Neurophysiological evidence of a second language

influencing lexical ambiguity resolution in the first language.

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Abstract

The main objective of this dissertation is to investigate the effects of acquiring a second language (L2) at later periods of language development and native-like homonym processing in the first language (L1) from the perspective of Event-Related brain Potentials (ERP) using a cross-modal lexical decision task. To date, there is a lack of neurophysiological investigations into the effect that acquiring an L2 can have on processing strategies in the L1, and whether or not there is a precise age at which L2 exposure no longer affects native-like language processing. As such, my goal is to pinpoint this sensitive period specifically for homonym processing. To achieve this, I will present and discuss the results of two studies. The first study employs behavioural response measures using a cross-modal lexical decision task where participants simultaneously heard a sentence and made a decision to a visually-presented pseudoword or real word. The second study employs ERP measures using a novel ERP paradigm which investigates not only the main objective of this dissertation, but the second objective as well. This second objective is for this dissertation to become the first to evaluate the outcome of combining the cross-modal lexical decision task with ERPs.

The behavioural and neurophysiological results for the monolingual group support the Reordered Access Model (Duffy, Morris, & Rayner, 1988) while the results for the bilingual groups do not. The results of the current studies indicate that those bilinguals who acquired French as an L2 rather than as a second native L1 show increasing divergence from monolingual native speakers in L1 homonym processing, with later acquirers exhibiting an exponentially marked divergence. This was found even though the task was carried out in English, the L1 (or one of the L1s) of all participants. The diverging performances of the bilinguals from the monolinguals were apparent in behavioural responses as well as in the amplitude, scalp distribution, and latency of ERP components, These differences were unique to each group, which supports the hypothesis that the acquisition of an L2 influences processing in the L1 (Dussias & Sagarra, 2007). Specifically, the early and late bilingual groups exhibited a marked divergence from the monolingual group as they revealed syntactic priming effects ($p<.001$) as well as lexical frequency effects ($p<.001$). They also revealed the greatest P600-like effect as they processed target words which were inappropriately-related to the priming homonyms (such as *skin* in *Richard had a shed in the back of the garden*). This suggests a heightened sensitivity to surface cues due to the L2 influencing homonym processing in the L1 (Cook, 2003; Dussias & Sagarra, 2007). Comparatively, the monolingual group revealed equal N400-like effects for lexical ambiguities overall compared to the unrelated conditions, and a context-by-frequency-interaction slowing their processing of the target word that is appropriately-related to the subordinate reading of the priming homonym, suggesting that they are not as sensitive to these same surface cues. Importantly, these results confirm that using ERPs along with a cross-modal lexical decision task is a promising paradigm to further study language processing.

Résumé

L'objectif principal de cette dissertation est d'examiner les effets de l'acquisition d'une langue seconde (L2) à des périodes plus tardives dans le développement du langage et du traitement des homonymes chez un locuteur natif dans la langue première (L1), de la perspective du potentiel évoqué (PE); le tout en utilisant une tâche de décision lexicologique transmodale. À ce jour, il y a une insuffisance d'investigations neurophysiologiques qui touchent les effets que peuvent causer l'acquisition d'une L2 sur les stratégies de traitement dans la L1, ainsi que sur la question à savoir s'il y a ou non un âge précis auquel l'exposition à une L2 n'a plus aucun effet sur le traitement du langage chez un locuteur natif. Ainsi, mon but est d'identifier cette période sensible, spécifiquement pour le traitement des homonymes. Afin d'y arriver, je vais présenter et discuter les résultats de deux études. La première étude se consacre à des mesures de réponses comportementales tirées d'une tâche de décision lexicologique transmodale dans laquelle les participants entendaient une phrase et devaient, simultanément, faire une décision par rapport à un mot - soit vrai ou inventé - qui leur était présenté visuellement. La deuxième étude se consacre à des résultats de PE en utilisant un nouveau paradigme de PE qui examine non seulement l'objectif principal de cette dissertation mais aussi le second. Ce deuxième objectif est que cette dissertation devienne la première à évaluer les résultats de la combinaison d'une tâche de décision lexicologique transmodale avec des résultats de PE.

Les résultats comportementaux et neurophysiologiques pour les groupes monolingues appuient le *Reordered Access Model* (Duffy, Morris, & Rayner, 1988), alors que les résultats pour les groupes bilingues ne les appuient pas. Les résultats des présentes études démontrent que les personnes bilingues qui ont acquis le français comme une L2 plutôt qu'une seconde L1 innée font davantage preuve d'une divergence croissante à comparer aux monolingues natifs en ce qui concerne le traitement des homonymes dans leur L1. D'autre part, il y a preuve que cette divergence devient exponentielle plus l'acquisition se fait tard dans la vie. Ces résultats restent constants et ce, même si la tâche a été effectuée en anglais qui est la L1 (ou l'une des L1) de tous les participants. Les performances divergentes des personnes bilingues et des personnes monolingues étaient manifestes dans les réponses comportementales ainsi que dans l'amplitude, la distribution sur le cuir chevelu et la latence des négativités des PE. Ces différences étaient uniques à chaque groupe, ce qui appuie l'hypothèse selon laquelle l'acquisition d'une L2 a une influence sur le traitement de la L1 (Dussias & Sagarra, 2007). Plus spécifiquement, les groupes des personnes bilingues tardives et des personnes bilingues séquentielles ont fait preuve d'une grande divergence à comparer au groupe de personnes monolingues en ce qui concerne les effets d'amorçage syntaxiques ($p<.001$) et les effets de fréquence lexicales ($p<.001$). Ils ont aussi généré le plus d'effets similaires au N600 lors du traitement des mots-cible qui étaient inadéquatement reliés aux homonymes d'amorçage (tels que *skin* dans *Richard had a shed in the back of the garden*). Ceci évoque une sensibilité accrue aux repères de surface en raison de la L2 qui influence le traitement des homonymes dans la L1 (Cook, 2003; Dussias & Sagarra, 2007). Relativement,

le groupe monolingue a généré des effets similaires au N400 en quantité égale pour ce qui a trait aux ambiguïtés lexiques à comparer aux conditions qui n'étaient pas reliées, ainsi qu'une interaction par fréquence-de-contexte qui ralentissait leur traitement du mot-cible inadéquatement relié à la lecture subordonnée de l'homonyme d'amorçage. Ceci semble suggérer que les membres de ces groupes ne sont pas aussi sensibles à ces mêmes repères de surface. Il est important de noter que ces résultats confirment que l'utilisation des résultats de PE combinés à une tâche de décision lexicologique transmodale est un paradigme prometteur pour les futures études qui touchent au traitement de la langue.

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LIST OF ABBREVIATIONS

AoA	age of acquisition
AoL2A	age of second language acquisition
EEG	electroencephalography
ERP	event-related brain potentials
L1	first language
L2	second language
LG	language group
LG1	monolingual group
LG2	simultaneous bilingual group
LG3	early bilingual group
LG4	late bilingual group
RT	reaction time
synsub	priming condition: target word is appropriately-related to the subordinate reading of the syntactically-constrained priming homonym.
syndom	priming condition: target word is inappropriately-related to the subordinate reading of the syntactically-constrained priming homonym, but is appropriately-related to the dominant reading.
synunr	priming condition: target word is unrelated to the syntactically-constrained priming homonym.
semsub	priming condition: target word is appropriately-related to the subordinate reading of the semantically neutral and unconstrained priming homonym.
semdom	priming condition: target word is appropriately-related to the dominant reading of the semantically neutral and unconstrained priming homonym.
semunr	priming condition: target word is unrelated to the semantically neutral and unconstrained priming homonym.
synsubcntrl	non-priming control condition: target word is appropriately-related to the subordinate reading of the syntactically-constrained priming homonym, but sentence contains no priming homonym.
syndomcntrl	non-priming control condition: target word is inappropriately-related to the subordinate reading of the syntactically-constrained priming homonym, but is appropriately-related to the dominant reading. Sentence contains no priming homonym.
synunrcntrl	non-priming control condition: target word is unrelated to the syntactically-constrained priming homonym, but sentence contains no priming homonym.
semsubcntrl	non-priming control condition: target word is appropriately-related to the subordinate reading of the semantically neutral and unconstrained priming homonym, sentence contains no priming homonym.
semdomcntrl	non-priming control condition: target word is appropriately-related to the dominant reading of the semantically neutral and unconstrained priming homonym, sentence contains no priming homonym.
semunrcntrl	non-priming control condition: target word is unrelated to the semantically neutral and unconstrained priming homonym, sentence contains no priming homonym.

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CHAPTER ONE: INTRODUCTION

The age at which a speaker acquires a second language (L2) may be one of the most influential factors affecting not only the extent to which a speaker can master his or her L2 (Meisel, 2009; among others), but age of L2 acquisition (AoL2A) has also been found to affect the speaker's first language (L1) (Brien & Sabourin, 2012; Bylund, 2009; Cook, 2003; Pavlenko, 2000). This is not to say that acquiring a L2 will hinder a speaker's ability to achieve native-like behaviour in either language. Rather, acquiring a L2 at varying periods of development has been found to correspondingly affect both languages to varying degrees in terms of proficiency and reaction times (Brien & Sabourin, 2012), but it may also affect the neurological organisation of the bilingual mental lexicon, evidence of which may be found during lexical retrieval and processing (Joss & Virtue, 2010; Kotz & Elston-Guettler, 2004).

In order to address these issues, this dissertation will compare and discuss the results of two experiments investigating the possible effects that acquiring a L2 might have on the mental lexicon. Both experiments were conducted in English – the L1 of all participants, and the dominant language of the unbalanced bilinguals. Canadian French was the only L2 and no participants were functionally proficient in any other language[1]. Bilingual participants were grouped according to the age at which they acquired French as the L2, enabling a comparison investigating the effects of AoL2A at varying stages of development. More specifically, this study examines the effect of priming on syntactically-disambiguated homonyms versus ambiguous homonyms. The aim of which is to investigate how learning an

1 Unfortunately, proficiency testing was not conducted from the onset of testing, and therefore I am unable to report conclusively on the possible effects that proficiency might have in this particular study.

L2 later in life might affect one's ability or strategy to process homonyms in the L1 which are (a) constrained to only one appropriate meaning due to the priming sentential frame, or (b) presented in unconstrained sentential frames and thus remain ambiguous as to the intended meaning. As varying ages of L2 acquisition have been found to result in differences in language processing in the L2 (see Meisel 2009, among others), as well as the L1 (Bylund, 2009; Cook 2003; Pavlenko, 2000), any differences found between groups in processing the homonyms of this study were to be considered evidence of the speaker's mental lexicon having been affected by acquiring the L2 at certain periods of development.

This dissertation will also serve as a pilot study of sorts as not only is there no previous research investigating L2 effects on L1 homonym processing, but there are no published studies to the author's knowledge that have used this particular paradigm combined with ERPs. While my study aims to further investigate the findings of the behavioural experiment presented here as Study 1, my secondary aim is to confirm the validity of using the complimentary combination of a cross-modal lexical decision task involving sentential priming with ERPs. Consequently, Chapter 5 will include numerous exploratory statistical analyses to verify the existence of found differences in homonym processing by language group. This will mainly be due to a lack of existing methodological results to draw from and subsequently replicate or counter. As such, this ERP study will also serve as an exploratory study investigating how well the cross-modal paradigm can be used while measuring ERPs to the visually presented target word. Future analyses may also investigate possible ERPs to the auditorily presented homonym word.

1.1 Overview of the Experiments

This dissertation presents and compares two experiments used to investigate on-line processing differences of lexical ambiguities. Study 1 involves a behavioural experiment, where I employed a cross-modal lexical decision task involving lexical ambiguities. This cross-modal lexical decision task entailed participants to hear a sentence containing a priming homonym at the mid-point of the sentence coupled with the visual presentation of a related or unrelated target word. Differences in on-line processing of lexical ambiguities were investigated by examining variations in accuracy and reaction time (RT) between monolinguals and groups of speakers who had acquired L2 French at varying periods of development. Study 2 involves a neurophysiological method, namely event-related potentials (ERPs), which were captured simultaneously with the presentation of the cross-modal lexical decision task. Differences were investigated by examining variations in accuracy, RT, and also by variations in the brain responses time-locked to the target item that was visually presented to participants.

1.2 Overview of the Chapters

CHAPTER 2 of this dissertation will begin by presenting a background of this study as a whole. CHAPTER 3 will present the methodology used for this two-part study. CHAPTER 4 will present and discuss the method and results of Study 1: the behavioural experiment. CHAPTER 5 will present and discuss the method and results of Study 2: the ERP experiment. CHAPTER 6 will discuss the implications of these results within the current field of psycholinguistics.

CHAPTER TWO: REVIEW OF THE LITERATURE

2.1 The mental lexicon

The 'mental lexicon' is used to refer to the store of words one accesses and processes within the brain. This storage area is often referred to as the mental dictionary because it theoretically resembles an intangible dictionary (Pinker, 1994). However, the mental lexicon differs greatly from a typical dictionary in its volume, organisation, and retrieval. The mental lexicon is considered to be like a network in which words are related to each other and interconnected at many levels, which include but are not limited to, the levels of orthography, pronunciation, meaning, and conceptual representation. The number of words stored in the mental lexicon varies with each individual, although the total for an average English-speaking adult is estimated at about 150,000 words (Aitchison, 2003). The acquisition of an L2 adds another dimension of complexity to considerations regarding the organization of the mental lexicon, since any theory of language processing needs to account for the storage and retrieval of lexical items from more than one language. A vast number of studies over the past 50 years have attempted to resolve the issue of whether speakers with two languages maintain a single lexicon or recruit separate ones for their two languages (for a review, see Costa, 2005). These studies have dealt with factors such as proficiency and age of acquisition (AoA): factors which do not have to be accounted for in studies of monolingual native speakers. Monolinguals tend to acquire their language within a predictable developmental time span, while the acquisition of a L2 can be achieved at any period of a speaker's life, albeit with varying degrees of success. It is these differing degrees of success that have led a number of studies to suggest that AoL2A may be one of several important determinants of the structure of a mental lexicon which involves more than one

language (i.e.: Wartenburger, Heekeren, Abutalebi, Cappa, Villringer, & Perani, 2003; Weber-Fox & Neville, 2001; among others).

