$, $p=.000$); and 751-800 ms ($F(1, 35)=15.461$, $p=.000$).

4.2 Inflection Condition

4.2.1 Early Anterior Negativity

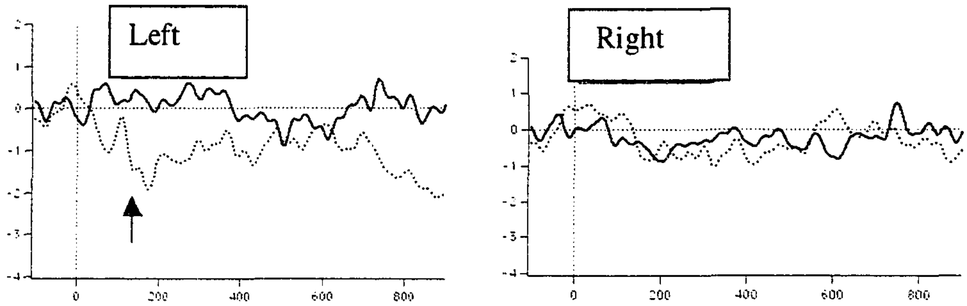
The monolingual group shows a main effect of condition at frontal sites 13(F3/5) and 62(F4/6) ($F(1,27)=7.301$, $p=.024$) in the 100-250 time interval. Figure 5 shows grand means for the Monolingual group in the Inflection condition, and Figure 6 shows grand mean ERPs to grammatical and ungrammatical sentences for all L2 groups. No interactions or main effects involving condition are seen in the 100-250 time window for the HPE, HPL, or LP groups.

4.2.2 Anterior Negativity (250-450 ms)

Monolingual: Analysis for hemisphere and condition reveals a trend in the direction of a hemisphere by condition interaction at frontal sites F3 (13) and F4 (62) ($F(1,9)=3.754$, $p=.085$). An analysis at site F7 (15) reveals a main effect of condition in the 250-450 ms time interval ($F(1,9)=7.527$, $p=.023$). Table 4 shows that mean amplitudes for ERPs to ungrammatical sentences at the left frontal sites to be more negative than for grammatical sentences in the 250-450 time interval.

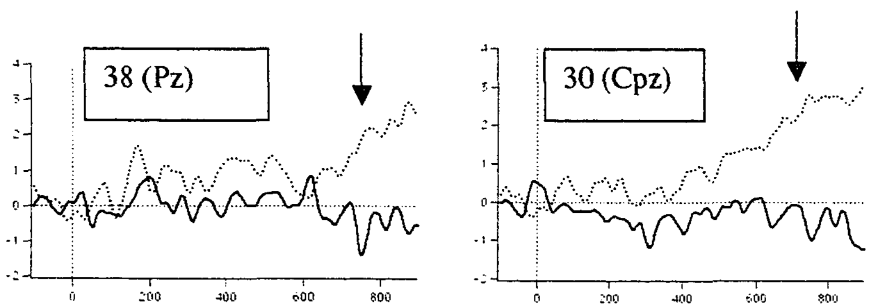
Figure 5a. Grand means for the Monolingual group at left and right frontal sites 13 (F3/4) and 62 (F4/6). Inflection condition

_________ grammatical
.... ungrammatical



-4-2 µV
-100-900 ms

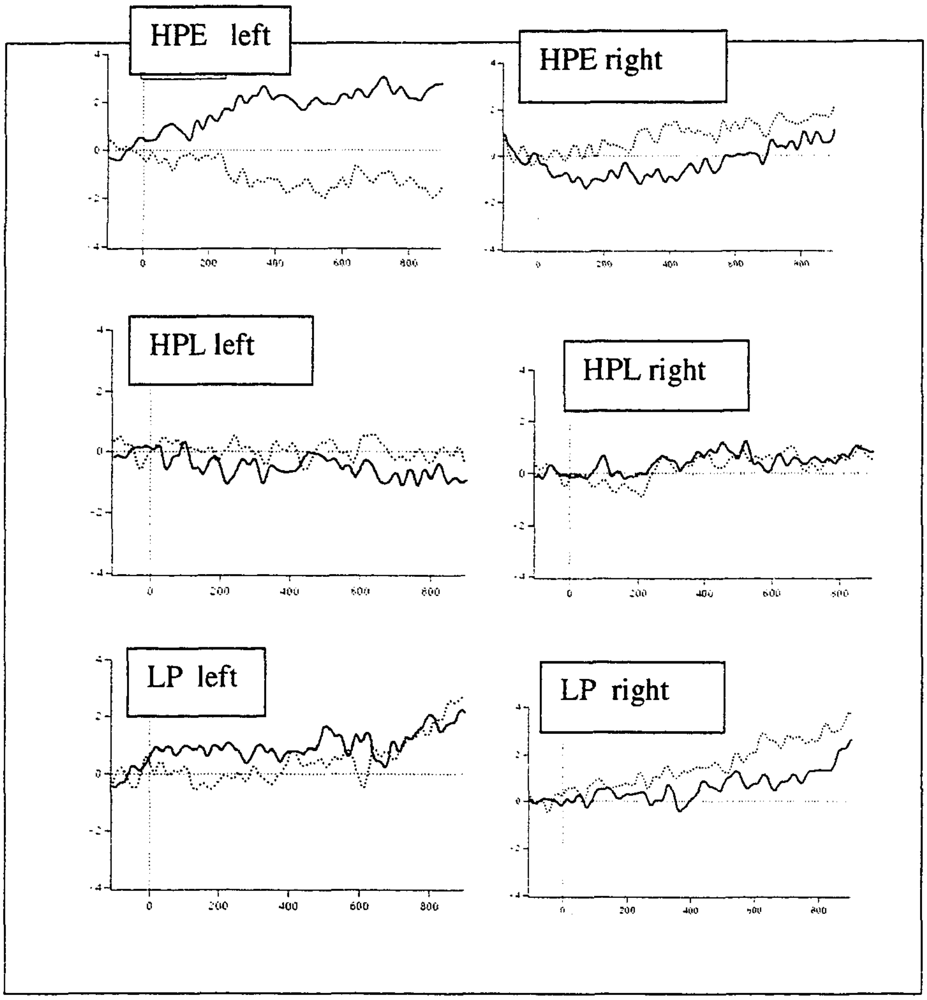
Figure 5b. Grand means for the Monolingual group at centro-parietal sites Pz(38 and Cpz (30). Inflection Condition



-2-4 µV
-100-900 ms

Figure 6. Grand mean ERPs to grammatical and ungrammatical sentences at left and right frontal sites for L2 groups. Inflection Condition

________ grammatical
.... ungrammatical



HPE=High Proficiency Early
HPL=High Proficiency Late
LP=Low Proficiency

±4 μV
-100-900 ms

Table 4. Subtracted amplitudes for the 250-450 ms time window at left and right frontal sites. Inflection Condition

	Left Frontal site 13(F3/5)				Right Frontal site 62(F4/6)			
Time in ms	[200-250]	[251-300]	[301-350]	[351-400]	[200-250]	[251-300]	[301-350]	[351-400]
MONO	-2.0	-1.83	-1.29	-1.6	-1.97	-0.33	-2.16	-2.21
HPE	-1.87	-1.99	-1.46	-2.02	0.23	2.25	0.91	0.62
HPL	0.44	0.54	-0.13	0.12	0.24	0.12	0.79	0.82
LP	-0.35	-0.44	-0.24	-0.12	-1.18	-1.07	-0.99	-0.74

MONO = Monolingual
HPE = High proficiency early
HPL = High proficiency late
LP = Low Proficiency

High Proficiency Early: No significant differences are found at frontal sites.

High Proficiency Late Group: No main effects or interactions including condition are found at frontal sites.

Low Proficiency: No interactions or main effects involving condition are found at frontal sites.

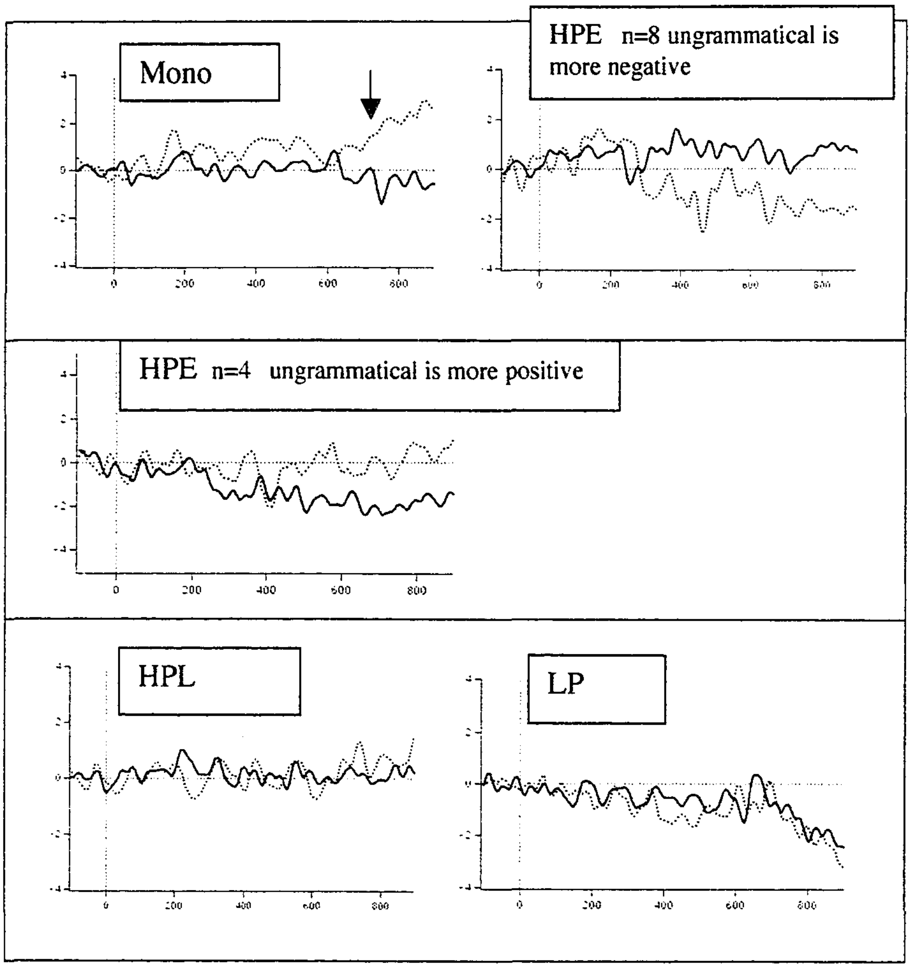
4.2.3 Late Positivity

Monolingual: ANOVAs were performed at centro-parietal site Pz(34) for the 500-800 time interval. A condition by time interaction is found over the 300 ms interval F(5, 45)=9.663, p=.000) and at P4 (F(5, 45)=6.05, p=.000). Grand means at centro-parietal site Pz(38) (Figure 7) indicate that this positivity begins gradually, after about 700 ms.

High Proficiency Early: Results of an ANOVA comparing grammatical and ungrammatical sentences reveals no interactions or main effects involving condition. Visual inspection of the individual ERP data from the 8 subjects in this group reveals that four show a late centro-parietal positivity, which is consistent with the P600. In contrast, the other four show a negativity at centro-parietal sites from about 200 post stimulus onset to the end of the epoch. Grand mean for ERPs from both subgroups along with the grand means from the Monolingual and HPL groups are included in Figure 7. ANOVAs performed on the amplitudes for the four subjects showing the late positivity reveal a main effect of condition at Pz(34) F(1, 3)=32.836, p=.011 and Pz(38) F(1, 3)=14.570, p=.032 in the 751-800 ms time interval.

Figure 7. Grand means for grammatical and ungrammatical at Pz (38)
for all groups. Inflection Condition

________ grammatical
.... ungrammatical



Mono=Monolingual
HPE=High Proficiency Early
HPL=High Proficiency Late
LP=Low Proficiency

±4 µV
-100-900 ms

High Proficiency Late: No interactions involving condition are found at posterior sites for this group in the 500-800 ms latency range though there appears to be an increase in positivity at centro-parietal sites at around 800 ms.

Low Proficiency: No interactions or main effects of condition are found at posterior sites for this group between 500 and 800 ms.

ANOVAs performed with group as a between subjects factor show a marginal but not significant difference at Pz in the 751-800 ms time interval $F(3,33)=2.516$, $p=.75$.

In sum, statistical analyses indicate the presence of a P600 effect for monolinguals. Individually, half of the HPE learners (4 of 8) appear to have a P600 response. No significant differences are found for the High Proficiency Late or the Low Proficiency learners in ERP responses to inflectional violations at later latencies.

Chapter 5: Behavioral Results

One-way ANOVAs were performed in order to compare means for reaction time and accuracy for each sentence type across the four groups. Separate comparisons for accuracy included percent correct from the total number of possible responses, percent correct from the number of attempted responses, and an average of the two, which reflects the number of missed responses and accuracy level. Comparisons of variance for each accuracy measure were also performed, in order to assess variability in latency and accuracy of responses for grammatical and ungrammatical sentences. Charts of mean accuracy and reaction times for all groups are shown in Figures 8 and 9.

Accuracy for the low proficiency group is consistently lower for all sentence types than for the other three groups. Accuracy for the high proficiency late group and high proficiency early group is not different, in general, nor are latencies for reaction time across these two groups. Accuracy differences across groups are largest for ungrammatical sentences in both the Word Order condition and the Inflection condition. Greater differences are seen in the ungrammatical word order condition.

5.1 Word Order Condition

5.1.1 Grammatical

Accuracy: Mean accuracy rates for all groups are shown in Table 5. A One-Way ANOVA comparing means for correct responses to grammatical Word Order (**WO-G**) sentences, based upon the number attempted, reveals that the responses for the Low Proficiency group are significantly less accurate than responses for the

Figure 8. Mean reaction times for all groups in both conditions.

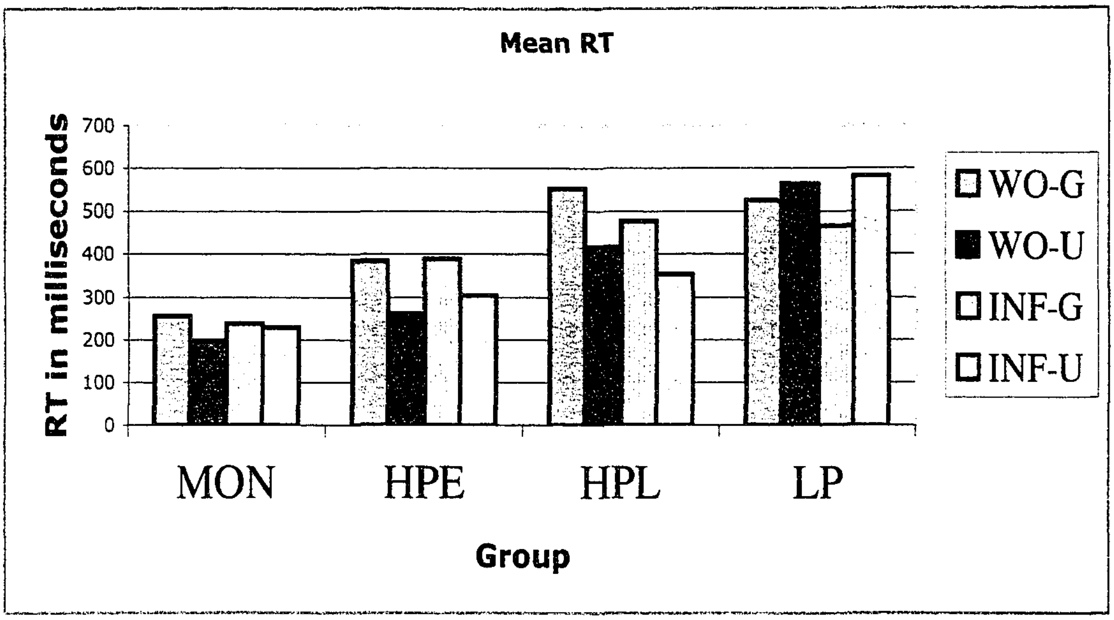
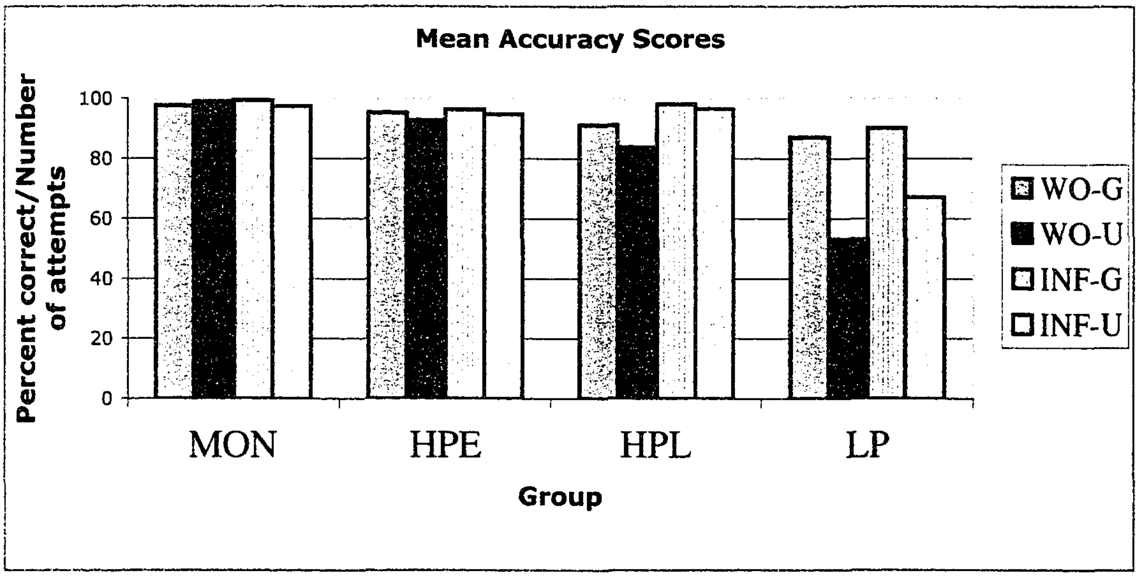


Figure 9. Mean accuracy scores for all groups for both conditions.