2. 2 The bilingual mental lexicon

The issue of the mental representations of the words of a bilingual's two languages being stored and accessed in one large shared and integrated system, or rather in two separate systems, has been investigated widely over the past decades. Evidence has been found for each of these theories. On the one hand, recent evidence suggests that bilinguals activate their two languages in parallel during language comprehension in the auditory modality (Marian & Spivey, 2003) and the visual modality (Dijkstra & Van Heuven, 1998; Van Hell & Dijkstra, 2002). This evidence suggests that the bilinguals in these studies are recruiting from an integrated lexicon during bilingual language processing. On the other hand, evidence suggests that the activation of one language does not entail the activation of the other (Ibrahim, 2009; Li, Mo, Wang, Luo, & Chen, 2009). Still others have begun asking not *is the conceptual store shared or separate,* but rather *what is shared and what is separate* (Pavlenko, 2009) based on evidence consistently suggesting that specific factors may affect specific levels of language activation and processing in bilinguals. For instance, language dominance has been suggested as a property of the bilingual mind which may be related to underlying competence (Yip & Matthews, 2006). Bilingualism in infancy has been called a challenge (Yip & Matthews, 2006) for the child acquiring language because their language input is generally considered to be divided between the languages being acquired. Consequently, the amount and frequency of exposure to each language at any given time is reduced compared to that of a monolingual child acquiring only one language (Paradis & Genesee, 1996). Due to this imbalance of input, one of the two languages may develop more

quickly and with greater complexity, resulting in the more advanced language being considered the dominant language. Unfortunately, although language dominance has been used as a measure of degree of bilingualism, it has been found that dominance patterns may change over time depending on individual experiences (Romaine, 1995). What this means for the bilingual mental lexicon is this experiential frequency is an important factor in the acquisition and storage of mental representations (Paivio, 1990). As a result, it cannot be taken for granted that the mental representations of either language, even the dominant one, in the minds of bilinguals are the same mental representations as the corresponding one of monolinguals.

Further, during bilingual word-recognition tasks, factors such as proficiency have been found to constrain parallel language activation. Van Hell and Dijkstra (2002) found that parallel language activation is more reliable when proficiency in the unused language is high compared to low proficiency. Further, Silverberg and Samuel (2004) investigated the role of AoA in a cross-language lexical decision study. They found evidence of a shared lexicon at the semantic level for early bilinguals but not late bilinguals when proficiency was controlled for. These findings led them to propose a mixed model of the bilingual mental lexicon, where early bilinguals have separate lexical stores but one shared semantic store, and late bilinguals have an integrated lexical store but separate semantic stores. This suggests that, compared to proficiency level, the age at which a speaker acquires his or her L2 may be more influential on the organization of the mental lexicon.

Evidently, language dominance, proficiency, and AoA are all crucial factors to be considered when dealing with bilingual speakers. However, due to the limited scope of the current study, AoA is the main focus. Specifically, the current study focuses on the issue of

AoL2A in regards to the effect that the L2 might have on the L1, and what this might reveal in regards to the bilingual mental lexicon. Some recent studies investigating AoL2A and the bilingual mental lexicon are presented and discussed next.

2.2.1 The bilingual mental lexicon and AoL2A

It appears that the physiology of any L2 learner's mental lexicon varies depending on the age at which the L2 was acquired. Speakers who acquired both languages early in childhood – before the age of seven (Fabbro, 2001) - have been found to recruit the same language areas in the brain for language processing as monolingual native speakers, specifically the left inferior frontal and temporal lobe areas, as well as the basal ganglia (Fabbro, 1997; Fabbro, 2000; Hernandez, Li, & MacWhinney, 2005; Paradis, 1998, 2001; Ullman, 2001a; 2001b). In contrast, speakers who acquired their L2 after puberty - also referred to as late L2 learners - appear to recruit other areas, most notably of the right hemisphere (Paradis, 1998) and less so, of the basal ganglia (Hernandez et al., 2005; Osterhout, Poliakov, Inoue, McLaughlin, Valentine, Pilkanen, Frenck-Mestre, & Hirschensonhn, 2008; Ullman, 2001b). Furthermore, the mental lexicon of early bilinguals appears to resemble the monolingual mental lexicon more closely than the mental lexicon of late bilinguals (Hernandez et al., 2005). These findings suggest two things; 1) the existing models of the mental lexicon (Bock & Levelt, 1994; Gaskell & Marslen-Wilson, 1997; Jackendoff, 2003; Marslen-Wilson, 1984; Ullman, 2001a) need to account for the fact that the mental lexicon of early bilinguals is similar to that of monolinguals while that of late bilinguals is not, and 2) further research needs to investigate exactly how early bilinguals and monolinguals may be differing in ways which have not yet been discovered.

Bilinguals acquire the L2 at varying stages of development, with simultaneous bilinguals acquiring two native languages concurrently from birth, early bilinguals acquiring the L2 before proposed sensitive periods of language acquisition, and late bilinguals acquiring the L2 after these sensitive periods. Compared to adults, young children's brains have been found to be more plastic (Klein, Zatorre, Chen, Milner, Crane, Belin, & Bouffard, 2006), enabling them to shift function specificity according to input much more easily than older brains (Paradis, 1998, 2001). This early flexible period of acquisition raises much speculation as to the effect of L2 learning on the organization of the younger mental lexicon. Consequently, current theories of language processing have not only been concerned with how simultaneous, early, and late bilinguals might be different from monolinguals neurologically, but also how they might differ from each other.

The current study presents evidence from a behavioural study supporting the suggestion that, as a result of acquiring the L2 during the early flexible period of acquisition, the organization of the younger mental lexicon differs from that of the mental lexicons of later L2 learners. The proposed study further intends to investigate this evidence more in-depth by drawing on recent neurophysiological studies which suggest the younger the brain, the more plastic it is. Linguistically speaking, the behavioural evidence suggests that a prepubescent brain is flexible enough to acquire and store the new lexical items of two languages within the same memory system (Hernandez et al., 2000; Klein et al., 1999). Indeed, fMRI studies involving bilingual lexical processing have shown bilinguals who acquired their L2 before puberty recruiting two overlapping locations of neural substrates within the left inferior frontal lobe (Hernandez et al., 2000; Hernandez et al., 2005; Kim, Milner, Zatorre, Zhao, & Nikelski, 1997; Klein et al., 1999; Klein et al., 2006; Proverbio,

Čok & Zani, 2002), whereas late L2 learners have been found recruiting two non-overlapping locations (Hernandez et al., 2005). Thus, the development of overlapping substrates may reflect early bilinguals effectively organising two languages as if they were one native language, since both languages are being acquired while the brain is still flexible enough to store the words and mental grammar of both languages collectively. This has resulted in what has been referred to as a state of simultaneous bilingualism. Such speakers are often referred to as having two L1s or 2L1 (Meisel, 2009). Yet conceivably, these two languages must be kept separate, as they are unique from each other, and so the bilingual brain utilises dual neural substrates to keep them separately and neatly organised. The shared and overlapping segment(s) of the two locations of neural substrates has been suggested as reflective of a shared storage for object representations (Costa & Caramazza, 1999; Green, 1998; La Heij, 2005).

2.2.2 ERPs and bilingual language processing

What does this entail for the mental lexicon dealing with more than one language? In L1 processing, the nature and time-course of the many different subsystems involved in language processing, including phonological, syntactic, lexical, and pragmatic, as well as the interaction of these subsystems, have yet to be clarified completely. Even less is known about L2 processing and the possible interactions that L1 and L2 may have on each other. Using ERPs, many researchers have investigated one of the unresolved hot topic questions regarding how more than one language might be stored, accessed, and processed with respect to each other within the brain of one speaker. Studies which have explored the issue of the bilingual mental lexicon are vast and varied, focusing on many aspects of bilingualism, including, but not limited to, lexical processing (Costa et al., 2009; Frenck-Mestre & Prince,

1997; Kotz & Elston-Guettler, 2004), word recognition (Bialystok, 1987, 1999; Lehtonen, Hultén, Rodriguez-Fornells, Cunillera, Tuimainen, & Laine, 2012), cognates and interlingual homographs (Joss & Virtue, 2010), and other lexical ambiguities (Elston-Guettler & Friederici, 2005, 2007; among others). For the purpose of this dissertation, I will focus on those studies which are relevant to the current issue, that is, in particular, how the L2 might affect L1 lexical processing in general and how the L2 might affect lexical ambiguity resolution in particular and what these effects might reveal about the bilingual mental lexicon.

Kotz (2001) and Kotz and Elston-Guettler (2004) used categorical priming (*heart-liver*) and associative semantic priming (*heart-love*) to test predictions of the Revised Hierarchical Model (RHM: Kroll & Stewart, 1994) of the bilingual lexicon. Based on the RHM positing weaker conceptual links for words in the L2 than in the L1, they predicted weaker categorical priming effects for L2 speakers compared to L1 speakers. Kotz (2001) tested proficient early L2 learners (AoA 4 years) of English, while Kotz and Elston-Guettler (2004) tested late L2 learners of English (AoA 11 years) with high and low proficiency. The results of Kotz (2001) revealed native-like N400 patterns for both categorical and associative priming in the early proficient bilinguals as they showed larger N400s to unrelated words. Kotz claimed that this indicates that word-to-word and word-to-concept links in the L2 were just as strong in the lexicons of the L2 speakers as in the native speakers, which did not support the predictions of the RHM. On the other hand, Kotz and Elston-Guettler (2004) did find differences between native speakers and late L2 speakers with varying levels of proficiency. The late L2 speakers revealed evidence of an N400 effect for associative priming irrespective of proficiency level, but no N400 effect for categorical priming. There were further differences correlating to proficiency level, with the high proficiency group

revealing a longer-lasting negativity to unrelated words in the associative priming condition compared to the low proficiency group. The authors interpreted these results as suggesting that the development of a direct link to the conceptual level (as tested by categorical semantic priming) in the L2 is strongly influenced by AoA, whereas associative priming at the lexical level appears to be influenced by proficiency level, which was indicated by an enhanced and longer-lasting N400 effect to unrelated words for the high proficiency group compared to the low proficiency group (Kotz & Elston-Guettler, 2004).

Lehtonen et al., (2012) used a visual lexical decision task and simultaneous ERP recordings to investigate bilingual word recognition within the domains of frequency of real words, morphology of real words, and lexicality: real words vs. pseudowords. Their study compared Finnish monolinguals to highly proficient Finnish–Swedish bilinguals who had acquired both languages during childhood. The results revealed longer response latencies overall in bilinguals compared to monolinguals. Further, the larger negativities found for pseudowords over real words, larger negativities for low frequency over high frequency real words, and larger negativities found for inflected over monomorphemic real words, were themselves larger in the bilinguals than in the monolinguals. The authors suggest that the discrepancies found between the bilinguals and monolinguals reflect the result of a decreased exposure to the lexical items being tested, as they argue that the language input of bilinguals is divided between two languages, therefore resulting in the bilinguals' words having lower frequencies. They argue that their findings are supported by previous studies also showing bilinguals as being slower than monolinguals even in their dominant language, and especially so with lower frequency words (Gollan, Montoya, Cera, & Sandoval, 2008; Ivanova & Costa, 2008). In a previous study reporting similar findings, Gollan et al. (2008) interpret their results as a reflection of bilinguals tending to use their two languages constantly

compared to the exclusive use of only one language by monolinguals. Consequently, they argue that each word in the bilingual lexicon receives less exposure, thus resulting in a lower frequency for each word. These lower frequencies in turn result in weaker links between phonology and the semantic representations in each lexical system, subsequently resulting in the words in the bilingual lexicon to be conceivably less easily available than those in the monolingual lexicon. This theory reflects the RHM (Kroll & Stewart, 1994) and has been coined "the weaker links hypothesis" (Gollan & Silverberg, 2001; Gollan et al., 2008).

Another hypothesis accounting for the delay in bilingual responses involves the language non-selectivity of lexical access. This theory, cited by Duyck, Vanderelst, Desmet, & Hartsuiker, (2008) and Gollan et al. (2008), posits that the mental lexicon is organized by bins where lexical items are located. These bins are believed to be ordered on the basis of frequency, resulting in low frequency words being found at a less-accessible location within the mental lexicon, which are postulated as being further away than high frequency words (Murray & Forster, 2004). Words are considered to be ranked according to frequency, and in lower frequency ranges (where L2 words are conceivably found due to lower exposure and usage) the number of lexical entries is larger than in higher frequencies. This storage system results in a longer search time for the low frequency items as the mechanism underlying processing thus has to consider more words before arriving at the correct one in the bin. As there are more items in the bilingual mental lexicon, especially in the low frequency range, it would take an exponentially longer time to search for and retrieve the correct item. Indeed, there is word recognition evidence of bilingual lexical access that is non-selective of language (Dijkstra & van Heuven, 2002a; Sabourin, Brien, & Burkholder, in press; Spivey & Marian, 1999; Thierry & Wu, 2007) whereby bilinguals appear to process translation equivalents similarly to semantic associations. In a recent masked lexical priming study by

Sabourin, Brien, and Burkholder (in press), the RTs of monolingual native English speakers and bilinguals who varied by AoL2A were compared across four priming conditions, that of repetition (*snow – snow*), association (*cold - snow*), translation equivalents (*neige – snow*), and unrelated (*table – snow*). Although each group showed the greatest priming effects for the repetition priming conditions and secondly for the associative priming, the greatest difference between the groups was revealed in the results of the translation equivalent priming conditions. These results found that the ease and speed of processing translation equivalents appear to reflect an earlier AoL2A, as the earlier L2 acquirers revealed larger translation priming effects compared to later L2 acquirers while monolinguals and the latest L2 acquirers showed no translation priming effect. Further, the RTs to the translation equivalents were comparable to the associative priming conditions for the earlier acquirers, suggesting that for earlier L2 acquirers, translation equivalents and associations are closely linked to the target words within a shared mental lexicon. This suggests that bilinguals may store and access the associations and translations of words in the same or nearby bins, thereby influencing access and processing of the L1 lexical items (Sabourin, Brien, & Burkholder, in press). Consequently, this suggests that translation equivalents that are themselves high frequency words are conceivably stored at more-accessible locations within the bilingual mental lexicon (Murray & Forster, 2004).