WO-G = Word Order, grammatical
WO-U = Word Order, ungrammatical
INF-G = Inflection, grammatical
INF-U = Inflection, ungrammatical

Table 5. Mean Accuracy, % correct out of total attempts in both conditions.

Group	WO-G	sd	WO-U	sd
MONO	97.8	(2.0)	99	(2.0)
HPE	95.4	(2.5)	92.7	(9.4)
HPL	91.2	(8.5)	83.9	(19.0)
LP	87	(9.1)	53	(40)

Group	INF-G	sd	INF-U	sd
MONO	99.5	(1.04)	97.5	(4.0)
HPE	96.4	(4.6)	95	(2.7)
HPL	98.0	(4.6)	97	(5.3)
LP	90.2	(9)	67	(21.4)

Monolingual group (p=.006), and that the difference between the Low Proficiency group and the HPE group approaches significance (p=.074). Differences in the number of correct responses from the total number of possible responses are not significant across groups for **WO-G** sentences.

Comparisons of within-group variance in accuracy scores for grammatical Word Order sentences reveal significant differences between HPL and Monolingual groups (df 8/9 F > 0.002), and between LP and Monolingual groups (df 8/9 F > 0.002). Therefore, for group comparisons of the Monolingual and HPL groups which show no significant difference, we cannot be entirely confident of the validity of this finding. Further non-parametric testing and normalization are required to ensure confidence levels in this case.

Reaction Time: A One-way ANOVA comparison for reaction time reveals that the HPL and LP groups are significantly slower in responding to **WO-G** sentences than the Monolingual group (mono/HPL, p=.009; mono/LP, p=.020). Table 6 shows mean reaction times and standard error values for all groups in both conditions.

5.1.2 Ungrammatical

Accuracy: One-Way ANOVA analysis for Accuracy-Total Attempts for ungrammatical Word Order (**WO-U**) sentences reveals that the Low Proficiency group's responses are significantly less accurate than each of the other three groups (Monolingual group, p=.001; HPE group, p=.009; HPL group, p=.038.) Comparisons of within-group variance indicate that there are significant differences at the .002 alpha level between the Monolingual group and each of the other groups and

Table 6. Mean Reaction Times and Standard Error values for all groups.

Sentence Type	Mean Reaction Times			
	MONO (SE)	HPE (SE)	HPL (SE)	LP (SE)
Word Order G	256.0 (43.6)	385.5 (51.6)	552.6 (88.9)	525.8 (60)
Word Order U	196.5 (35.5)	260.3 (40)	417.7 (48)	563.5 (92)
INFL G	238.5 (35.2)	389.2 (58)	478 (58)	466.6 (56)
INFL U	229 (30.7)	302.5 (38)	352.6 (22)	581.5 (82)

Mono = monolingual
HPE = High Proficiency Early
HPL = High Proficiency Late
LP = Low Proficiency

Table 7. Standard Deviations for accuracy in grammatical Inflection sentences, based upon percent correct out of total number of attempted responses.

Group	SD
MONO	1.04
HPE	4.6
HPL	4.6
LP	9

Mono = monolingual
HPE = High Proficiency Early
HPL = High Proficiency Late
LP = Low Proficiency

between the HPE and LP groups. Due to this violation of homogeneity of variance, further non-parametric analyses are required in order to ensure confidence in the statistical findings that there is no significant difference in accuracy for ungrammatical WO sentences across Monolingual HPE and HPL groups.

<u>Reaction Time</u>: A One-Way ANOVA comparing reaction time in **WO-U** sentences reveals significant differences between the Monolingual group and LP group (p=.000) and between the Monolingual group and the HPL group (mono/HPL, p=.047). A significant difference between the HPE and LP groups is also found (HPE/LP, p=.009).

In sum, accuracy rates for the LP group are significantly slower than they are for the Monolingual group and are also marginally slower than the HPE group for grammatical Word Order sentences. The LP group is also significantly less accurate in judging ungrammatical Word Order sentences. The number of correct responses for this group is significantly lower than for each of the other three groups. Reaction times are significantly slower for the LP group in judging ungrammatical word order sentences than they are for both Monolingual and HPE groups. Reaction times for the HPL and LP groups are significantly slower than reaction times for the Monolingual group for grammatical Word Order sentences. The HPL and LP groups also show more variability in reaction time than the Monolingual and HPE groups in both grammatical and ungrammatical sentences. Standard deviations are higher for High Proficiency Late learners and Low Proficiency learners, whereas they are identical for Monolingual and High Proficiency Early groups for grammatical sentences and are nearly identical for ungrammatical sentences.

5.2 Inflection Condition

5.2.1 Grammatical

Accuracy: A comparison of percent correct/number attempted across groups reveals no significant differences across groups for **INF-G** sentences. Significant differences in variance for grammatical Inflection sentences were found between HPL and Monolingual groups (df 8/9 F > 0.002), LP and Monolingual groups (df 8/9 F > 0.002) and LP and HPE groups (df 8/7 F > 0.002). Due to these violations of homogeneity of variance, confidence levels in statistical results showing no significant differences between accuracy scores for this condition are reduced, pending further non-parametric analyses. Table 6 shows the standard deviation values associated with each mean accuracy score.

Reaction Time: Reaction times to grammatical inflection (**INF-G**) sentences are significantly slower for the LP group than the Monolingual group, as revealed in a One-Way ANOVA (df 3, 34) p=.014. The HPL group's responses are also significantly slower than the Monolingual group to **INF-G** sentences (p=.009).

5.2.2 Ungrammatical

Accuracy: The number of correct responses out of the total attempted for the LP group for ungrammatical Inflection sentences (**INF-U**) are significantly fewer than for all three of the other groups (LP/Mono, p=.007; LP/HPE, p=.024; LP/HPL, p=.007). Comparisons of variance show significant differences between LP and Monolingual (df 8/9 F > 0.002), LP and HPE (df 8/7 F > 0.002) and LP and HPL (df 8/8 F > 0.002) groups, reducing confidence levels for results showing no significant differences across these groups. Standard deviations are shown with accuracy rates in Table 5.

Reaction Time: Reaction times for the LP group are significantly slower than for the other three groups (LP/Mono, p=.000; LP/HPE, p=.004; LP/HPL, p=.012).

ANOVAs were performed to compare Reaction Time and Accuracy in grammatical and ungrammatical conditions for all groups. Factor analyses included sentence type (word order vs inflection) and grammaticality (grammatical vs ungrammatical).

Similar analyses were performed to compare reaction time and accuracy in grammatical and ungrammatical conditions for all groups. Factor analyses included sentence type (word order vs inflection) and grammaticality (grammatical vs ungrammatical).

Accuracy: Accuracy scores for grammatical and ungrammatical sentences in both Word Order and Inflection conditions were not significantly different for the Monolingual, HPE or the HPE groups. The LP group shows a significant difference in accuracy scores between grammatical and ungrammatical sentences in both the Word Order condition (F(1,8)=6.870, p=.031) and in the Inflection condition (F(1,8)=5.422, p=.048).

Mean accuracy rates and standard deviations (Table 7) show that variability is greatest for the HPE and HPL groups in ungrammatical Word Order sentences (9.4 and 19.0 respectively). When one outlier who responded to less than half of the grammatical Inflection sentences was removed from the analysis for grammatical Inflection sentences, accuracy results for the HPL group are quite similar to the HPE group (mean accuracy: 98, sd: 4.6). The LP group's standard deviations for accuracy are highest in ungrammatical Word Order sentences (40.0), and they are also quite high in ungrammatical Inflection sentences (36.0). Their accuracy scores are close to chance for both sentence types, compared to 87% and 90% in judging grammatical sentences.

Reaction Time: For Monolinguals, an ANOVA for reaction time including factors of sentence type and grammaticality reveals an interaction of grammaticality and type ($F(1,9)=10.402$, $p=.010$). For the HPE group a main effect of grammaticality is found ($F(1,5)=17.723$, $p=.006$). The HPL group has a main effect of grammaticality but not sentence type ($F(1,9)=6.498$, $p=.031$). No main effect for grammaticality is found for the LP group.

In sum, sentence type (Word Order or Inflection) and grammaticality affect reaction time for the Monolingual group, with responses to ungrammatical sentences significantly faster than responses to ungrammatical sentences and the greater difference between the two occurring in Word Order sentences. Grammaticality but not sentence type affects reaction time for the HPE and HPL groups, while for the LP group there is no effect of grammaticality on reaction time. For Monolinguals, reaction times in judging violations of Word Order are significantly faster than they are to grammatical sentences of the same type. This is not the case with their responses to grammatical versus ungrammatical Inflection sentences. Accuracy rates for the HPE and HPL groups do not differ based upon grammaticality or sentence type. The LP group shows the same amount of variability across grammatical and ungrammatical sentences, regardless of sentence type (Word Order or Inflection). Their accuracy, however, differs significantly in both Word Order and Inflection sentences, depending on whether the sentence is grammatical or ungrammatical, with correct judgments on ungrammatical Word Order sentences at nearly chance level, in contrast to relatively high accuracy scores on grammatical sentences. Nonetheless, accuracy remains significantly lower than it is for the three other groups, even for grammatical sentences.

Chapter 6: Discussion

6.1 Word Order and Inflection Processing in Monolingual English Speakers: ERP Effects

6.1.1 Early Left Anterior Negativity

The early anterior negativity elicited by phrase structure violations and sometimes larger on the left is generally taken to reflect automatic processing. The (fronto-central) negativity observed in the current study in the Word Order condition in the 100-250 ms latency window is consistent with this established pattern. This robust, broadly distributed early negativity elicited by Word Order violations includes left and right frontal sites. Given previous findings, a fronto-central distribution for this response was not expected. It is possible that the occurrence of the word order violation very early on in the sentence, specifically at the second word, is a factor in this finding. Unlike many of the previous studies (Friederici et al., 1993; Gunter et al., 1999; Neville et al., 1991), in which phrase structure violations occur at or very near the end of the sentence, in the current study, initial phrase structure building is disrupted before the basic IP clause is even established, whereas the general pattern across similar studies involves phrase structure violations in a post-verbal prepositional phrase (Friederici et al. 1993; Gunter and Friederici 1999; Gunter et al., 1997; Neville et al., 1991) or in a subordinate clause between the subject and verb (Gunter et al., 1997). Moro et al. (2001), in a PET study involving Italian, investigated brain activation associated with syntactic, morphosyntactic (s-v agreement), and phonotacatic tasks, using visually presented stimuli. Their syntactic condition was similar to that in the current study, in that the word order violation occurred in the second word of the sentence. In their case, the initial words were a determiner-noun sequence which, in the incorrect condition were reversed to noun-determiner. They found bilateral activity in the inferior frontal region (Brodman's area 45 and the right-hemisphere homologue), as well as left insula and left caudate nucleus. The right hemisphere activity also included additional activity in the inferior frontal gyrus (Ba 44). These findings, as well as those of the current study, suggest that bilateral activity in the inferior frontal gyrus, which is likely to be responsible for the negative potentials recorded at frontal and fronto-temporal scalp sites, is elicited by phrase structure violations occurring near the beginning of a sentence.

Surprisingly, responses to violations of Inflection also elicited a frontal modulation of negativity. In contrast to the ELAN elicited by Word Order violations, the effect elicited by Inflection violations is realized as a small but still significant negativity, more narrowly distributed and only appearing on the left. Frazier's 1987 model, upon which widely accepted interpretations of the ELAN response are based, holds that sentence processing involves two stages, the first of which is initial structure building stage driven by word category information (Friederici, et al., 1993; Friederici, 1996, 1999). The second stage, which is associated with anterior negativity in the 300-500 latency window, is thought to reflect processes of thematic role assignment, involving lexical-semantic information and verb argument structure (Friederici, et al., 1993; Friederici, 1996). This later response occurs close to or simultaneous with the N400 response to semantic incongruities, but is generally more fronto-temporal or frontal in distribution. In terms of spatial distribution, the above mentioned PET evidence from Moro et al. (2001) suggests that processing syntactic information involves bilateral inferior frontal cortical activation. Though limited temporal resolution prevents any conclusions to be drawn regarding functionally distinct processes of early structure building and later lexical-semantic processes, they do not disconfirm the model.

Based upon the current interpretation of the ELAN, then, the observation of an early anterior negativity (before 300 ms) would not be expected in the context of sentences containing violations of inflection. Presumably, inflection violations involving verb affixation would not impact initial structure building in any substantial way. On the other hand, when an uninflected verb is encountered in place of an inflected verb, a local mismatch occurs, possibly similar to detection of mismatches in agreement, Case, grammatical gender. Since latency of the increased N1, an obligatory response to auditory stimuli, precedes the end of the verb stem, (about 360 ms), it is unlikely a response to the encounter of an uninflected verb. It is possible, however, that despite carefully performed editing of the auditory stimuli, subtle acoustic differences in the verb stems may have been detected. Ruling this out would require testing a larger group of subjects. However, post experimental interviews did not indicate any differences in perception of acoustical information involving the verb stem. While the larger N1 in ungrammatical inflection sentences is statistically significant, it was not a part of a planned comparison. Nonetheless, more stringent alpha levels would be needed to rule out Type I error. Although the p value at frontal sites is .024 (>.01), the result is not consistent with our predictions. Therefore, interpretation remains speculative with respect to this particular finding.

One very recent study is of particular interest regarding this finding. Hinojosa, Martín-Loeches, Casado, Muñoz, and Rubia (2003) appears to be the only other ERP study in which early negativity is elicited by verb inflection and word order violations. Though their study was conducted using Spanish, the types of inflection violations are similar to those used in our study. They substituted what should be a third person singular past-tense verb with a first person singular past-tense conjugation:

1) La prueba ocultada por el fiscal apareció.
   The proof (that was) hidden by the public prosecutor appeared (3-p s).

1) *La pruaba ocultada por el fiscal aparecí.
   The proof (that was) hidden by the public prosecutor appeared (1-p s).

Crucially, their verbs and ours contained identical stems with different suffixes, the only difference in verb structure (other than tense) is that our incorrect form lacks a suffix rather than substitutes one for another. An example of our inflection violation is repeated below:

1) Now John is eating pizza in a restaurant.

1) *Now John is eat pizza in a restaurant.

Hinojosa et al.'s results are quite similar to ours, in that they found an early anterior negativity elicited by verb inflection violations. While they acknowledge that insufficient converging evidence is available regarding early negativities in this linguistic context, they refer to results from one other study, Hagoort and Brown (2000), in which early negativities were elicited by inflectional violations in the auditory modality (in this case they were subject-verb agreement mismatches). In light of these findings, Hinojosa et al. (2003) point out that neither their data nor

Hagoort and Brown's support the model provided by Friederici et al. (1993)[5]. The current study provides a third set of data that is inconsistent with the claim that only word-category information is involved in the early processes underlying the ELAN.

An interesting result was reported in Gunter et al., (1997). They found the presence of what they referred to as an early "syntax-related negativity" in one of two experiments using Dutch, in which sentence-final infinitive verbs replaced past participles in sentences such as:

*De vuile matten werden door de hulp geklopt/*kloppen.*

*The dirty doormats were by the houskeeper *beat/beaten.*

This violation type is categorized as a syntactic incongruity; however, it is similar to our "inflectional" incongruity, in that it involves an incorrectly conjugated verb, which is obligatory in the context of a preceding past-tense auxiliary. In an experiment in which they increased sentence complexity, an enhanced N1 and a LAN were observed in sentences with incorrect versus correctly conjugated verbs. It is not clear from these and previous findings (Neville et al., 1991; Weber-Fox and Neville, 1996) whether an "enhanced N1" is a result of the onset of underlying processes reflected in the early left anterior negativity, which is typically slightly later in latency (150-180 ms), overlapping with the N1 component of the obligatory response. In any event, while the processes associated with the ELAN are relatively automatic in nature, the extent to which they are triggered by word category information alone is unclear, given the results of these four studies.

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[5] This is based upon Frazier (1990) and Frazier & Rayner (1982).

The presence of negativities associated with morphosyntactic processing in the current study and in Gunter et al., (1997), and Hihojosa et al., (2003), all of which involve incorrectly conjugated verbs in contexts that specifically do not involve word order, suggests that early underlying processes involved in detecting at least some violations of inflection may be similar to those which are purely structural in nature. Hinojosa et al. conclude from these results that processing of verb inflection information and word category information are accessed in a similar manner and that the theoretical view maintaining the primacy of word-category information in early automatic processing is therefore in question. The results of the current study seem to support this conclusion.