In a lexical decision task also measuring ERPs, Elston-Guettler and Friederici (2005) tested native speakers of English and German learners of L2 English and found evidence of what they called "multiple accesses". At 200ms after the presentation of a homonym, they found that both groups activated both meanings, despite the presence of a semantic context biasing towards only one meaning. Evidence of the activation was shown in significant RT

priming and increased amplitudes of the N400 component for both contextually appropriate and inappropriate targets. However, by 500ms, both groups showed RT priming for the contextually appropriate meanings only, and native speakers showed ERP evidence of activation of only the contextually appropriate targets, whereas the L2 learners did not appear to show evidence of full disambiguation as they still showed ERP evidence of activation of both meanings. Based on these findings, Elston-Guettler and Friederici suggest that there are two stages of homonym processing. The first stage of homonym processing, occurring around 200ms, involves accessing all the possible meanings of the homonym, resulting in both native speakers and L2 learners processing homonyms similarly. They argue that this suggestion is supported by the previous findings of Frenck-Mestre and Prince (1997) whereby they report finding both native speakers and learners showing comparable priming of both homonym meanings at initial stages (100 and 300ms) in single word processing. The second processing stage, occurring around 500ms, involves the initial use of contextual cues to disambiguate homonyms. It is in this stage that native speakers and L2 learners appear to diverge in their processing. L2 learners appear to require more time than native speakers to apply contextual information to disambiguation. They present a RT-ERP dissociation found at 500ms, whereby the L2 learners did not reveal ERP evidence of having disambiguated the homonym, yet the RT results of this same group suggested that they had selected the correct meaning. Elston-Guettler and Friederici (2005) suggest that if given more time, L2 learners may show similar ERP effects as native speakers and they hypothesize that native speakers and L2 learners differ in the time-course of processing, not in the underlying mechanisms involved.

In a subsequent study, Elston-Guettler and Friederici (2007) investigate their previous suggestion that L2 learners require more processing time to match native speakers' ERP

effects in homonym disambiguation. In fact, by 800ms, RTs and ERPs revealed that both native speakers and learners had activated the contextually appropriate meanings only. They report that there were no group differences for either RT or ERP data, and suggest that this reflected comparable processing of context information late in processing. Both groups showed a significant reduction of the N400 component for contextually appropriate homonym meanings compared to inappropriate meanings. They also report that the N400 modulation did not differ statistically in degree, latency, or scalp distribution across groups and they argue that the disambiguation reflected in the RTs and ERPs are supported by the same underlying neuropsychological mechanisms in both groups.

In a reading task of cognates and interlingual homographs using visual field-hemisphere correlation and RTs, Joss and Virtue (2010) found hemispheric differences in processing constrained sentences. They report that bilinguals who had acquired the L2 before the age of six showed evidence of processing strongly constrained sentences more quickly than weakly constrained sentences in both hemispheres, whereas monolinguals processed the same only in the left hemisphere. Joss and Virtue suggest that these findings are consistent with previous findings showing language non-selectivity when the level of constraint is weak (Schwartz & Kroll, 2006; van Hell & de Groot, 2008). They suggest that the language not in use may be activated to a greater extent in the right hemisphere than in the left.

Thus, these studies have enlightened current research on bilingualism in regards to the nature and time-course of the many different subsystems involved in L2 processing, how more than one language might be stored, accessed, and processed with respect to each other within the brain of one speaker. These studies suggest the development of a direct link to the conceptual level in the L2 may strongly be influenced by AoA (Kotz, 2001; Kotz & Elston-Guettler, 2004) and that the frequency of both sets of a bilingual's words may be lower,

resulting in longer RTs (Lehtonen et al., 2012) as suggested in the Weaker Links Hypothesis (Gollan & Silverberg, 2001). Although it appears L2 learners differ in the time-course of processing, not in the underlying mechanisms involved in disambiguating homonyms (Elston-Guettler & Friederici, 2007; among others), the language not in use may be activated to a greater extent in the right hemisphere than in the left (Joss & Virtue 2010). Thus, it appears that bilinguals may or may not differ in the underlying mechanisms of lexical processing, and bilinguals' RTs may be slower due to lexical links or retrieval due to bilateral activity. What remains to be investigated are the possible interactions that the L1 and L2 may be having on each other, and what kinds of influence the L2 may have on the L1. These issues may explain the discrepancies in the results of the studies discussed above and is investigated in section 2.7: L2 Effects on the L1 of this chapter.

2.3 Language processing

Even in light of these complex systems of lexical storage, the access and retrieval of words is accomplished with amazing speed, even in the case of 2L1 speakers. Typically-developing speakers can recognise a word of their language in 200ms (milliseconds) or less and can reject a non-word sound sequence in about half a second (Aitchison, 2003). In light of this efficacy, it is implausible that speakers systematically examine the entire contents of their mental lexicon(s) when retrieving a word. Instead, psycholinguists have posited more efficient mechanisms for accessing and processing lexical items. These complex psychological mechanisms, while remaining below the speakers' level of consciousness, rely on phonological, morphological, syntactic, and semantic properties of the words that are ostensibly stored as part of the mental lexicon representation (Gaskell & Marslen-Wilson, 1997; Jackendoff, 2003; Swinney, 1979). According to context-independent or modular

theories of language processing, such as Fodor's (1983) modular system which remains under investigation using current neurophysiological methods (e.g., Sereno, Brewer, & O'Donnell, 2003; Sheridan, Reingold, & Daneman, 2009), each property, such as phonological form, meaning, and part of speech, is associated with a module which includes subsystems that are responsible for the storage, access, and processing of that property (see Coltheart, 1999 for a discussion). Thus, each speaker has a phonological module, a syntactic module, and a semantic module for his or her language. How might the mental lexicon of a L2 learner differ? Is it possible that he or she would have duplicated modules to account for the demands of storing and processing two languages? Based on the recent evidence of separate but overlapping neural substrates in early bilinguals, Hernandez, Li, and MacWhinney (2005) do indeed suggest an Emergentist View of L1 and L2 acquisition, stating that language modules are made, not born. That is, at least in the case of lexical processing, these modules are found to be formed as necessary. Thus, the simultaneous learning of two languages (2L1) leads to the formation of extra separate language modules, whereas monolinguals do not display such separate formations since the monolingual brain does not need to accommodate for the acquisition of a L2.

Each module in the mental lexicon must then conceivably have a subsystem which connects to and communicates with other modules in order to achieve language processing. There is considerable debate among modular theorists regarding the degree to which the subsystems of each module operate independently from one another during lexical processing. For example, Tanenhaus and Lucas (1987) consider them to be independent of one another, based on the fact that quite different rules and representations are used to portray each one. On the other hand, Prinz (2006) refutes Fodor's (1983) classical modular

view as a "carving up of the mind" (pg. 9) and which results in scattered islands of modularity. He suggests instead that the mind is made up of a variety of parts which are organized into a network of interconnected systems and subsystems.

The question of whether the mind functions by recruiting independent modules or modular parts within a system has received considerable attention in research on the processing of lexical ambiguities during sentence comprehension. The results have not been definitive, but have provided support for both independent modular theories (Cairns, 1984; Cosmides & Tooby, 1994; Fodor, 1983; Forster, 1979; Gorrell, 1989; O'Seaghdha, 1989, 1997; Sperber, 1994) as well as for interactive processing theories (Elman & McClelland, 1984; MacDonald, Perlmutter & Seidenberg, 1994; Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welsh, 1978; McClelland & Rumelhart, 1981; Pinker & Jackendoff, 2005; Prinz, 2006), suggesting a need to account for varying empirical evidence. Thus, as the purely-modular and purely-interactive models of language processing fail to account for all empirical evidence, Boland (1993) introduced a mixed view of syntactic and semantic analyses as being distinct processes, with semantic processing occasionally being aided by syntactic information. This hybrid view suggests that storing items along with their syntactic information in the mental lexicon may simplify the process of comprehending sentences as the item's information would be retrieved simultaneously with the item itself, resulting in a more efficient system of language processing. This hybrid view appears to be a more plausible explanation as to the nearly effortless manner in which we comprehend sentences. Indeed, a hybrid view may help to resolve the long-standing debate concerning the order in which these modules are recruited for language processing, that is, the manner of processing.

2.3.1 Manner of processing

The order in which each of these modules functions to achieve lexical access and processing has been proposed as being bottom-up, top-down, or both, given the proposed ability of the modules to interact. Both processes progress from a) the phonological module which handles the processing of the incoming acoustic signal to the segments of phonemes, syllables, and morphemes, to b) the syntactic module which deals with information of the individual words, and then to c) the semantic module which processes incoming contextual information. Bottom-up models of language processing suggest that processing strictly adheres to this chronological sequence of modular recruitment. Support for this view has been found in experiments such as that carried out by Taft and Forster (1975) which showed that words were first decomposed into their morphological constituents even in the absence of any semantic contextual aid. On the other hand, top-down models suggest that the higher levels of processing can influence and affect the lower levels. Using higher level, semantic information at an early stage in top-down processing may allow a speaker to predict what is to follow in the utterance (Binder & Morris, 1995; Schvaneveldt, Meyer, & Becker, 1976; Swinney, 1979). Both of these manners of processing have been suggested as serial processing, as the properties of a word are processed one at a time in sequence (Fodor, 1983; Frazier, 1979). Alternatively, there are theories of parallel language processing which complement Boland's (1993) hybrid view. In parallel processing, there is no strict chronological order of processing and some of the properties of words are processed simultaneously. Indeed, linguists remain divided between those who believe that lexical access and processing occur in a serial manner (Fodor, 1983; Frazier, 1979; Friederici, 1995; Klepousniotou, Pike, Steinhauer, & Gracco, 2012) and those who argue in favour of parallel processing (Costa, Caramazza, & Sebastien-Galles, 2000; Gaskell & Marslen-Wilson, 1997;

Ihara, et al., 2007; Pienemann, 1998; Sereno, Brewer, & O'Donnell, 2003; Swaab, Brown, & Hagoort, 2003; Ullman, 2001a; van Hell, 2005; van Hell & Dijkstra, 2002).

2.3.2 Initial stages of processing

Irrespective of whether lexical access and processing is achieved in a serial or a parallel manner, evidence continues to suggest that the phonological properties of words are dealt with in the initial stages of language processing (Gaskell & Marslen-Wilson, 1997). That is, during lexical access, multiple lexical candidates which share the initial phoneme(s) of the word onset are activated for processing (Lukatela & Turvey, 1994; Marslen-Wilson, 1987; Marslen-Wilson & Welsh, 1978; Norris, 1994). These initial findings led to the introduction of a cohort model of auditory word recognition (Gaskell, & Marslen-Wilson, 1997; Marslen-Wilson, 1984). This model posits that as a speaker hears the first 200ms of a word, he or she unconsciously activates a cohort of all possible words that the utterance might become. For instance, "*cap*...." could possibly be *capital* or *captain*, or any number of other possibilities. As more of the word is heard, such as "*capi*....", candidates such as *captain*, which no longer match the incoming acoustic information, become less activated. Selection of the appropriate candidate takes place when only one remaining candidate matches the acoustic signal best, in this case *capital* (Marslen-Wilson, 1984). The cohort model of language processing is not restricted to auditory presentation of lexical items. In a visually-presented masked priming experiment, Longtin, Segui, & Hallé (2003) found participants predicting the rest of a word solely on the basis of the first syllable. Longtin and colleagues argued that the task did not provide enough time for the participants to access the semantic level of the prime. As will be seen in the next few paragraphs, timing is crucial to the understanding of the accessing and processing of lexical items (Friederici, 2002).

2.3.3 Later stages of processing

The original cohort model of processing included candidates of words to be activated on the basis of acoustic information and phonology without aid or influence of context, and was thus a strictly bottom-up model (Marslen-Wilson, 1984). However, subsequent versions of this model allowed context to be a factor during later stages of lexical processing, while the initial phonological stage remained independent and unaffected by context. Referred to as the distributed cohort model (Gaskell & Marslen-Wilson, 1997), this revised version considers lexical items to be represented by both phonological and semantic output nodes. Each of these nodes contains information: the phonological nodes contain information about the phonemes in each lexical item, and the semantic nodes contain information about the meanings of the word. As more bottom-up information is received, the processing system progresses towards the candidate which is most appropriate for all nodes involved. This is also true with sentences containing a semantic context which constrains the meaning of a word towards only one appropriate meaning. In effect, the sequence of processing does not skip the initial phonological step even though the later contextual stage would immediately eliminate any inappropriate candidates. The distributed cohort model (Gaskell & Marslen-Wilson, 1997) maintains that only at later stages of processing, when a number of possible candidates still remain, does context affect the inhibition of unsuitable candidates and the further processing of appropriate candidates. This suggestion is supported by findings of Elston-Guettler and Friederici (2007) who posit a three-phase model of homonym processing for both natives and L2 learners. Phase 1 involves early processing of single words or short SOAs (200ms or less). In Phase 1, multiple access occurs, where both meanings of a homonym are activated for processing, which suggests that the activation of both appropriate and inappropriate meanings of homonyms is automatic. Phase 2 is found 500ms post-

stimulus onset, where monolingual native speakers show RT and ERP evidence of homonym disambiguation due to contextual information. This second phase is where L2 learners differ from the monolingual native speakers. Elston-Guettler and Friederici (2007) found L2 learners showing RT evidence of homonym disambiguation due to the same contextual information, with no ERP evidence of disambiguation, suggesting that the L2 learners require more time for processing. It is in Phase 3 of the three-phase model, found at 800ms post-stimulus onset, where the L2 learners reveal the same underlying processing of meaning disambiguation as do the monolingual native speakers. Thus, Elston-Guettler and Friederici (2007) claim that the initial activation of homonym meanings occurs at 200ms post-stimulus onset, contextual integration begins at 500ms, and disambiguation occurs during the final processing phase which occurs at 800ms post-stimulus onset. They further suggest that the timing differences found between the native speakers and the L2 learners is due to the automaticity of the connections between the words and concepts for the native speakers in comparison to the L2 learners. In other words, the more automatic the connections can be made within the mental lexicon between the words and the concepts, the less time it will take for this three-phase model of homonym processing to be carried out.