To summarize, we expected Word Order violations to elicit an ELAN in monolingual speakers. This prediction was borne out, as demonstrated by a fronto-centrally distributed negativity in the 100-250 ms latency window which includes right and left frontal electrode sites. These results are consistent with previous studies and with the claim that early frontal negativities reflect automatic processes involving initial structure building. An early left anterior negativity was also elicited by Inflection violations. These findings are similar to those observed in three previous studies, two of which involved verb conjugation violations. On the other hand, these results are not consistent with a number of other previous studies involving a broad variety of morphosyntactic violations. The ERP findings from this latter group of studies have served as evidence in support of the two-stage parsing model.

6.1.2 Anterior Negativity (250-450 ms)

The later anterior negativity (250-450 ms) observed in this study is fronto-centrally distributed for Word Order violations. A similar negativity, which is not as robust and more left lateralized, was elicited by Inflection violations. Gunter and Friederici (1999) observed the anterior negativity to be more fronto-centrally distributed in auditory processing and more left oriented in visual processing. We found the increased negativity to be more narrowly distributed in the Inflection condition than in the Word Order condition.

Despite a number of studies that have examined various kinds of morphosyntactic and syntactic violations, the underlying processes responsible for the later anterior negativity remain unclear. ERP responses that fall into this category, in terms of latency and distribution, have been associated with a number of processes, including argument structure (Rosler et al., 1993 Friederici et al. 1993, Gunter et al., 1997; Gunter and Friederici 1999), agreement (Kutas & Hillyard, 1893; Coulson et al., 1998, Osterhout & Mobley, 1995; Gunter et al., 1997; Penke et al., 1997), filler-gap dependencies requiring a moved element, which must be held in working memory until identification of the original position occurs (Kluender and Kutas 1993; King and Kutas 1995; Kluender et al., 1998), complex (object) versus simple (subject) relative clauses (Kluender et al., 1998), grammatical NPs involving a Case-marked article prompting a less preferred analysis (Rösler et al., 1998), and classifier and Case violations in Japanese (Mütter et al., 2003). It is not clear whether the underlying processes reflected in the LAN response to syntactic violations and the LAN responses elicited by other types of contexts--some of which are grammatical--

are the same, whether they tap similar resources, or whether topographical differences indicate that these reflect different types of processing altogether. It has been noted (Gunter and Friederici, 1999) that within-category inflection violations involving agreement versus violations involving a substitution of one word category for another elicit topographically different LAN responses, the former being more centrally distributed and the latter having a left anterior distribution. The results of the current study are not consistent with this observation, as the inflection violations included here elicit a negativity in the same latency range, which is distributed over left anterior regions.

An additional complicating factor in the interpretation of mid-latency negativities is the mixed evidence regarding possible overlap of N400 effects and syntax-related negativities occurring in the same latency range. As noted by Hinijosa et al., (2003), the position of a phrase structure violation in the sentence may affect the type of cortical response elicited. For example, phrase structure errors occurring in sentence-final position have been found to elicit N400-like effects (Osterhout and Holcomb, 1992, Hagoort et al., 1993). In addition, some results have revealed what appear to be co-occurring anterior and posterior negativities to morphosyntactic errors (Gunter et al., 1997; Gunter et al., 2000).

Hinojosa et al., (2003) report finding co-occurring N400 effects and anterior negativities elicited by their word-order violations, which involved the substitution of a relative clause object by the verb which should have been associated with the main clause subject, as in the following example:

1) *La prueba ocultada por el *apareció*.
   *The proof (that was) hidden by the *appeared*.

They attribute this finding to some degree of disruption of semantic integration, resulting from a lack of reinterpretability relative to the verb inflection condition. This is plausible, assuming the existence of some initial structure to support reinterpretation. In the case of the current study, however, little if any structure is established; the Word Order violation occurs immediately after the sentence-initial proper noun, at which point little information would be available for semantic or syntactic reinterpretation. Presumably, syntactic structure building is essentially stopped by the encounter of a function word (*not*) before any further semantic integration can occur. Differences such as these might account for the occurrence of N400-like effects in some manipulations of phrase structure and not others. The current study design was specifically intended to minimize semantic involvement in a sentence-context phrase structure violation.

The presence of a significant and clearly anterior negativity in the 250-450 latency range strongly suggests that the observed response indexes processes that are syntactic in nature. On the other hand, a weak, narrowly distributed anterior negativity in the context of verb inflection violations may suggest that the detection of a mismatch between an uninflected verb and an auxiliary signaling progressive aspect is similar in some way to the detection of a phrase structure violation. The nature of concurrent processing that takes place in this event, however, is not as easily explained by these data. Two possibilities, which are not mutually exclusive, are suggested by the finding that the distribution of activity is much broader in the Word Order condition. One is that the intensity of the cortical response is greater, leading to broader distribution in the negativity recorded over the anterior regions of the scalp. The other is that—notwithstanding the likelihood of overlapping areas of activity—more widely distributed networks of neuronal activation may be involved when a highly salient word-order violation is encountered, particularly at the beginning of a sentence.

In sum, our results are consistent with previous studies finding anterior negativities in response to structural violations and morphosyntactic violations of various types. Word Order and Inflection violations elicited negativities in the 250-450-ms latency range, though they differ in magnitude and distribution. The anterior negativity elicited by Word Order violations was robust and distributed broadly over fronto-central regions of the scalp. In contrast, the anterior negativity elicited by Inflection violations was only marginally significant and more narrowly distributed over left frontal regions, suggesting greater intensity and/or a broader range of neuronal assemblies employed in detection and recovery from a Word Order violation.

6.1.3 Late Positivity

Word Order violations elicited a clear P600. A weaker late positivity was elicited by Inflection violations These findings suggest a quantitative difference in more controlled processes associated with a violation involving a local mismatch between an uninflected verb following an auxiliary, on one hand, and a phrase structure violation on the other.

Late positivities similar to those found in this study have been systematically reported in contexts ranging from word order violations (Friederici et al., 1993), and subjacency violations (Neville et al., 1991) to Case violations in Japanese (Müller et al., 2003). They have been elicited by ambiguous or unexpected/non-preferred structures that are thought to require processes of reanalysis and repair (Osterhout and Holcomb, 1992, 1993; Osterhout, Holcomb, & Swinney, 1994; Gunter et al. 1997), and by violations of subject-verb agreement (Coulson et al., 1998; Münte et al., 1997; Kaan et al., 2000). Late centro-parietal positivities have been elicited with increased difficulty in integration (Kaan, et al., 2000). This finding has lead to the hypothesis that some subcomponents of the P600 reflect syntactic integration difficulty.

P600 effects are associated with a rather broad scalp distribution, as well as a range of possible processes that have recently been under empirical examination (Friederici 1998); therefore, the claim that this effect may involve a set of subsystems is uncontroversial. Further study is needed to isolate possibly different foci within the 500-900 ms window, and including even earlier latencies, beginning at 345 ms (Mecklinger et al., 1995; Friederici 1998). Though several sentence processing models have been proposed with respect to diagnosis and reanalysis of ambiguous input (Fodor and Inoue, 1994; Gorell, 1996; Friederici, 1998) and of preferred and non-preferred structures (Hickock, 1993; Gorrell, 1987; Gibson, 1991; Inoue and Fodor, 1995), these models do not generally addresses the issue of diagnosis without recovery. Friederici (1998) hypothesizes that two possibly distinct sub-processes may follow the first-pass parse. She proposes that these dual aspects of a second-stage parse correlate with distinct centro-parietal positivities, which may reflect 1) diagnosis of whether reanalysis is possible, and 2) the reanalysis process itself. According to this view, each of these steps may independently contribute to the difficulty of revision, overall, which may, in turn, be reflected in the onset latency and duration of these centro-parietal positivities.

Additional evidence supports the hypothesis that two primary sub-processes may be responsible for at least some P600 effects. In a study involving temporarily ambiguous syntactic structures in German subject and object relative clauses, Friederici et al. (2001) report finding an earlier positive component (latency between 400 and 600 ms), which they claim may reflect initial processes of diagnosis--particularly in easier-to-diagnose contexts--and a later component (latency between 600 and 900 ms), which may reflect processing cost.

In the case of monolingual speakers in the current study, results suggest that the detection and diagnosis of an unrecoverable ungrammaticality is reflected in the robust centro-parietal positivity elicited by Word Order violations. Here we speculate that if, upon further analysis, we confirm the presence of two subcomponents in the 400-800 latency range, this would suggest that easy detection and diagnosis of an ungrammaticality from which recovery is impossible follow similar patterns as easy detection and diagnosis leading to subsequent processes of reanalysis and repair. Based upon the current analysis, however, the late positivities that were elicited by both Word Order and Inflection violations confirm that native speakers of English detect both types of violations, triggering activity which may reflect similar or overlapping subsystems. Differences in the onset latency and magnitude of the responses observed across Word Order and Inflection conditions suggest that perhaps the diagnosis mechanisms employed in each context are not the same.

Behavioral responses suggest that Word Order violations are particularly salient, as indicated by the significantly faster reaction times for sentences containing Word Order violations compared to grammatical sentences. In contrast, reaction times to sentences containing inflection violations are no faster than reaction times to grammatical sentences. Accuracy, on the other hand, is more than twice as variable in response to sentences containing Inflection violations than to all other sentence types. These factors, taken together, suggest that for highly salient Word Order violations, later controlled processes begin earlier and are more robust than for somewhat less salient violations of verb inflection that do not cause a complete breakdown of structure building.

The nature of later processes following an incorrectly conjugated verb that does not violate phrase structure constraints is not clear. The question remains as to whether or not integration continues on some level after the encounter of an infinitive verb in place of an inflected verb, when the mismatch does not impact word order or reassignment of thematic roles, as it might in German, for example. The current state of knowledge does not provide an account that allows us to clearly distinguish between responses that may reflect *partial* breakdown of integration, in the case of morphosyntactic mismatches, and processes that reflect *complete* breakdown of the integration, in the case of phrase structure violations.

Further questions have been explored regarding the relationship between late positivities and processing costs due to integration[6]. Kaan et al., (2000) claim that these processes are characterized by an earlier effect (500-700 ms) followed by a later

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[6] These accounts are not inconsistent with Friederici et al. (2001).

effect (700-900 ms). the former being triggered by a previously encountered ungrammaticality, and the latter being triggered by a –wh word, which increases resources needed for integration. They also speculate that these sub-processes may be related but possibly independent of one another.

As discussed above, the sentences in the current study involve limited syntactic structure existing at the onset of the Word Order violations and local Inflection violations. Therefore, questions of integration difficulty for native speakers do not seem applicable here, as the degree of complexity of the sentences is not being manipulated, nor is it high enough in the first place to be considered taxing. If anything, in this case, we might expect to see a ceiling effect among this group[7]. Despite the low complexity level and relatively high probability of ungrammaticality in the sentences used in this study, clear P600 effects were observed, confirming the robustness of the results. Taken together, these findings confirm that somewhat basic processes of diagnosis and recovery, as well as more complex processes of analysis, repair, and integration, potentially fall within the scope of so-called P600 effects, and that more fine-grained analysis is required in order to identify the particular sub-processes that come into play at later latencies.

As they stand, the data from the current study indicate that the P600 effect elicited by easier-to-detect, Word Order violations has an earlier onset, as well as a broader and more posterior distribution, compared to the later, more centro-parietally

[7] Kaan et al. (2000) claim that ceiling effects diminish P600 amplitude when enough resources are available for integration (i.e. when they are not being recruited for additional analysis). Our preliminary results are not consistent with this view.

distributed effect observed in the relatively less salient Inflection condition. These results are consistent with the findings reported in Friederici et al. (2001).

Visual inspection of preliminary topographical maps indicates that in the Word Order condition there appears to be an increase in positivity in the 400 ms latency range over superior occipital sites. By 700 ms a more centro-parietal focus develops. Interestingly, a centro-parietal positivity is also seen in both high-proficiency L2 groups at about 400 ms. If further analysis shows these effects to be significant, the findings would suggest that different integration effects may occur in L2 compared to L1 processing, and that in monolinguals, early posterior positivities may be attributable to relatively early and possibly more automatic processes of detection and diagnosis.

In the Inflection condition, there appears to be an increase in positivity in the Monolingual group at 400 ms, occurring over centro-parietal and occipital sites and oriented slightly to the right. As sub-processes associated with earlier P600 effects were not among the predictions made in this study, analysis for positivities associated with posterior activation within the 400-600 ms window were not part of the planned comparisons for either condition. Further analysis will determine the extent to which these findings represent significant effects, and the extent to which they can be attributed to multiple sub-processes that follow a two-phase pattern similar to those found in Friederici (1998), Kaan et al., (2000), and Friederici et al. (2001).

6.2 Accessing Knowledge of Syntactic and Inflectional Information: Behavioral Measures

A behavioral study conducted by Juffs and Harrington (1995) offers evidence of differential linguistic processing in non-native and native speakers, in this case high-proficiency Chinese-English bilinguals and native speakers of English. While Juffs and Harrington found no differences in mean accuracy in rejecting ungrammatical sentences involving subject and object extraction in finite and infinitive clauses for the two groups, reaction times were significantly slower for the non-native speakers. This dissociation suggests that even if the end-state grammars are similar in L2 and monolingual speakers, processing is different. The precise nature of such underlying processing differences is of particular importance to SLA theory. If it can be shown that a processing deficit is responsible for L2 learners, demonstrating their ability to recognize syntactic violations with the same accuracy as native speakers but also showing that they require more time to make the relevant judgments, this would confirm the hypothesis that L2 learners have the capacity to acquire the same grammatical knowledge as native speakers. While evidence of impairment at the level of processing would not specifically disconfirm the fundamental difference hypothesis (Bley-Vroman, 1990), which posits that L2 acquisition is diverges fundamentally from L1 acquisition relying upon non-UG constrained processes, it suggests the need for a shift in focus in examining divergent acquisition patterns.

The behavioral results of the current study are consistent with Juffs and Harrington (1995). In general, monolinguals and high-proficiency L2 learners do not differ in accuracy in judging grammatical sentences and ungrammatical sentences, regardless of whether they contain violations of Word Order or Inflection. Low proficiency learners' accuracy scores were significantly lower than monolinguals for grammatical sentences, and they were lower than all groups for ungrammatical sentences, as expected, based upon their general scores on the Wisconsin Test of English Proficiency. Based on these data, therefore, it appears that both early- and late-onset high proficiency learners have the ability to access the same grammatical knowledge as monolinguals do.

In terms of the *way* L2 learners access grammatical knowledge, their speed of processing grammaticality judgments offers some insight. We found that mean reaction times for monolinguals and high proficiency *early* learners were faster than those of either the *late* learners or the low-proficiency learners in judging Word Order sentences, with significantly slower RT scores on both grammatical and ungrammatical sentences for the high-proficiency late and low-proficiency learners. These results suggest that there is an age effect for L1 Spanish speakers, with respect to processing word order in L2 English. This is not surprising, given the one-to-one reversal of grammaticality in word order for negation of progressive sentences in Spanish and English (Juan no está comiendo pizza/*John not is eating pizza). Taken together, these results are consistent with the prediction that there will be processing difficulties for low-proficiency learners of English whose native language is Spanish, in the particular case of Neg-Aux word order.

The picture is not as clear with the high proficiency learners, however. The fact that we found differences between speed of processing in a grammaticality judgment task across early and late high-proficiency learners suggests the employment of different processing strategies. Taken alone, these data do not provide evidence as to the specific kind of processing differences responsible for delays in reaction time in late learners. However, converging evidence from behavioral and ERP data may help in this endeavor. These findings will be discussed in the following section.

In contrast to the Word Order condition, no difference was found in reaction times for monolinguals and either of the high proficiency groups in judging ungrammatical Inflection violations. All three groups, however, were significantly faster than the Low Proficiency group learners in this condition. On the other hand, Monolinguals were faster than both the HPL and LP groups in judging the *grammatical* inflection sentences, though Monolinguals were no different from HPE learners in this condition. Thus, when word order patterns alternate across the L1 and L2, delays in age of acquisition--even when proficiency level is commensurate with that of early learners--have a negative effect on the processing time required in judging a sentence's grammaticality.

In terms of accuracy, judgments of Inflection sentences were quite similar across groups. Low-Proficiency learners' accuracy scores did not differ from the other three groups in judging *grammatical* inflection sentences (*Right now, John is eating pizza in a restaurant*), in contrast to their accuracy in judging grammatical Word Order sentences (*John is not eating pizza in a restaurant*), which did differ significantly from the Monolingual group. In terms of reaction time, the only difference across sentence type is seen in ungrammatical Inflection sentences

(**Right now, John is eat pizza in a restaurant*), in which case, High Proficiency Late learners differ from High Proficiency Early learners (as well as Monolinguals). These results suggest that high proficiency learners with either early or late L2 exposure can accurately recognize verb inflection violations, and that their ability to make accurate grammaticality judgments matches that of native speakers. Even Low-Proficiency learners identify verb inflection violations with a similar degree of accuracy compared to Monolinguals, suggesting that the similarities between Spanish and English verbal morphology patterns in progressives are relatively easy, whereas the cross-linguistic contrast in word order poses problems for L2 learners.