2.3.4 The manner of bilingual language processing

Let us revisit what this entails for the mental lexicon dealing with more than one language. If we consider simultaneous bilinguals to have overlapping neural substrates for each language, one semantic representation may be stored with networks to the words for it in each language. Thus, as the semantic representation is accessed and processed based on phonological information, both words, one in each language, are activated for processing. This is commonly referred to as competition (Costa & Caramazza, 1999; Green, 1998; La

Heij, 2005). From a bottom-up serial perspective, for example, the auditory presentation of *duck* will lead both monolingual English speakers and simultaneous French/English bilinguals to access and process the phonological information of *duck* which will in turn lead to accessing and processing the conceptual representation associated with *duck*, namely that of a water fowl. In the minds of the monolinguals, processing is complete as there are no further associations. For simultaneous bilinguals however, the access and processing of *duck* the water fowl may also lead to the translation equivalent, that of *canard*, being accessed. Therein lies the competition between *duck* and *canard* for processing and comprehension, with contextual information aiding to dictate which of the two words, *duck* or *canard*, is more appropriate and which is to be inhibited.

It has been suggested that there are no factors strong enough for most proficient bilinguals to inhibit or "switch off" the other language (Grosjean, 1998; Van Assche et al., 2009), which suggests the possibility for the two languages to interact (Bylund, 2009; Green, 1998; Pavlenko, 2000). If speakers with more than one language are not aware of the influence his or her L2 may be having on the L1, would he or she be able to prevent this influence? This calls into question studies which have tested native speakers in the L1 without regard to their other languages. Thus, this dissertation proposes to investigate the possible influences and effects that acquiring an L2 may have on the strategies of lexical processing at the lexical level and the syntactic level of a speaker's L1, as well as any possible interactions between these two. By screening the participants carefully according to a strict set of criteria (see Methods section below), I hope to understand the varying effects that the L2 has on the L1 as well as the relationship between these variations and the age at which the learner acquired the L2.

Despite any speculations regarding how bilinguals might access their larger vocabularies, there is as yet no empirical evidence to suggest that the language processing of 2L1 speakers differs fundamentally from that of monolinguals. Evidence that 2L1 speakers have the same overall locus of processing within the brain would be seen as support for the notion that 2L1 speakers must access and process language in the same manner as monolinguals. On the other hand, given the evidence of overlapping dual neural substrates in early bilinguals (Hernandez et al., 2005), the amount of time required to access and process language might be longer, since L2 speakers are believed to be searching dual modules of vocabulary (i.e. Costa, 2005; among others). Evidence for a longer period of processing has been provided by a delay which simultaneous bilinguals display in both behavioural and on-line tasks compared to those of monolinguals (Fabbro, 2001; Paradis, 1998, 2001). However, the question of whether grammatical processing differs between simultaneous bilinguals and monolinguals remains open, as this issue has yet to be investigated in-depth. The present study proposes to addresses this issue through a study of the role of the syntactic frame in constraining and aiding the resolution of ambiguous homonyms using both behavioural and neurophysiological measures.

Grammatical processing evidence suggests simultaneous and early bilinguals have a similar system to monolinguals (Brien & Sabourin, 2012), where the lexicon and grammar are two systems with distinct computational, psychological, and neural bases which play parallel roles in the access and processing of lexical items (Ullman, 2001b). Thus, save for a timing delay, the effects of syntactic context and semantic context on lexical access and processing are not likely to differentially affect these groups. However, recent evidence does suggest that the effects of context, both syntactic and semantic, have been found to affect

homonym processing in later L2 learners even when processing in their L1 (Brien & Sabourin, 2012). Such differences suggest that the acquisition of a L2 at a later period of development affects L1 processing possibly due to a heightened sensitivity of contextual information.

2.4 Syntactic and semantic contextual effects on lexical decisions

While the models discussed previously (e.g. serial, parallel, and hybrid) acknowledge the existence of the syntactic and semantic modules, they do not provide a detailed account of the effects of their interaction with each other. Evidence gathered in regards to these effects has been varied. That is, while results of some studies show that semantic context predominately facilitates lexical processing (Swinney, 1979), other studies show that syntactic context precedes the effects of semantic context and can strongly influence lexical processing (Folk & Morris, 2003). Still other studies have found that lexical access is not guided by syntactic context (Tanenhaus & Donnenwerth-Nolan, 1984) and conversely, that semantic and syntactic effects occur independently and in a parallel manner (Van den Brink & Hagoort, 2004). Such findings appear to commonly suggest that syntactic category information is not a prerequisite to initiating semantic processing of a perceived lexical item. Nor is the reverse true. In other words, neither the syntactic nor the semantic modules are dependent on the results of the other for processing. Yet, as per the distributed cohort model of spoken-word processing, only after the initial stages of processing have activated a set of lexical candidates, is higher-level contextual information found to influence lexical processing, whether it be syntactic, semantic, or both (Marslen-Wilson, 1987; Marslen-Wilson & Welsh, 1978; Norris, 1994).

In the light of these conflicting findings, a number of studies, including the present research, have been set up to clarify the effects of syntactic context on later stages of processing (e.g. Elston-Guettler & Friederici, 2005). The main focus of many of these studies has been the investigation of exactly how and where the syntactic module fits into the stages of lexical processing. The syntactic module is considered to contain a system of rules required for a speaker to be able to combine words appropriately. This rule system is commonly referred to as the mental grammar (Pinker, 1994). Within this mental grammar, words are grouped into phrases and phrases are joined or expanded into bigger phrases. The rules which dictate how and when these words can be joined are heavily directed by the syntactic category of the words themselves such as whether they are nouns or verbs. Of course, the unconscious processing of a word's syntactic category, as well as the rules required to process that word appropriately, occurs very quickly, after the initial phonological stage of processing.

There is evidence that syntactic context affects lexical decisions without aid or influence of semantic context effects, supporting the possibility of syntactic processing dominating semantic processing. In one of the earliest studies investigating this possibility, Goodman, McClelland, and Gibbs (1981) found that lexical decisions were faster to target words when they were syntactically-appropriate continuations of a phrase following a prime word, such as *he agreed*, compared to when they were syntactically-inappropriate continuations, such as *no agreed*. That is, even though participants were instructed to make a word/non-word response to only the second word of the pair presented, the results indicate that the first of the pair influenced participants' reaction times. The target word *agreed* was responded to more quickly when preceded by *he* than when preceded by *no*, suggesting an

effect of syntactic priming. Similarly, Lukatela and colleagues (1983) found that lexical decisions to nouns in Serbo-Croatian were faster when the target was preceded by an appropriate preposition than when preceded by an inappropriate preposition. The authors suggest that these findings provide evidence of syntactic category priming the access and processing of appropriate lexemes without the aid or influence of semantic information. This in turn suggests that the processing of lexemes may involve a bottom-up manner of processing as the recruitment of the syntactic module appears to occur before the semantic module.

2.5 Lexical frequency

Levels of processing other than the syntactic level have also been found dominating early stages of processing. A sentence reading task by Keller, Carpenter, and Just (2001) showed lexical and syntactic factors interacting, while Green (1998) found lexico-semantic information being processed independently from syntactic information in lexical decision tasks. Whether lexico-semantic information is processed after syntactic, or vice versa, is still a matter of debate and under investigation in the current study. In an auditorily-presented lexical decision task, Bilenko, Grindrod, Myers, and Blumstein (2008) found that lexical information such as the frequency of a word affects the access routes and speed of lexical processing within the brain. In the case of ambiguity, where a word has more than one meaning, the two meanings are rarely balanced in frequency, resulting in one meaning found to be dominant over the other in frequency of use (Duffy, Morris, & Rayner 1988, among others). Bilenko and colleagues (2008) found increased activation in the bilateral inferior frontal gyrus in native English speakers for prime-target pairs where the prime is ambiguous compared to when the prime is unambiguous. These findings not surprisingly indicate an

increase in neural recruitment in order to resolve the ambiguity of the prime word. Interestingly, when participants were presented with the subordinate (lower frequency) meaning of an ambiguous word, such as *ball: dance,* compared to the dominant (higher frequency) meaning, such as *ball: soccer,* other areas, such as the left inferior frontal gyrus and the left cingulate gyrus, were also found to be active. This finding suggests that additional neurological resources are recruited to overcome lexical competition when a speaker is accessing the subordinate meaning of an ambiguous word. The more frequently a word's meaning occurs in one's lexicon, the faster and more easily that word is accessed over the less frequent meaning since fewer neurological resources need to be recruited. Thus, in the case of L2 learners, lexical experience must be taken into consideration since L2 learners have to build experience, or higher level processing, to draw on before they can recruit additional neurological resources to overcome such lexical competition (Green, 1998).

To account for the varied and/or contradictory evidence regarding which module dominates the later stages of contextually-bound lexical processing, many researchers (Friederici, 2002; Ihara, et al., 2007; Klepousniotou et al., 2012; MacDonald, Perlmutter & Seidenberg, 1994; Ullman, 2001a) have adopted a theory that spoken language processing involves an interaction of top-down and bottom-up processing. Particularly in cases of lexical ambiguity resolution, there is compelling evidence, discussed in the following section, that comprehension processes are of a highly interactive, impressionable nature, so that any level of contextual processing can be affected by another level (Beretta et al., 2005; Jenkins, 1977; Marslen-Wilson, 1975; Marslen-Wilson & Welsh, 1978; Pylkkanen et al.,

2006; Sereno, Brewer, & O'Donnell, 2003; Swaab, Brown, & Hagoort, 1997; Swinney & Hakes, 1976).

2.6 Lexical ambiguity resolution

In cases of lexical ambiguity, one word includes more than one property within one module of processing. Thus, an ambiguous word can contain different semantic properties, each of which will affect the processing of the sentence in such a way that any sentence containing the ambiguity could result in two different interpretations. As an illustration, Malmkjaer (2004) notes that "*James was looking carefully at the coach"* has two interpretations: either James was looking at a sportsman, or he was looking at a bus. In addition to general lexical factors such as the relative frequency of the two interpretations of *coach*, contextual information may aid in the final selection of a single appropriate interpretation. Although discourse information such as topic, setting, and interlocutors may aid in resolving the ambiguity, sentence internal contextual information located close to the ambiguity itself may also play a major role in its resolution. For instance, "*James was looking carefully at the angry coach"* adds the contextual expectation that an animate entity will follow *angry* prior to presentation of the ambiguous word *coach*. Hence, a contextually-based interpretation of what words might fit next is made prior to presentation of the ambiguous word. This is referred to as the process of "prior decision" (Foss & Jenkins, 1973) and is constant with the view that lexical access is a contextually restricted, non-independent, serial process. However, if one takes the view that lexical access is an independent, relatively autonomous, and parallel process, then immediate context would not be as useful to ambiguity resolution. Instead, a single appropriate reading for the word can be reached only after complete access of all the information (i.e. phonological, syntactic, and semantic) about

that word has occurred. This position, put forward by Swinney (1979), is referred to as the process of "post decision".

2.6.1 Semantic context effects on lexical ambiguity resolution

In what was arguably the first study to test the post-decision view of lexical access, Swinney (1979) conducted a cross-modal lexical decision task involving homonyms. Although Swinney expected to find evidence of the post-decision process being influenced by semantic context, the results revealed an unexpected reflection of other effects, such as phonological and syntactic effects, which precede semantic processing. In a second study, Swinney (1979) controlled for phonological effects, yet the results still pointed to the conclusion that semantic context does not direct lexical access. Rather, immediately following the appearance of an ambiguous word, such as the homonymous noun *bug*, all meanings for that word seem to be momentarily accessed during sentence comprehension. Consider the following example, as given by Swinney, "*Rumour had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several* ***bugs*** *in the corner of his room"* (Swinney, 1979, p.650). Without semantic context to facilitate one meaning over the other, and possibly inhibit the inappropriate one, the noun *bug* could mean the noun *insect* or it could equally mean the noun *spy device*. The results of this study found that both possible readings are initially accessed, with equivalent speed of decision to targets related to both. This was the case even when a strong biasing context towards one reading of the homonym was present, such as in this second example, "*Rumour had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several spiders, roaches, and other* ***bugs*** *in the corner of his room*" (Swinney, 1979, p.650).). The only evidence of semantic context aiding

lexical decisions was found when appropriately-related target words were presented four syllables after presentation of the ambiguity. This delay suggests that semantic context effects appear to be the result of some process which follows lexical access and are not a reflection of the access process itself (Cairns & Hus, 1979; Swinney, 1979). This suggests that semantic context influences lexical decisions only in the latest stages of processing; revealing a need to investigate whether or not the dominant influence on lexical decisions could be syntactic.

2.6.2 Syntactic context effects on lexical ambiguity resolution

The role of syntactic context in the resolution of lexical ambiguity was addressed in a study by Folk and Morris (2003). Whereas Swinney (1979) investigated the effects of semantics on homonyms of only one syntactic category, such as nouns, Folk and Morris' (2003) study investigated homonyms which differed in syntactic category. For instance, without a sentential frame to contextually disambiguate its meaning, the homonym *duck* could mean the noun *water fowl* or the verb *to put one's head down*. Folk and Morris found that lexical ambiguity was indeed sufficiently eliminated during on-line reading through syntactic category information alone. This finding fit with the view that such homonyms are stored with differing syntactic properties in the mental lexicon. Thus listeners can use preceding syntactic context to decipher the appropriate meaning even in such cases where distinguishing semantic context is lacking. For example, in "*Construction workers often* ***duck*** *on site*", *duck* is preceded by the adverb *often*. Adverbs usually precede adjectives and verbs, but they never precede nouns. Therefore the only meaning appropriate for this homonym is *duck* the verb. Now consider a similar sentence with the same homonym, "*Construction workers will often see a* ***duck*** *on site*." In this second sentence, *duck* is

preceded by the article *a*. As articles always precede nouns or noun phrases, but never verbs, the meaning of the homonym in this very similar sentence is *duck* the noun. These examples illustrate the strong influence of syntactic context (Gorrell, 1989) in interpreting ambiguous lexical items with differing syntactic categories (Folk & Morris, 2003). Thus, there are strong indications that syntactic category information can influence the semantic resolution of lexically ambiguous words even before semantic processing can occur. Hence, a preceding syntactic context may sufficiently facilitate contextually-appropriate interpretations.

Unfortunately, there is a limitation to the eye movement methodology that Folk and Morris (2003) used for measuring lexical access and processing. This methodology monitors eye movements as participants read. Conclusions are then drawn regarding participant strategies in resolving semantic ambiguity based on length of time spent reading particular lexical items within a sentence's structure. It is believed that the longer a participant spends looking at a particular item, the more difficult that item is to process. Unfortunately, eye-tracking alone cannot reveal online neurological processing. The eye-tracking experiment of Folk and Morris proved their hypothesis as looking time, and therefore access, was shorter, and therefore selective, towards a syntactically-constrained reading of a homonym compared to the control condition. However, looking time of the disambiguated syntactically-constrained homonyms did not differ significantly from that of ambiguous and unconstrained homonyms. Despite acknowledging that the processing of homonyms was more complex than they had anticipated, they were unable to offer a more detailed account of it. Thus, Folk and Morris could only speculate as to what might be causing longer gaze duration on certain items and shorter gaze duration on others.