These behavioral results demonstrate that High Proficiency Early learners acquire and access the same grammatical knowledge as Monolinguals, and that for these learners, the process of making grammaticality judgments occurs with the similar speed. For late learners of the same proficiency level, however, decreased reaction time, especially for ungrammatical Inflection sentences, in conjunction with equivalent accuracy rates overall, suggests that the same knowledge is accessed, but via different underlying processes.

Juffs and Harrington (1995) report that while accuracy scores for ungrammatical sentences were no different across monolingual and L2 groups, accuracy on grammatical sentences was significantly lower for the L2 groups. We found that for later learners, grammaticality affects reaction time but not accuracy. One possible reason for this difference across studies is the relatively high degree of complexity in both grammatical and ungrammatical sentences in the earlier study in comparison to the relatively low complexity in the current study.

In Juffs and Harrington (1995), grammatical sentences included subject and object extractions from finite and non-finite clauses, the former requiring reanalysis of structural position and theta role, and Case variables (Nom, Acc).

1. Who$_i$ does Jane expect t$_i$?
2. Who$_i$ does Jane expect [$_{IP}$ t$_i$ to]?
3. Who$_i$ does Jane$_k$ expect [$_{CP}$ [$_{IP}$ PRO$_k$ to fire t$_i$]]?
4. Who$_i$ does Jane$_k$ expect [$_{IP}$ t$_i$ to fire Bill]?

A clear contrast is therefore established among grammatical sentences. Their least complex sentences involved reanalysis of structural position, in contrast to their more complex sentences, which involved reanalysis of Case and Theta-role assignment. Therefore, the delay in processing speed for the L2 learners in Juffs et al.'s study is clearly attributed to greater difficulty, even in the grammatical sentences. Our experimental sentences, on the other hand, were much simpler; the main contrast is established between grammatical and ungrammatical sentences. Though the grammatical sentences differed across the two conditions, this difference was not due to complexity or ambiguity, i.e, ungrammatical sentences require no reanalysis of thematic roles. Grammatical sentences are unambiguous, movement of constituents being specifically limited to auxiliary verb raising.

6.3 Age and Proficiency Effects on Processing Syntactic and Inflectional Information in L2 Learners: ERP Effects

6.3.1 Early Anterior Negativitiy

ERPs to sentences containing violations of Word Order, indicate the presence of an early anterior negativity in HPE learners. This response is left lateralized, unlike the fronto-central response seen in monolinguals. The finding that this response does not occur in high proficiency late learners suggests that age plays a crucial role in early automatic processes involving structure building. This is supported by the fact that early anterior negativities have not been observed in ERP studies investigating L2 processing (Hahne, 2001; Friederici & Hahne, 2001; Weber-Fox and Neville, 1996). Behavioral evidence supports the claim that early L2 learners process inflectional and syntactic information similarly to monolinguals, in that there is no measurable difference in accuracy and reaction time between the HPE and Monolingual groups.

With respect to early automatic processes of structure building, it appears that early learners employ similar underlying resources, which have the same latency as the responses elicited by ungrammatical Word Order in native speakers. This finding is inconsistent with Weber-Fox and Neville (1996), who reported an absence of early anterior negativity in the 100-250 ms latency range for violations of phrase structure in all of their L2 learners of English (ages 1-3, 4-6, 7-10, 11-13, or >16 at onset of exposure). Similarly, Hahne (2001) reports no evidence of a clear ELAN in her L2 group. The latter investigation does not include specific information about the age at which the L2 learners were exposed to German. Only mean age at time of testing (27 years) and mean length of formal study (6 years) are reported. Specifically, though they report that the L2ers were native speakers of Russian who had lived in Germany for an average of 5.5 years, they do not indicate whether the 6-year period of formal study and the 5.5 years of overlap or whether they represent consecutive time periods. Therefore, while the facts suggest that their subjects are all late learners, the precise ages of onset are not clear.

Since reaction time and accuracy data indicate that the HPE and HPL learners do not differ from native speakers in terms of their grammatical knowledge of properties of word order in English, two possible explanations arise from the ERP data. Weber-Fox and Neville (1996) report that accuracy for phrase structure violations was lower for L2 learners exposed after 6 years of age. Therefore, even subtle differences in proficiency level may contribute to differences in the early ERP responses across the two studies. And unlike our High Proficiency Early group, who were exposed to English after 3 years of age, with Spanish as the sole language spoken in the home, Weber-Fox and Neville's earliest L2 group was exposed to Chinese and English simultaneously (1-3 years), which represents a potentially fundamental change in the nature of the acquisition process.

Another difference between the two studies is that in the current study auditory sentences were used, as opposed to visual stimuli in the earlier study. Friederici (1999) notes that the only studies reporting an ELAN besides Neville et al. (1991), the study from which the monolingual data from Neville et al. (1996) were taken, are auditory studies. In addition, Neville et al. (1991) and Weber-Fox and Neville (1996) referenced electrodes to linked mastoids and Hahne (2001) used an online left mastoid reverence with offline re-reference to averaged mastoids. The current study used a vertex reference with offline re-referencing to an average of all electrodes. These differences could have contributed to differences in ERP patterns.

Differences in the early ERPs across the early and late proficiency learners suggest that the manner in which initial detection of structural incongruities differs for the two groups. The fact that late learners have significantly slower reaction times in judging grammatical and ungrammatical Word Order sentences corresponds with the ERP data and supports the claim that age factors affect early structural processing, despite the fact that accuracy for early learners, late learners, and monolinguals remains the same.

6.3.2 Anterior Negativity (250-450 ms)

A weak left anterior negativity in the 250-450 ms latency range was elicited in the HPE group in response to violations of Word Order. This response, which is only marginally significant, differs qualitatively from those of the Monolingual group, as it is lateralized to the left and its peak latency is delayed. This difference suggests an age effect associated with syntactic processes that occur in the latency range of the LAN, as no increase in negativity at left anterior sites is seen in the late learners of either high proficiency or low proficiency groups.

These results are partially consistent with previous studies examining phrase structure violations in L2 learners. Weber-Fox and Neville (1996) report a delayed and narrower LAN in the 1-3, 4-6 and 7-10 groups, compared to monolinguals, in response to phrase structure violations. The 11-13 group showed marginally significant negativity on the left. As in the current investigation, the effect in the L2 groups compared to native speakers was narrower, becoming significant only in a later time window. In contrast, however, accuracy for the phrase structure violations in the previous study was significantly different for the 7-10 and 11-13 groups, and it was marginally different even for the 4-6 year old group compared to monolinguals; whereas we found no differences in accuracy across the early and late high proficiency groups. It is possible that differences between Spanish and Chinese, the L1s in these two studies, affected the acquisition of specific types of structural information, leading to behavioral differences, despite the similarity in ERP responses in the somewhat intermediate latency window. Examples of phrase structure violations from each study are shown below:

Neville et al. (1991); Weber-Fox and Neville (1996):

The scientist criticized Max's proof *of* the theorem.

*The scientist criticized Max's *of* proof the theorem.

The current study:

John is *not* eating pizza in a restaurant.

*John *not* is eating pizza in a restaurant.

In addition, we cannot rule out the possibility that auditory phonological cues versus reading had an effect on grammaticality judgment across the two studies.

The fact that LAN-like responses are observed in the absence of the early LAN associated with structure building, suggests that detection of structural violations in even subtly less proficient and certainly later learning L2 speakers follows a different time course from native speakers, requiring different resources that come into operation in roughly the same latency range as lexical-semantic and verb argument processing in native speakers. L2 learners may rely more heavily on lexical-semantic information, leading to activity similar to what is reflected in the LAN in native speakers. An argument can be made that later learners are simply slower in processing these types of violations, in general. If this were the case, however, we would expect to see the presence of an ERP response but with a delayed latency. This is not the case, as we find the LAN to be absent entirely in both late-learner groups.

In sum, the current study demonstrates that ERP responses to Word Order violations in high proficiency L2 learners with early exposure to English are similar to ERP responses observed in monolinguals. These responses take place in the latency range generally associated with lexical-semantic processing and may reflect processes associated with previously encountered syntactic disruption. The LAN-like response is not present in high proficiency late learners, suggesting an age effect, which may also be responsible for the absence of such a response in the later learners studied in a handful of other investigations of syntactic processing in L2 learners.

6.3.3 Late Positivity

In terms of late positivities, the results of the current study indicate that the P600 response to Word Order violations is quantitatively different in the L2 groups compared to monolinguals. A weak, more narrowly distributed, late positivity occurs in both High Proficiency groups but not the Low Proficiency group. The fact that the observed response is less robust in both High Proficiency groups than it is in the Monolingual group suggests that unlike the earlier more automatic processes involved in syntactic processing, later, more controlled processes are sensitive to proficiency level.