In an earlier study, Tanenhaus and Donnenworth-Nolan (1984) also investigated ambiguous words which differed in syntactic category. The methodology used was similar to that of Swinney (1979), and the motivation behind doing so, they argued, was that previous studies did not test lexical access sufficiently for two reasons. First, they argued that the syntactic contexts of previous studies, (Seidenberg et al., 1982; Tanenhaus, 1979) were not truly restrictive and secondly, there was not enough time for the context to be integrated before processing the ambiguous word. In the Tanenhaus and Donnenwerth-Nolan (1984) study, participants were auditorily presented with an ambiguous word at the end of a sentence which contained a pause between the context and the ambiguous word. Participants then made a lexical decision to a target word which was related to either the appropriate or the inappropriate reading of the ambiguous word. The ambiguous word found at the end of the sentence had unrelated noun and verb meanings, such as *tire*. The syntactic category of the sentence-final ambiguous word was dictated by virtue of the preceding syntactic context: either noun or verb. For example, "*John began to tire*" or "*John bought a new tyre*[2]" (Tanenhaus & Donnenworth-Nolan 1984, p. 653). They found that listeners accessed both readings of the ambiguous words even when the syntactic context constrained against one of those meanings (Tanenhaus & Donnenworth-Nolan, 1984). These findings suggest that lexical access may be autonomous (Seidenberg et al., 1982; Tanenhaus, 1979; Tanenhaus & Donnenworth-Nolan 1984).

Indeed, the contradictory findings of studies investigating the effects of preceding syntactic context on lexical access leads me to agree with Tanenhaus and Donnenworth-Nolan (1984) who suggest that lexical ambiguity itself may represent a special case as it

2 This study was conducted in the UK, where the North American spelling of *tire* is *tyre*. As this was an auditory task, the authors did not consider the difference in spelling to be a confounding factor.

appears that context can be recruited in early stages of word recognition without eliminating contextually incompatible meanings of ambiguous words. They suggest that any syntactic context effects that have been found may be due to either post-lexical decision processes or to special-purpose strategies such as predicting the target word. Thus, the "special case" of lexical ambiguity resolution and its contradictory findings in previous and current studies has lead researchers to spend much time and effort on creating a model of lexical processing which will resolve the differences in existing findings and will accurately account for the timing and manner of all cases of lexical access.

2.6.3 Models of lexical ambiguity resolution

Results of studies on homonym processing using sentential context are varied but tend to fall within three types of models: selective access models, multiple access models, and ordered access models. Selective access models suggest that only the contextually-appropriate meaning of a homonym is accessed when the homonym is presented in a constraining context (Folk & Morris, 2003; Schwaneveldt, Meyer, & Becker, 1976; Sereno, Brewer, & O'Donell, 2003; Simpson, 1981; Tabossi, 1988). Multiple access models suggest that, at least initially, all meanings of a homonym are accessed regardless of contextual information constraining the homonym to only one appropriate meaning (Ihara, et al., 2007; Klepousniotou et al., 2012; Lucas, 1987; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979; Tanenhaus & Donnenwerth-Nolan, 1984). Finally, ordered access models suggest that initial activation of homonym meanings is influenced more by frequency than by context, and that these two factors can interact (Duffy et al., 1988; Rayner & Frazier, 1989; Sheridan et al., 2009; Tabossi, 1988).

According to selective access models, the context of a sentence presented prior to the presentation of an ambiguous word facilitates the access processes towards the selection of the one most appropriate meaning for that word. This disambiguating context has been found to be either syntactic (i.e.: Folk & Morris, 2003, among others) or semantic in nature (i.e.: Swinney, 1979, among others).

Without prior disambiguating context, multiple access models of lexical processing suggest that all possible meanings of an ambiguous word are accessed initially, and it is only in the subsequent selection stage that one meaning is preferred. The timing of this appears to be influenced by the relative frequency of the various meanings. That is, for ambiguous words with two equally likely and frequently-used meanings, the two meanings are accessed simultaneously (Seidenberg et al., 1982; Swinney, 1979; Tanenhaus & Donnenwerth-Nolan, 1984). However, for ambiguous words with one dominant meaning, that is more likely and more frequently-used than the other subordinate meaning, the dominant meaning becomes available earlier than the subordinate meaning (Duffy et al., 1988; Sheridan et al., 2009; Simpson & Burgess, 1985).

According to the Reordered Access Model (Duffy et al., 1988), prior disambiguating context affects the access process by increasing the availability of the appropriate meaning without influencing the alternative meaning. This causes competition when the appropriate meaning is the subordinate meaning as the model predicts that the subordinate meaning would become available earlier than usual and consequently simultaneously with the dominant meaning.

Eye-tracking studies investigating the roles of preceding sentential context and meaning dominance in lexical ambiguity resolution in monolinguals (Duffy et al., 1988;

Sheridan, Reingold & Daneman, 2009) have shown that preceding context and meaning dominance tend to interact and influence the timing of the availability of meanings. Duffy and colleagues (1988) found that fixation times were longer on homonymous nouns when the preceding sentential context biased them towards only the subordinate meaning compared to control words, an effect also known as the Subordinate Bias Effect (Kambe et al., 2001; Pacht & Rayner, 1993; Rayner et al., 1994). However, fixation times on homonyms and control words did not differ when presented with a preceding neutral context or a context that supported the dominant meaning only (Duffy et al., 1988). Conversely, in a previous study, balanced homonymous nouns presented in a neutral context resulted in longer fixation times compared to control words (Rayner & Duffy, 1986). Unlike the Reordered Access Model, Duffy, Morris, and Rayner (1988) claimed that neither modular nor interactive theories of language processing could account for these findings. They argued that modular theories could not account for the different types of preceding context resulting in differing fixation times and that interactive theories were inconsistent with the Reordered Access Model due to the expectation of preceding disambiguating context selectively accessing the subordinate meaning without any processing delays.

According to the Reordered Access Model, lexical access is exhaustive, and the order by which meanings are accessed is determined by both preceding contextual information and meaning dominance, with contextually-biased meanings and higher frequency meanings being accessed faster than unbiased and lower frequency meanings (Duffy et al., 1988). Possible interactions of these factors can result in two or more meanings simultaneously becoming available and competing for processing, which lead to processing delays. For instance, if the subordinate (less frequent) meaning of a homonym is supported by preceding

sentential context, the access to that meaning speeds up, causing the subordinate meaning to become available at the same time as the usually more available dominant (more frequent) meaning, resulting in the Subordinate Bias Effect.

2.6.3.1 ERPs and frequency effects

ERP evidence also appears to support the above findings concerning lexical frequency effects. Barber, Vergara, and Carreiras (2004), among others, found that high-frequency words elicit reduced N400 effects relative to low-frequency words (Barber, Vergara, & Carreiras, 2004; Van Petten, 1993; Van Petten, & Kutas, 1990). In other words, a smaller negative response was found for words which tend to be more common, whereas the more infrequently-used words tend to elicit a greater N400 effect (Van Petten & Kutas, 1990). Within a sentence, Kutas, Van Petten, and Kluender (2006) found that semantic context reduces the N400 of low-frequency words. They found that low-frequency items elicit significantly larger N400s compared to high-frequency words when presented early in a sentence, but this discrepancy progressively reduces over the course of the sentence.

Clearly, lexical frequency is an important factor to be considered in studies of language processing, and indeed, it has provoked a number of studies, including the current one, to investigate the possible effects frequency has on processing when presented with words of more than one meaning. Because lexical ambiguities such as homonyms are associated with more than one semantic representation (as well as possibly more than one syntactic category), it is believed that all meanings of that word must compete for processing when a speaker is presented with an ambiguous word (Klepousniotou, Pike, Steinhauer, & Gracco, 2012; Lee & Federmeier, 2011; Van Petten & Kutas, 1987). The case of lexical ambiguities, then, is a special case which requires taking into consideration the effects of

lexical frequency as well as priming contexts, whether lexical or sentential. Some key existing literature on the study of lexical ambiguity resolution using ERPs is presented next.

2.6.3.2 ERPs and lexical ambiguity resolution

In perhaps what is the earliest investigation of lexical ambiguity resolution using the ERP technique, Van Petten and Kutas (1987) adapted the cross-modal priming paradigm of Swinney (1979) and Tanenhaus, Leiman, and Seidenberg (1979) to a visual lexical priming paradigm and they recorded ERP responses to targets which followed the visual presentation of ambiguous words. They found that, based on context, responses to appropriately-related target words were less negative compared to responses to the inappropriate target words. They account for these findings by suggesting that the appropriate target words were considered less anomalous, and they conclude that the findings overall support an interactive position of language processing. However, Sereno, Brewer, and O'Donnell (2003) argued that the negativities found in this study occurred too late to be a direct reflection of lexical processing and launched their own investigation as to whether or not contextual influence on lexical processing can be traced to an earlier time period. Sereno and colleagues used a reading task to investigate whether prior context influences lexical access in the N1 from 132ms to 192ms post-stimulus. The N1 is the first negative-going component of the ERP waveform and has been found for word frequency differences (Sereno et al., 1998). In their analysis, greater amplitudes in the waveforms were found for ambiguous words presented in biasing context which they attributed to increased processing difficulty. Their results revealed both word frequency and context effects in the N1 component. They found a mere marginal biasing effect of context for low frequency control words (*Pirates headed out to the cove*) , but not high frequency words, which they suggest provides support for the context-

by-frequency interaction found in behavioural studies (e.g., Stanovich & West, 1981, among others) and the Reordered Access Model (Duffy et al., 1988). Responses to ambiguous words in neutral contexts (*James peered over at the bank*) were comparable to responses to high frequency words (*She looked over the book*) which showed reduced negative amplitudes. They suggest that this indicates that these items were easier to process. Comparatively, once these ambiguous words were within biasing context (context instantiated the subordinate sense), responses to ambiguous words (*The mud was deep along the bank*) were comparable to responses to low frequency words (*Pirates headed out to the cove*) which showed more positive amplitudes and were therefore harder to process. It appears that the biasing context made ambiguous words more difficult to process. They suggest that their results establish the existence of context effects on lexical access very early on in the ERP record and are more consistent with an interactive account of language processing rather than a modular account.

A more recent reading study by Lee and Federmeier (2011) investigated age effects on lexical ambiguity resolution. Of interest to the current study are their reported results from the younger adult participants, particularly as their study also involved contextually-constrained ambiguous words in sentence-final position. The authors found noun/verb homonyms in congruent sentences eliciting larger, although otherwise qualitatively similar, N400 responses compared to cloze-probability-matched unambiguous words. They found that these N400 differences arose mainly when semantic context constrained towards the subordinate sense of the ambiguous word, such as "*season*" in the sentence, "*I knew the meat needed more flavor, but found that it wasn't all that easy to season*." Crucially, the sentences used for this study contained noun/verb homonyms and the congruent sentences provided a noun- or verb-specifying syntactic frame as well as constraining semantic information (such as *meat* and *flavour*, above). They suggest that this N400 difference reflects a residual

mismatch between meaning features associated with the contextually irrelevant dominant sense and those highlighted by the context. They explain that although ambiguous words in congruent contexts may still elicit features associated with multiple meaning senses, when information is available to shape semantic activation in advance, settling into a single interpretation can be done via stimulus-driven activity associated with semantic access. This access appears to unfold in a qualitatively-similar manner for ambiguous as for unambiguous words. However, when semantic constraints are unavailable, the young adults of this study appear to recruit additional resources to help resolve ambiguity. Lee and Federmeier claim that noun/verb homonyms elicited sustained frontal negativities (200-700ms) relative to unambiguous words. They suggest that this frontal negativity reflects top-down processing which recruits selection-related neural resources when meaning interpretation is difficult. They did not find these frontal effects when semantic context was available, even when the context biased towards the less frequent meaning, demonstrating that the facilitating effects of semantic constraints can alleviate selection demands, and consequently mitigate the need to recruit additional processes. In sum, they suggest that the processes involved in lexical ambiguity resolution differ in their cognitive nature (stimulus-driven vs. more controlled) and their neural roots (temporal lobe and frontal lobe areas).

Although more evidence is needed of the precise time-course of activation of regions involved in lexical ambiguity resolution, recent neuroimaging research such as the one above has identified potential regions of interest. Both of these issues, that is, the time-course of activation and regions involved in lexical ambiguity resolution, are investigated in a study by Klepousniotou et al., (2012). Specifically, this study investigated the time-course of meaning activation using ERPs. Although their study involved various types of ambiguity, I will present and discuss their findings regarding homonyms as these are of relevance to the

current study. The authors point out that previous studies using magnetoencephalography (MEG) and ERPs to investigate ambiguity resolution have varied in the interval between stimuli presentations. So much so, that the results of these studies fall under two categories, that of short inter-stimulus intervals (ISI), such as 50-100ms, and long ISIs, such as 1250ms (Swaab, Brown, & Hagoort, 2003). At short ISIs, it appears that both readings of homonyms, whether dominant or subordinate, are at least partially activated for processing. Whereas at long ISIs, the contextually-appropriate reading appears to be more activated and the dominant and inappropriate reading is less so. Klepousniotou and colleagues used a short ISI of 50ms in a visual single-word priming delayed lexical decision task. The delay entailed participants making a decision 1000ms after presentation of the target word. The pairs of words involved in the study were either balanced or unbalanced for frequency. Their results showed priming effects as a reduced N400 observed for dominant meanings of homonymous words, regardless of whether they were balanced or not, indicating effects of dominance and frequency. The authors claim that these effects were found over both hemispheres, suggesting that the dominant meaning initially activates a large network involving many neural generators over both hemispheres in order to activate the full set of semantic representations. In contrast, relatively reduced N400 effects were found for subordinate and related target words which were confined predominantly to electrode sites in the left hemisphere. They suggest that this may indicate a limited involvement of the right hemisphere in the processing of subordinate meanings, since these meanings activate only a subset of the semantic representation subsequently leading to weaker observed priming effects. Klepousniotou and colleagues conclude that the selection process of the different meanings of homonyms from their separate locations within the mental lexicon, and the

hemispheric network of neural generators involved in the selection process would be better evaluated using techniques which offer better spatial resolution such as MEG or fMRI.

Indeed, a study by Ihara, Hayakawa, Wei, Munetsuna, and Fujimake (2007) did just this. Ihara and colleagues used a silent reading and judgment task and MEG to investigate the neural mechanisms involved in lexical access and the selection of contextually-appropriate meanings for ambiguous words. Their findings reveal weaker activity for related words (compared to unrelated) in the left posterior superior temporal/inferior parietal area and the left anterior middle/inferior temporal area. Contrastively, activity in the left inferior frontal cortex was influenced by ambiguities. Specifically, activation in the left anterior inferior frontal cortex was stronger from 200-300ms for ambiguous words than for unambiguous words, regardless of context. They suggest that these findings reflect an increase in controlled semantic retrieval and indicate that multiple meanings for ambiguous words are accessed irrespective of context. Further, at 400ms, the left posterior inferior frontal cortex showed a clear context effect for unambiguous words but not for ambiguous words. Interestingly, activation in the left posterior inferior frontal cortex was stronger for related ambiguous words than for related unambiguous words. They suggest that ambiguous words encompass contextually appropriate meanings as well as inappropriate meanings which can then be semantically integrated with a given context. In sum, the left inferior frontal cortex plays an important role in selecting an appropriate meaning from multiple alternatives after the integration of contextual information.

Thus, several ERP studies investigating the integration of an appropriately or inappropriately-related target word into a preceding sentence containing a priming homonym have suggested that speakers either use contextual cues (Van Petten & Kutas, 1987; among others) or lexical frequency (Gunter, Wagner, & Friederici, 2005; among others). These

results support the selective access theory (Tabossi, 1988) or the reordered access model (Duffy et al., 1988). Most of these studies seem to have focused on the initial stages of processing (Elston-Guettler & Friederici, 2005), have involved short ISIs (Klepousniotou et al., 2012), and have focused on variations of the modulations of the N400 - the amplitude of which appears to increase with integration difficulties and decreases with semantic priming (Van Petten & Kutas, 1990).

2.7 L2 effects on L1

While the literature on L2 influence remains scarce, a few researchers have suggested that a speaker's L1 competence may be subject to change even in adulthood and therefore, the stable "nativeness" of the L1 is not as fixed as is usually presumed (Pavlenko, 2000). Such evidence has led Pavlenko (2000) to suggest that the first problem with the elusive notion of native speaker competence is the monolingual bias which leads linguistic theory to deny or overlook the existence of multilingual contexts of interaction in which a L2 could influence L1 competence and bilinguals may behave differently from monolingual speakers in either language (Cook, 1999; Pavlenko, 2000). Such differences have often been explained as transfer and has been found in studies involving, but not limited to, morphosyntax (Cook, 1999; Pavlenko & Jarvis, 2000), the lexicon and semantics (Pavlenko & Jarvis, 2000; Van Hell, 1998a, 1998b; Van Hell & Dijkstra, 2000), clausal ambiguity (Dussias, 2003, 2004; Dussias & Sagarra, 2007), and conceptual perception (Bylund, 2009).

Recent studies involving morphosyntax have found instances of subcategorization transfer, exhibited as restructuring towards the L2. In a narrative task involving late Russian-English bilinguals, Pavlenko & Jarvis (2000) found speakers patterning morphological object indicators to verbs in an English manner, such as "*kakoi-to orkestr igral muzyku*" (some

orchestra played music) rather than in a Russian manner, such as "*igrala muzyka*" (was playing music), or "*igral orkestr*" (was playing orchestra), or "*kakoi-to orkestr igral muzyku Shostakovicha*" (some orchestra played music by Shostakovich). The result was specifications of verbs which were acceptable in L2 English but not acceptable in L1 Russian, even though the sentences were produced in the L1 Russian. Further, in the same study, Pavlenko & Jarvis (2000) found influence of L2 English on L1 Russian more clearly with speakers' descriptions of emotions. In Russian, emotions are typically depicted as actions and are used with verbs. In English, emotions are typically depicted as states and are used with adjectives. The Russian L2 users of English were found to use change-of-state verbs such as "*stanovit'sia*" (to become) followed by emotion adjectives whereas Russian monolinguals performing the same task employed action verbs, such as "*rasserdit'sia*" (to get angry). Cook (1999) used grammaticality judgements to investigate sentence processing strategies of adult L2 users and found that the sentence processing strategies of Japanese learners of English no longer favoured animacy or case (like those of monolingual speakers of Japanese), but were heavily influenced by word order (like those of monolingual speakers of English). Pavlenko argues that both of these cases appear to suggest that the L1 grammar is simplified or restructured when the L2 has a simpler, more widely distributed rule (Pavlenko, 2000).

Studies investigating L2 influence on L1 lexical and semantic processing have suggested that the lexicon may be the first and the main area where L2 influence becomes visible due to the large amount of borrowing, blends, semantic extension, and loan translations typically found with bilingual speakers (Pavlenko, 2000). Pavlenko & Jarvis (2000) found L1 Russian speakers using L2 English words as semantic extensions, lexical borrowing, and loan translations. The example of semantic extension that they give is

"*pomeniat'kak by....stsenu....*" (to change somehow....the scene). The Russian word *stsena* means an embarrassing display of anger or bad manners, but it does not mean a place where an event or action occurred, as it can in English. The example of lexical borrowing involved the words *landlord*, *appointment*, and *boyfriend*, while loan translations involved inappropriate use of expressions such as "*prediagaet ei kakuiu-to emotsional'nuiu pomoshch*" (offers her some emotional help) whereas the appropriate Russian expression would be "*podderzhka*" (moral, emotional support).

Further evidence of L2 influence on L1 lexical processing was found in a series of cognate studies by Van Hell (1998a, 1998b) and Van Hell and Dijkstra (2000) which investigated native language performance of advanced Dutch learners of English. In the first study, Van Hell (1998a) found bilingual speakers to be more sensitive to cognate status compared to monolinguals as they were faster and often more successful in finding an associate to Dutch words that were cognates with English, such as "*zilver*" (silver) as well as non-cognates (Van Hell, 1998a). The subsequent studies similarly involved advanced learners of English, but who also had knowledge of French. The findings of these studies similarly showed that lexical decision times and association times to Dutch words that were cognates with English, were shorter than those to the Dutch non-cognates (Van Hell, 1998b; Van Hell & Dijkstra, 2000). However, overall performance on the Dutch words which were cognates with French, such as "*muur*" (French "*mur*", English wall), was found to be equal to the overall performance on the Dutch non-cognates. The authors suggest that this indicates that the L2 may influence native language performance, but only at an advanced level of proficiency (Van Hell, 1998a, 1998b; Van Hell & Dijkstra, 2000).

Recent eye-tracking research suggests that parsing sentence-level ambiguity in a bilingual's L1 can undergo changes as a function of exposure to a L2 (Dussias, 2003, 2004;

Dussias & Sagarra, 2007). Dussias (2003, 2004) has studied how Spanish-English bilinguals resolve temporarily ambiguous sentences containing a complex noun phrase followed by a relative clause, as in "*Peter fell in love with the daughter of the psychologist who studied in California*." In this sentence, it is not clear whether it was the daughter who studied in California or the psychologist. Whereas monolingual Spanish speakers attach the relative clause to the first noun in the complex noun phrase (the daughter), and monolingual English speakers attach the relative clause locally (the psychologist), Dussias (2003) found that bilingual L1 Spanish-L2 English speakers attach the relative clause locally even when reading in Spanish, their L1. The authors suggest that these differences are due to experience from being immersed in the L2 environment (for an average of 7 years) and they argue that extensive exposure to a prevalence of English-specific local attachment constructions render local attachment more available, and consequently results in the local attachment observed in these Spanish-English bilinguals. Dussias (2004) employed the same task involving L1 Spanish-L2 English bilinguals with fewer years of immersion in the L2 (average of 3.7 years) in order to test whether or not a shorter period of L2 exposure would result in a more Spanish-like relative clause attachment. Their results again showed that the L1 Spanish speakers favoured local attachment even when reading in their L1. They suggest that these results support exposure-based or parallel interactive models of sentence parsing (Mitchell & Cuetos, 1991), which posits that frequency-based exposure affects parsing decisions. Dussias and Sagarra (2007) further employed the same task involving L1 Spanish-L2 English bilinguals with little L2 immersion experience (8.5 months on average), highly-proficient bilinguals with extensive L2 immersion experience (7.1 years on average), and Spanish monolinguals. The results of this study showed the bilinguals with limited exposure performing similarly to Spanish monolinguals by attaching the relative clause to the first

noun, as in the sentence "*Peter fell in love with the daughter of the psychologist who studied in California,*" it was the daughter who studied in California. On the other hand, the bilinguals with extensive exposure tended to attach the relative clause to the second noun, the psychologist, using an English-like local attachment. The authors suggest that these results reflect the information sources which normally guide L2 parsing decisions as actually seeping into the L1 comprehension system. This implicates that there is activation of L2 knowledge in memory during L1 sentence parsing.

2.7.1 AoL2A effects on L1

There are very few studies that have investigated AoL2A affecting L1processing. Among these select few, most have focussed on late bilinguals as it has been found that conceptual knowledge acquired through the L1 may be subject to change under the influence of a L2 (e.g., Pavlenko, 2000; Cook, 2003). To investigate whether L1 conceptual proficiency is equally affected in early and late bilinguals in situations of reduced L1 exposure, Bylund (2009) recorded and analysed the descriptions of video clips of L1 Spanish speakers living in Sweden. The results found that speakers with AoA over 12 years of age patterned with Spanish monolingual control subjects, whereas speakers with AoA at less than 12 years of age deviated from the monolingual control subjects in conceptualizing time and endpoints of events, which suggests that patterns of native-like L1 use are affected by AoL2A. Although this study set out to investigate AoA effects on attrition of the L1, Bylund claims that the results reveal evidence of L2 (Swedish) influence on L1 (Spanish) event conceptualization. Bylund argues that the findings of Swedish-like overproduction of endpoint and simple present tense are evidence of how L1 event conceptualization patterns have been affected by the L2, rather than a stagnation of or incomplete acquisition of the

stages of L1 Spanish end point encodings, which would suggest L1 attrition. In the case of the Spanish speakers living in Sweden in this study, Bylund claims that "*If a person with early AO is not exposed to a sufficient amount of L1 input or not given sufficient opportunities to make use of his/her L1, this person will be more likely to incorporate L2 features into the L1 repertoire*" (Bylund, 2009, pg 319).

The studies presented in this section reveal evidence of L2 influence on the L1 inmorphosyntax, the lexicon and semantics, clausal ambiguities, and conceptual perception. This evidence suggests that L1 competence is flexible and may be subject to change in the process of L2 acquisition. This mutability presents important implications for linguistic theory as it must account for current findings in the fields of bilingualism and L2 acquisition. But perhaps more importantly, it appears that the L2 starts influencing L1 at important developmental stages in the process of acquiring a L2. This interaction of the two languages require further investigation as this may enrich not only our understanding of L2 learning processes and the bilingual mental lexicon, but also current psycholinguistic theories in general.

To do so, perhaps one of the best methods currently used is the ERP methodology, which this study combines with the complimentary technique of a cross-modal lexical decision task. This combination of methodologies, to my knowledge, is the first to be carried out as such. Doing so will enable a detailed investigation of the online processing involved for lexical relationships, lexical integration, and sentence processing as accessed from a shared or a separate mental lexicon, and what effects the L2 might have on the L1 from these viewpoints. As such, the methodology used for the current study is described next.

2.8 Research Questions and General Predictions

The first question this study intends to answer is whether or not acquiring a L2 increases a speaker's unconscious sensitivity to surface cues in his or her L1. The specific surface cues which are investigated are syntactic priming and lexical frequency. Based on recent evidence of interlingual homograph processing differences occurring due to L2 acquisition before the age of six (Joss & Virtue, 2010), the second question this study intends to address is whether or not the expected sensitivity to surface cues can be found to be dependent on the age at which the L2 was acquired. The specific periods of acquisition chosen for the current study are i) from birth, ii) before the age of six, and iii) after the age of six.

Similar to the study by Tanenhaus, Leiman, and Seidenberg (1979), the current study, which includes both behavioural and neurophysiological experiments, employs a cross-modal lexical decision task to investigate whether both meanings of ambiguous noun/noun and noun/verb homonyms are accessed when presented with either neutral or preceding syntactically-constraining context. Based on the ordered access model studies discussed above, I anticipate, at least at the initial stages of lexical processing, a facilitation of lexical access for the slightly more subordinate meaning due to the presentation of the priming homonym. In consequence, both the dominant and subordinate meanings of the homonym might be retrieved at about the same time, resulting in lexical competition and observed longer reaction times. Specifically, according to the Reordered Access Model, biasing of the subordinate meaning in the syntactically-constrained condition should facilitate lexical access of this subordinate meaning such that it is more likely to compete with the dominant meaning, resulting in longer reaction times in the lexical decision task. In contrast, the neutral context condition is anticipated to support both the dominant and subordinate

meanings, thereby reducing the likelihood of lexical competition and resulting in a slightly shorter reaction time for the slightly more dominant meaning.

This sensitivity to both types of surface cues, of syntactic priming and lexical frequency, is anticipated to differ according to participant language background. Based on the recent evidence discussed above that L1 competence is flexible and may be subject to change in the process of L2 learning, participants with L2 (or L1) French in the current study are anticipated to show greater priming and lexical frequency effects. Secondly, because it appears that the L2 starts influencing the L1 at important developmental stages in the process of acquiring a L2, I anticipate the participants with L2 (or L1) French to differ from each other in sensitivity to priming and frequency, with the later acquirers showing the greatest divergence from the monolinguals.