The relationship between proficiency and the later controlled processes reflected in the P600 has been noted by Hahne (2001), who, in contrast to a previous study reporting no evidence of a P600 in their L2 group (Hahne & Friederici, 2001), found a delayed P600 in L2 learners. Notably, the L2 group in the latter study included lower proficiency late learners (L1 Japanese). One possible explanation for the absence of a P600 effect is an absence of syntactic repair processes in L2 learners. Our results are fairly consistent with Weber-Fox and Neville (1996), who report P600 effects in the 1-3, 4-6, and 7-10 groups but no P600 effect for the 11-13 or >16 groups.

Hahne & Friederici (2001) also report increased positivity for correct sentences, suggesting that processing load for comprehension of grammatical sentences is similar to that employed during repair processes of syntactically incorrect sentences. Similar observations were also made with respect to both earlier negativities, with increased negativity in both correct and incorrect sentences appearing in L2 learners compared to monolinguals, for whom increased negativity is associated only with ungrammatical sentences. The increased negativity at early latencies and increased positivity at later latencies for grammatical sentences as well as ungrammatical sentences was explained as a possible reflection of processing difficulty. Because their phrase structure violations involve passivized sentences, they suggest that difficulty in syntactic integration may have affected ERP amplitudes for correct sentences. The relatively easy phrase structure violations in the current study may be the reason we did not find increased negativity for grammatical sentences at earlier latencies.

Taken together, the results across the entire spectrum of ERP responses to violations of Word Order demonstrate that early processing of phrase structure violations in L2 learners compared to monolinguals are similar when exposure to L2 is early. These earlier processes, generally associated with the automatic build up of syntactic structure, differ when age of acquisition is delayed. Intermediate processes, which not as clearly interpreted, also seem to differ in L2 learners as a function of age of acquisition. In contrast, later, more controlled processes seem to approach those of native speakers in high proficiency L2 learners, regardless of age of acquisition.

In responses to sentences containing violations of Inflection, there appear to be greater differences between native and non-native speakers. The weak early left anterior negativity seen in monolinguals is not found in any of the L2 groups. No left anterior negativity is seen in the 250-450 latency range for L2 learners, and only half of the HPE learners individually show a P600 response to Inflection violations. These results suggest that processing of inflectional information in L2 learners does not follow developmental patterns that eventually approach the patterns seen in monolinguals. One way to explain these results is in terms of the salience of the violation. Behavioral data for monolinguals indicate that in listening to progressive sentences, they vary in accuracy for detection of missing inflection. This is consistent with the smaller, more narrowly distributed ERP responses observed for all three patterns under investigation.

Chapter 7: Conclusions

This study investigated the processing of word order and verbal inflection on two levels: cortical processing using on-line ERP methods, and behavioral processing, measured in terms of accuracy and reaction time in a grammaticality judgment task. With respect to ERP measures, specific patterns associated with syntactic and morphosyntactic processing were examined, assuming that differences in the timing and distribution of ERPs reflect the differences in underlying processes associated with the manipulation of different kinds of linguistic information. The relationship between inflection and word order is important to the current investigation because inflection errors typically characterize L2 acquisition. These types of errors have been associated with deficits in syntactic representation linked with functional categories (Vainikka and Young-Scholten, 1994, 1996; Eubank, 1993/1994) and with processing deficits that may include mapping, parsing mechanisms, or other processes occurring at an extra-syntactic level (Lardiere, 2000; Epstein, Flynn, and Martohardjono, 1996; Klein and Martohardjono, 1999).

ERP studies of monolingual speakers vary in the types of morphosyntactic phenomena they examine and have not focused in a principled way on differentiating one type of inflectional violation from another. The general approach has been to examine morphosyntactic violations, ranging from S-V number agreement to verb conjugation to Case, in contrast to phrase structure violations and/or semantic violations. In order to investigate questions stemming from SLA theory which involve the acquisition of inflectional elements of a target grammar (e.g. progressive

–ING) versus the acquisition of purely structural elements (e.g. Aux-Neg word order), the current study took a closer look at the processing of these types of information in both native and non-native speakers of English. Based upon evidence from SLA research and earlier ERP studies, we expected to find differences, keeping in mind the lack of converging evidence in the field.

Assuming Frazier's two-stage model of sentence processing, our data replicate previously established early modulations of negativity at anterior electrode sites, which have been attributed to a disruption in the initial build up of phrase structure. The presence of an early anterior negativity in the 100-250 ms latency range has been hypothesized to represent prima facie evidence of automatic processing that is based upon word category information and is unique to the integration of phrase structure. The finding of a similar response to inflection violations suggests that certain types of verbal inflection are recognized with a degree of automaticity similar to that which is operant when a word order violation is encountered. This also raises questions about the primacy of word-category information in initial parsing, indicating that further research in the processing of verbal inflection is needed to confirm or disconfirm this interpretation.

The observed patterns involving intermediate-latency anterior negativies elicited by Word Order and Inflection violations suggest that whether they reflect overlapping or distinct neural populations their activity follows a similar time course. The broad fronto-central negativity to Word Order violations appears to be a secondary process, following a salient disruption of structure building. Similarly, the left anterior response to Inflection violations follows or is a continuation of an initial response associated with the detection of a mismatch between morphosyntactic elements. While these topographically distinct responses are unambiguous, testing a larger population would enhance our confidence in interpreting these results.

With respect to later, more controlled processes of recovery and possible reanalysis, differences are qualitative and quantitative, though further analysis involving dipole modeling is necessary in order to tease out the extent to which the differences in the breadth of the positivity observed over the surface of the scalp are can be attributed to intensity, orientation, and distribution, respectively. Based upon the analysis performed so far, the broader distribution of the P600 response to Word Order violations suggests that more resources are involved in recovering from a structural violation than from an inflectional violation, even when they are both similarly local, with respect to the relationship between operating syntactic elements.

We examined proficiency and age effects, relative to these specific aspects of processing using two groups of high-proficiency L2 learners, one early and one late, as well as a low-proficiency group. We expected to see differences in phrase structure and inflectional processing in both ERPs and behavioral measures across proficiency groups. We also predicted that patterns in both domains for early learners would approach those of monolinguals, compared to late learners who have attained the same level of proficiency.

Among L2 learners, ERP responses vary based upon age of acquisition and proficiency, depending on the type of linguistic information. In terms of processing phrase structure information, we found an age effect for the early automatic processes reflected in the early left anterior negativity in the 100-250 ms latency range, as well as the left anterior negativy in the 250-450 ms latency range which have been fairly consistent in studies involving word order violations. High-Proficiency Late learners do not show either of these responses, while High-Profiency Early learners and Monolinguals do. ERPs to Word Order violations also reveal that later processes reflected in the P600 are not affected by age of acquisition but by proficiency level, as it is present in both high proficiency groups but not in low proficiency learners.

In terms of processing Inflection information, ERP patterns in L2 learners, regardless of proficiency or age of acquisition, do not resemble the patterns seen in Monolinguals. No early or mid-latency anterior modulations of negativity are seen across L2 groups, and only half of the High Proficiency Early learners tested exhibited a P600 effect.

Behavioral measures and ERP results appear to correlate with each other. We expected High-Proficiency L2 learners to be similar to monolinguals in accuracy in a grammaticality judgment task and to have similar ERP responses, based upon Kim et al. (1997) and Perani et al. (1998). In addition, we expected reaction times to vary across proficiency and age groups, based upon Juffs et al. (1995). If increases in reaction time are due to overall slower processing that entails similar underlying strategies and involves neural populations, we would expect to see the same ERP patterns but with delays in latency. If increases in reaction time are due to activation of different neural populations in the course of processing these types of linguistic information, we would expect to see qualitative differences in ERPs across proficiency and age groups. These expectations were borne out.

We found that behavioral measures support the hypotheses that High-Proficiency learners, regardless of age of L2 acquisition, access the same grammatical knowledge as Monolinguals, as indicated by equivalent accuracy rates on judgments for grammatical and ungrammatical sentences. However, late L2 learners, even when their proficiency is high, do not access that information in the same way as Monolinguals do, as reflected in slower reaction times and different ERP patterns. Increased reaction times occur in correlation with an absence of early and mid-latency ERP anterior negativities for Word Order violations, and an absence of mid-latency anterior negativity and P600 responses to Inflection violations in late learners. The conclusion to be drawn from these data is that there is a critical period for processing both syntactic and inflectional information in L2 and that early automatic processes involved in detecting phrase structure violations and mismatches of verbal morphology are the particularly vulnerable to maturation effects. Differences in processing appear to be greater when verbal inflection is manipulated. In contrast, the ability to attain abstract grammatical knowledge of word order and inflection is unaffected by age of acquisition. Although these types of knowledge are associated with functional categories, this conclusion is irrespective of a particular representational analysis.

We hope to have shown that in addition to proficiency level, age of acquisition is an important factor in the functional organization and operations of language comprehension processes in non-native speakers and that while it affects the manner in which grammatical information is processed, it does not impede ultimate attainment.

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