CHAPTER THREE: METHODOLOGY and HYPOTHESES

3.1 Aim of the Study

The aim of this study was to combine the behavioural method of a cross-modal lexical decision task (Swinney, 1979; Tanenhaus, 1979) with the neurophysiological method of ERPs. Although previous studies have successfully combined ERP measures with unimodal lexical decision tasks (Van Petten & Kutas, 1987) and cross-modal lexical decision tasks involving single word items only (Holcomb & Anderson, 1993), the cross-modal lexical decision task involving sentential frames has not been replicated using ERPs. This paradigm involving priming homonyms set within auditorily-presented constraining sentences and visually-presented target words has been successfully used not only testing behavioural RTs, but also using eye-tracking methodologies (Folk & Morris, 2003; Sheridan et al., 2009). As such, this study set out to be the first to combine this cross-modal paradigm with ERP measurements in order to find evidence of the L2 influencing homonym processing in the L1. Such evidence was anticipated to be found in differences in accuracy, reaction times, and positive or negative going deflections of brain waves between monolingual English speakers, simultaneous bilinguals, and English native speakers with French L2 when they were presented with appropriately-related or inappropriately-related prime and target word combinations in English, the L1 (or one of the L1s) of all participants. Further, this study intended to distinguish whether any of these differences could be correlated with the age at which these speakers had acquired French as a L2. Although I have no evidence for or contrary to the fact that French speakers are more sensitive to surface cues than English speakers due specifically to an influence of the language, I do not anticipate such evidence to be indicative of language specific effects. In other words, although this

study focused on French as L2, it is believed that any differences found could be extrapolated to other languages[3]. Further, it is hypothesized that the anticipated differences would also be found if other language pairings were used. This study anticipates finding L2 effects on the L1 due to the process of acquiring a second language improving a speaker's metalinguistic awareness overall. Therefore, it is anticipated that the results of this study will be replicable regardless of languages tested.

The main overarching question this dissertation aims to address is whether or not acquiring a L2 increases a speaker's unconscious sensitivity to surface cues in his or her L1. The specific surface cues which are investigated are syntactic priming and lexical frequency. Both the L1 and the L2 (or 2L1s) of all participants were kept constant in order to assess the impact of French as the other language being acquired on homonym processing in L1 English. However, the AoL2A varied in order to address the second question this study intends to answer, that of whether or not this sensitivity is dependent on the age at which the L2 was acquired, with specific periods of acquisition being from birth, before the age of six, and after the age of six. Until recently, scant research has investigated AoL2A effects on language processing in the L1, and those that have found such effects, have done so seemingly by accident as they were investigating age of onset effects on attrition (e.g. Bylund, 2009), or by length of exposure (Dussias & Sagarra, 2007; Pavlenko & Jarvis, 2000). Further, this previous research has thus far analyzed recordings of elicited production tasks and eye movements during reading. Since the bilinguals involved in these studies had acquired their L2 through listening as well as written comprehension, these tasks may have

[3] It is not clear whether the same results could be expected for language pairs which differ in writing systems. Although different writing systems have elicited varying locations of neurological activation, there is no evidence that acquiring a different script affects a person's processing in the L1.

underestimated the way as well as the extent to which the L2 may affect online processing in the L1. Consequently, the present study uses both auditory and visual stimuli while concurrently measuring accuracy, RT, and ERPs. This chapter presents the experiments and the experimental design that was chosen specifically to enable an in-depth investigation intoL2 effects on L1 homonym processing in bilinguals who vary in AoL2A.

The second aim of this study was to test the combination of the complimentary techniques of the cross-modal lexical decision task and ERPs. This examination was to evaluate the paradigm's ability to identify N400- and P600-like effects for both lexical and sentence processing. The processing involved in the task as well as the task itself was considered an issue due to the sensitive nature of ERPs. Specifically, in an early study by Holcomb and Anderson (1993) comparing a combination of the two modes of presentation, that of auditory and visual, they found that a cross-modal lexical decision task involving auditorily-presented lexical stimuli elicited negative ERP components. When the cross-modal lexical task involved visually-presented stimuli, they found N1 ERP components (negative effects found at 100ms post-stimulus onset) elicited at 0, 200ms, and 800ms SOA to language stimuli (Holcomb & Anderson, 1993). The combination of these two modes of stimuli presentation revealed different ERP components. The auditory – visual presentations elicited small posterior N1 and P2 (positive effects at 200ms) components at 0ms SOA, an anterior P2 at 200 SOA, and a widely-distributed P2 in the 800ms SOA. Visual – auditory presentations were found to elicit only N1 effects at the varying SOAs to language stimuli (Holcomb & Anderson, 1993). In comparison, cross-modal lexical decision tasks involving complete sentences which are auditorily-presented have not been carried out with ERPs to date. As such, it is unknown as to the effect of the task on the reliability of the ERP

technique to capture evidence of the underlying mechanisms involved for homonym processing.

3.3 Hypotheses

Overall, I anticipated all bilingual speakers to differ from the monolingual speakers due to L2 effects on the L1. As the participants were carrying out the task in English, the L1 of all participants, I did not anticipate finding a difference in accuracy rates for any group. However, as the cause of the effects was expected to reflect an increased metalinguistic awareness and L2 parsing strategies seeping into the L1 comprehension system (as per Dussias & Sagarra, 2007), this was expected to be reflected in longer RTs and ERP effects which diverged from the monolingual native speakers. The details of these effects will be discussed more in depth in the next two chapters.

3.4 Overall Experimental Design and Procedures

3.4.1 Participants

3.4.1.1 Recruiting and Participant selection

The majority of potential participants were recruited via short classroom visits where I or a fellow lab member briefly explained that we represented the Brain and Language Lab in the Department of Linguistics and that we were looking for right-handed individuals between the ages of 18 and 35 who were interested in carrying out behavioural and/or electrophysiological experiments. Individuals were given the opportunity to discretely write their contact information and a brief language background summary on individual slips of paper. These papers were collected by the professor after class and returned to the recruiter to be held in the Brain and Language Lab. Based on the language background information

given, I sent an invitation by email to those individuals who stated that they had acquired English as a L1 and did not have a L2, those who had acquired English and French simultaneously from birth, and those individuals who had acquired English as a L1 and French as a L2 at a later date. Any potential participant who indicated having acquired any L1 or L2 other than those just indicated was not contacted further. Any potential participant who indicated having been exposed to a third language past the level of one introductory course was likewise not contacted further. The email invitation clearly stated what was expected of them in order to participate, but did not explain the details or the goal of the experiment so as to maintain the unconscious and automatic processing of the participants within the experiment itself.

Handedness was taken into consideration for the selection of the participants. Although language is left-lateralized for most people, studies have found that left handed individuals reveal more variation in brain organization and activation (Obler & Gjerlow, 1999). Due to the focus on brain activity in the neurophysiological experiment presented and discussed as Study 2 (CHAPTER 5, STUDY 2), only right handed people took part in the ERP experiment. However, since the behavioural experiment presented and discussed as Study 1 was the initial experiment with no focus on investigating brain activity, left handed individuals who wished to take part in the study were allowed to do so. Two of the 107 participants in Study 1 were left handed.

3.4.1.2 Groups

After completing the required consent form, every participant filled out a language background questionnaire (see Appendix 6: Language Background Questionnaire) before carrying out the experiment. This questionnaire required participants to indicate any and all

language(s) learned, the order and AoA, the percentages of use in a variety of situations, the language(s) that the parents used to interact with them since their birth, when they felt that they had become bilingual, if their language had changed over time, percentage(s) of language(s) used by influential members of their family and how often they interacted with these family members in their childhood, the main language of instruction for various levels of education versus the language of classes taken, etc. In the case of any discrepancies or unclear information given, a short interview was conducted by the experimenter before the experiment began. At the time of testing Study 2: the ERP experiment, two Cloze Tasks testing general language proficiency (Brown, 1980) were being implemented as one of the criteria for justification of the allocating of participants into their appropriate language groups. Therefore, in Study 2, participants were asked to complete two cloze tasks, one in French (Tremblay, 2011; Tremblay & Garrison, 2010) and one in English (Brown, 1980), the scores of which also aided in allocating participants to the most appropriate language group. Based on the information given, participants were either allocated to one of four groups for inclusion in the analysis, or they were excluded from the analysis due to ineligibility. Because all participants carried out the lexical decision task either alone in the behavioural task or coupled with the ERP experiment, Study 1 analyses and reports the results of a larger number of participants compared to the Study 2 which involves the analysis of the ERP measures only. Participant recruitment and inclusion/exclusion information is as follows:

For the behavioural experiment, there were 106 participants recruited (83 female), but the results of only 99 participants (78 female) were included for the analysis of RT and accuracy. The numbers and reasons for participant exclusion are listed here: 1 participant's data was excluded due to the computer crashing; 6 were excluded for being functionally proficient in a third language; and 1 participant was excluded for having sign language as L2.

Based on the questionnaire and the interview, all participants were considered to be dominant in English or have English as one of the dominant languages as in the case of the balanced bilinguals. Therefore, the data of only 99 participants were included for the analysis of RT and accuracy.

For the ERP experiment, there were 44 participants recruited (29 female), but the results of only 39 participants (26 female) were included for the analysis of the ERP measures. The numbers and reasons for participant exclusion are as follows: 2 participants were excluded for having French as the dominant language during childhood; 2 participants were excluded for being proficient in a third language; 1 participant was excluded for having sign language as L2. Therefore, the data of 39 participants were included for the analysis of ERP responses. All participants were similarly considered to have English as (one of) the dominant language(s). Due to the low number of items in each condition, 5 participants carried out two different lists of the experiment. The results of the second list were not found to differ from the first and have been included in the analysis to increase the available data. The details are included within the language group information below.

The four groups for inclusion in the analysis are described here (for complete information on individual participants, see Appendix 7: Participant Information Study 1 and Appendix 8: Participant Information Study 2).

Language Group 1: Monolingual English speakers (henceforth monolinguals):

Participants were allocated to this group if they self-reported having been exposed to less than 10% French in any one environment such as school, family, friends, workplace, etc. These participants must have self-reported themselves as not being bilingual and not

confident in French[4]. For those participants who carried out the proficiency tasks, participants were further considered monolingual if they had low French cloze task scores: average score on the French cloze task was 7.83 out of 45. There were 29 monolingual participants, 6 of them males, between the ages of 18 and 28 with a mean age of 21. Nineteen of these participants were recruited for Study 1, the behavioural version and 10 were recruited for Study 2, the ERP experiment. Because both experiments involved the cross-modal lexical decision task measuring RT and accuracy, the results of all 29 participants were included in the analysis presented and discussed in Chapter 4: Study 1. The ERP data of the 10 monolingual participants recruited for Study 2 is presented and discussed in Chapter 5: Study 2. Three participants recruited for Study 2 carried out two different lists of the experiment. This resulted in 32 sets of data to be analyzed for accuracy and RT in Study 1 and 13 sets of ERP data to be analyzed in Study 2.

Language Group 2: Simultaneous bilingual speakers (henceforth simultaneous bilinguals):

Participants were considered simultaneous bilinguals if they self-reported having been raised in a balanced (at least 40% in each language) English-French home environment from birth and maintained both languages until the time of testing in more than one environment such as school, family, friends, workplace, etc. Maintenance of the two languages was assessed and confirmed in a short interview by the experimenter, or if applicable, by a high cloze task score: Simultaneous bilinguals' average score on the French cloze task was 36 out of 45. These participants self-reported themselves as being bilingual from birth or "ever since I can remember". There were 20 simultaneous bilingual participants, 8 of them males, between the ages of 18 and 37 with a mean age of 26. Thirteen

[4] It was extremely difficult to find "completely monolingual" English speakers as these participants were recruited from the Ottawa region, a bilingual English/French region of Canada.

of these participants were recruited for Study 1, the behavioural version and 7 were recruited for Study 2, the ERP experiment. Because both experiments involved the cross-modal lexical decision task measuring RT and accuracy, the results of all 20 participants were included in the analysis presented and discussed in Chapter 4: Study 1. The ERP data of the 7 simultaneous bilingual participants recruited for Study 2 is presented and discussed in Chapter 5: Study 2. One participant recruited for Study 2 carried out two different lists of the experiment. This resulted in 21 sets of data to be analyzed for accuracy and RT in Study 1 and 8 sets of ERP data to be analyzed in Study 2.

Language Group 3: Early bilingual speakers (henceforth early bilinguals):

Participants were allocated to this group if they self-reported having been exposed to French in one or more immersion environment such as school, family, or neighbourhood before the age of 6 years old. These participants must have self-reported maintenance of both languages until the time of testing and if applicable, achieved a mid-high proficiency score on the French cloze task. Early bilinguals' average score on the French cloze task was 28.3 out of 45. These participants self-reported themselves as being bilingual but not from birth. There were 29 early bilingual participants, 2 of them males, between the ages of 18 and 30 with a mean age of 22. 23 of these participants were recruited for Study 1, the behavioural version and 11 were recruited for Study 2, the ERP experiment. Because both experiments involved the cross-modal lexical decision task measuring RT and accuracy, the results of all 29 participants were included in the analysis presented and discussed in 4: Study 1. The ERP data of the 11 early bilingual participants recruited for Study 2 is presented and discussed in Chapter 5: Study 2. One participant recruited for Study 2 carried out two different lists of the

experiment. This resulted in 30 sets of data to be analyzed for accuracy and RT in Study 1 and 12 sets of ERP data to be analyzed in Study 2.

Language Group 4: Late bilingual speakers (henceforth late bilinguals):

Participants were allocated to this group if they self-reported having been exposed to French in one or more immersion environment such as school, family, or neighbourhood at or after the age of 6 years old. These participants must have self-reported maintenance of both languages until the time of testing and if applicable, achieved a mid-high proficiency score on the French cloze task. Late bilinguals' average score on the French cloze task was 20.10 out of 45. These participants self-reported themselves as being bilingual but not from birth. There were 21 late bilingual participants, 5 of them males, between the ages of 18 and 33 with a mean age of 23.5. Ten of these participants were recruited for Study 1, the behavioural version and 11 were recruited for Study 2, the ERP experiment. Because both experiments involved the cross-modal lexical decision task measuring RT and accuracy, the results of all 21 participants were included in the analysis presented and discussed in Chapter 4: Study 1. The ERP data of the 11 late bilingual participants recruited for Study 2 is presented and discussed in Chapter 5: Study 2.

3.4.2 Stimuli

All sentences were pre-recorded by a female native speaker of the local Canadian English dialect. The program CoolEdit 2000 was used to equalise volume, pitch, and frequency across conditions and items. A quick analysis of the acoustic measures of 6 random sample items in each condition revealed no differences between priming items priming items (p=.157), nor between piming items and the sentences (p=.240).

Participants heard sentences that included either a priming item or a control item located at the mid-point within the sentence. At the offset of the priming or control item, a target item was presented visually. One set of priming items included homonyms (such as *watch*) which were constrained by the syntactic information of the sentence toward only one appropriate reading, such as *Albert bought a fine new **watch** on the weekend* (N=15). The control items included the same sentence but with a non-priming item such as *house* in the sentence, such as *Albert bought a fine new **house** on the weekend* (N=15). These conditions are presented and discussed more in detail in the next subsection 3.4.2.1 Subgroup of Stimuli: Syntactic Condition. A second set of priming items included homonyms (such as *bank*) which were not disambiguated by any contextual information, such as *Veronica walked to the **bank** across the street* (N=15). The control items for this condition also included an identical sentence containing a non-priming item such as *mall* in the sentence, such as *Veronica walked to the **mall** across the street* (N=15). These conditions are presented and discussed more in detail in the next subsection 3.4.2.2 Subgroup of Stimuli: Semantic Condition.

It should be noted that although care was taken to choose stimuli items which were high-frequency, salient, and easily-processed items, later analyses revealed cases of polysemy (one meaning being derived from another), cognates (French-English equivalents), and abstract concepts. These are discussed only briefly here.

Although a concerted effort was made to choose stimuli items with only one meaning and homonyms with only two unrelated meanings, there were a few words with multiple meanings included in the experiment. These were confined to cases of polysemy, such as *cure*: "to cure someone" and "to find a cure", whereby one meaning is derived from the

other. As such, these were therefore not considered possible confounding factors (Klepousniotou et al., 2012). Specifically, in the Syntactic Condition, there were 53 cases of polysemous items out of a total of 150, with 1 of these being relatively rare: *floor*, such as "to floor someone" or to "floor it" when driving. In the Semantic Condition, there were 42 items out of a total of 150, with 4 of these being relatively rare: *card*: "to card someone" (ask for identification at a bar or a liquor store); *harbour*: "to harbour resentment or negative feelings"; *tail*: "to tail someone" (follow); and *moon*: "to moon someone" (show one's buttocks) or "to moon over someone" (to feel emotional towards someone).

A later analysis of items used in the experiment found that in the Syntactic Condition, there were 12 cases of true cognates (such as *change*), 4 false cognates (such as *coin*), and 4 regional borrowings between English and French (such as *jacket*). In the Semantic Condition, there were 16 cases of true cognates, 4 false cognates, and 11 borrowings. Based on similar studies investigating cognate processing (Joss & Virtue, 2010; van Hell, 1998a, 1998b; van Hell & Dijkstra, 2000), these cognate items are not considered to be a confounding factor as the sentences used were constraining each item toward only one appropriate meaning within English (see Joss & Virtue, 2010 for a discussion) and all bilinguals were considered to be functionally proficient in L2 French (see van Hell & Dijkstra, 2000 for a discussion). Although I cannot be sure that the bilinguals were not accessing the translation equivalents of the cognates discussed here, an overall items analysis did not reveal any particular item to be an outlier. However, a more in-depth comparison of cognate and non-cognate items is needed and will be carried out in a future analysis.

Finally, the later analysis also found that in the Syntactic Condition, there were 9 cases of abstract concepts (such as *need*), while in the Semantic Condition, there were 6

cases. Based on the findings of Kroll and Merves (1986), I would expect a specific comparison of abstract versus concrete concepts to find a "small speed advantage" (Kroll & Merves, 1986) for the concrete concepts. However, an overall items analysis did not reveal any particular item to be an outlier. I would argue that any apparent lack of an "effect of concreteness" (Kroll & Merves, 1986) may be due to a difference in task involved. The task used by Kroll and Merves (1986) was a single word lexical decision study, whereas the task of the current study was a cross-modal lexical decision task using full sentences. The constraining nature of the sentential information surrounding both abstract and concrete conceptual items may have negated the advantage found for the ambiguous single items in the study by Kroll and Merves (1986).

All visually-presented target items displayed at the offset of the priming items were in one of three relations to the priming items: either the subordinate reading such as *wrist*; the dominant reading such as *view*; or unrelated such as *lake*. Lexical frequency for all items was ascertained using the Collins Cobuild database (1995) and is described for each condition in more detail in the respective subsections below.

As the homonym conditions totalled 60 items and were expected to elicit "*yes*" answers in the lexical decision task, an equal number of auditorily-presented non-homonymous priming sentences presented with visually-presented pseudowords were included to prompt an equal number of "*no*" answers. An example of a non-homonymous control sentences is *Theresa should find the* ***milk*** *at the back of the fridge.* At the offset of the non-homonymous word *milk,* the pseudoword *jayl* was presented visually. These pseudoword conditions are presented and discussed more in detail in subsection 3.4.2.3 Subgroup of Stimuli: Filler Condition.

Consequently, the total number of items used in the study was 420. These 420 items were divided equally into 6 lists such that there were no repetitions and each participant saw only one of these 6 lists. Each list contained 5 unique items of each condition (total N=60) and all the items of the pseudoword condition (N=60). Examples of the stimuli for the syntactic conditions are outlined in the next section in Table 1 and discussed in detail following Table 1. Examples of stimuli for the semantic condition are presented in the following section in Table 2 and discussed in detail following the table. For each of these tables, the bolded word presented in the auditory prime is the priming word after whose offset the visual target word was presented. For a list of stimuli by all conditions, please see Appendix 3: Stimuli by Condition.

3.4.2.1 Subgroup of Stimuli: Syntactic Condition

Each syntactically-constrained priming item, such as *watch,* is a homonym whose two possible meanings differ in grammatical category, one a noun (*a wristwatch*) and the other a verb (*to view*). To facilitate syntactic priming, only homonyms with meanings which are balanced within a frequency log of 1.50 of each other were included. This was in an attempt to reduce frequency effects on lexical processing. For example, the noun reading (*a wristwatch*) has a frequency log of 3.23 and the verb reading (*to view*) has a frequency log of 4.28 (COBUILD, 1995).

To further control for frequency effects, the auditorily-presented sentences were biased towards the reading with the lower frequency. Our intention was to bias for the subordinate reading in an attempt to reduce activation of the more dominant reading in order to investigate possible effects of priming. This basically gave the weaker homonym a "fighting chance". For example, the syntactic context preceding *watch* in (1) below, such as

the preceding article "a" and the adjectives "*fine new*", directs its interpretation to the noun reading, which is less frequent (3.23 frequency-log) than the verb reading (4.28 frequency-log) (COBUILD, 1995).

(1) *Albert bought a fine new* ***watch▲*** *on the weekend.*

Thus, in the case of (1) above, the noun reading of *watch* was auditorily-presented in a biasing sentence while the verb reading was not. An example of the unused verb reading of the homonym *watch* might be: *Albert really likes to* ***watch*** *soccer on the weekend*. This design resulted in the 30 sentences in the syntactic condition containing 15 verb readings (50%) and 15 noun readings (50%).

While each stimulus sentence was auditorily-presented, one of three possible visually-presented target items was presented on a computer screen immediately upon offset of the priming homonym, indicated above in (1) with "▲". The visually-presented target items were in one of three relations to the priming item: either the subordinate reading such as *wrist*; the dominant reading such as *view*; or unrelated such as *lake.* As the subordinate reading of the homonym was chosen to be presented in the sentence, each target word was consequently either a) appropriately-related to the subordinate reading of the homonym in the sentence, such as *wrist*, b) appropriately-related to the dominant reading of the homonym, such as *view*, and therefore inappropriately-related to the homonym given the sentence, or c) unrelated, such as *lake*. Examples are given in Table 1 below for clarification.

Table 1: Syntactic Condition Stimuli with Relatedness

CONDITION	SENTENCE	TARGET WORD	RELATIONSHIP
synsub	*Albert bought a fine new **watch** on the weekend.*	*WRIST*	appropriately-related, subordinate frequency
syndom	*Albert bought a fine new **watch** on the weekend.*	*VIEW*	inappropriately-related, dominant frequency
synunr	*Albert bought a fine new **watch** on the weekend.*	*LAKE*	unrelated
synsub control	*Albert bought a fine new **house** on the weekend.*	*WRIST*	control condition, subordinate
syndom control	*Albert bought a fine new **house** on the weekend.*	*VIEW*	control condition, dominant
synunr control	*Albert bought a fine new **house** on the weekend.*	*LAKE*	control condition, unrelated

All visual target words had a frequency of 2.00 frequency-logs or higher according to the COBUILD database (1995), were offered as associations to the homonyms by the majority of native Canadian English and French volunteers in a questionnaire, and were balanced for length, complexity, and syntactic category. The specific items statistics for the syntactic condition are as follows: for length, 8 of the 156 words were 3 letters in length, 54 words were 4 letters long, 49 words were 5 letters long, 22 words were 6 letters long, 14 words were 7 letters long, 7 words were 8 letters long, and 2 words were 9 letters long. Of the 30 pairs of visual target words, 14 did not match in complexity, for example, for the priming homonym *cross*, the subordinate target word *traverse* is 8 letters in length, while the dominant target word *crucify* is 7 letters in length. For complexity, 112 words were monosyllabic, 30 words were bisyllabic, and 8 words were trisyllabic. Of the 30 pairs of visual target words, 8 did not match in complexity, for example, for the priming homonym *draft*, the subordinate target word *recruit* comprises two syllables while the dominant target word *sketch* is monosyllabic. Of the 30 target words appropriately-related to the priming homonyms, 13 of these were verbs and 17 of these were nouns, resulting in 11 verbs and 4

nouns appropriately-related to the verb reading of the priming homonyms and 1 verb and 14 nouns appropriately-related to the noun reading of the priming homonyms. Of the target words inappropriately-related to the priming homonym, 17 of these were verbs and 13 of these were nouns, resulting in 10 verbs and 5 nouns appropriately-related to the verb reading of the priming homonyms and 7 verbs and 8 nouns appropriately-related to the noun reading of the priming homonyms. For a complete list of stimuli and frequencies used in the syntactic condition, please see Appendix 1: List of Stimuli – Syntactic Condition Primes with Target Words and Frequencies.

All sentences were also balanced in length and complexity. Only simple declarative sentences were used. Non-identifying words in each sentence, such as *Albert* and *on the weekend* were balanced and lexically-neutral to avoid semantically biasing lexical decisions. Only the preceding syntactic information, such as modal verbs or definite or indefinite articles, was expected to disambiguate the noun/verb ambiguity of the homonym by selectively favouring either the verb or the noun interpretation. By maintaining semantic neutrality, while deliberately varying biasing syntactic contexts of the primes, differences in access times for the targets could be attributed to the effects of syntactic activation.

3.4.2.2 Subgroups of Stimuli: Semantic Condition

The second type of auditorily-presented priming and control items followed by visually-presented target items included unconstrained and semantically-ambiguous items (N=30) such as *cellar/seller*[5]. The number of auditorily-presented priming and control items, as well as the visually-presented target items for this condition was identical to the syntactically-constrained conditions. The two readings of the homonyms presented in this

5 Note that although *cellar* and *seller* are spelled differently, they are pronounced identically. As the stimuli were presented to participants aurally within neutral sentences containing no disambiguating information, the difference in orthography was not considered to be a confounding factor.

condition were of the same syntactic category, that of noun/noun, such as *cellar* (a basement used for storage) and *seller* (a vendor). The sentence containing the noun/noun homonymous prime, such as in (2) below, was contextually-neutral such that either noun reading was equally plausible.

(2) *Peter and Joe knew of a* ***cellar***▲ *that later proved to be extremely valuable.*

Each homonym pair, in this case *cellar/seller*, was chosen for its common usage and close frequency between both readings (1.69 – 2.15 -log frequency) according to the COBUILD database (Collins, 1995). For a complete list of stimuli and frequencies used in the semantic condition, please see Appendix 2: List of Stimuli – Semantic Condition Primes with Target Words and Frequencies.

An equal number of duplicate control frame sentences were also included and followed the same criteria as the control sentences described above for the experimental syntactically-constrained priming homonym items.

The visually-presented target words for this condition followed identical criteria as the target words of the syntactic homonyms. While each stimulus sentence was auditorily-presented, one of three possible visually-presented target items was presented on a computer screen immediately upon offset of the priming homonym, indicated above in (2) with "▲". The visually-presented target items were again in one of three relations to the priming item: either the subordinate reading such as *storage*; the dominant reading such as *vendor*; or unrelated such as *napkin.* As each sentence was semantically and syntactically unbiasing towards any one reading of the priming homonym, none of the target words in the semantic condition were inappropriately-related to the priming sentence. Consequently, each target

word was either a) appropriately-related to the subordinate reading of the homonym, such as *storage*, b) appropriately-related to the dominant reading of the homonym, such as *vendor*, or c) unrelated, such as *napkin*. Examples are given in Table 2 below for clarification.

Table 2: Semantic Condition Stimuli with Relatedness

CONDITION	SENTENCE	TARGET WORD	RELATIONSHIP
semsub	*Peter and Joe knew of a **cellar** that later proved to be extremely valuable.*	*VENDOR*	appropriately-related, subordinate frequency
semdom	*Peter and Joe knew of a **cellar** that later proved to be extremely valuable.*	*STORAGE*	appropriately-related, dominant frequency
semunr	*Peter and Joe knew of a **cellar** that later proved to be extremely valuable.*	*NAPKIN*	unrelated
semsub control	*Peter and Joe knew of a **kennel** that later proved to be extremely valuable.*	*VENDOR*	control condition, subordinate
semdom control	*Peter and Joe knew of a **kennel** that later proved to be extremely valuable.*	*STORAGE*	control condition, dominant
semunr control	*Peter and Joe knew of a **kennel** that later proved to be extremely valuable.*	*NAPKIN*	control condition, unrelated

Similar to the syntactic condition, all visual target words had a frequency of 2.00 –log frequency or higher according to the COBUILD database (1995), were offered as associations to the homonyms by the majority of native Canadian English and French volunteers in a questionnaire, and were balanced for length, complexity, and syntactic category. The specific items statistics for the semantic condition are as follows: for length, 15 of the 156 words were 3 letters in length, 33 words were 4 letters long, 42 words were 5 letters long, 31 words were 6 letters long, 21 words were 7 letters long, 7 words were 8 letters long, and only 1 word was 9 letters long. Of the 30 pairs of visual target words, 13 did not match in complexity, for example, for the priming homonym *crane*, the subordinate target word *bird* is 4 letters in length, while the dominant target word *machine* is 7 letters in length. For complexity, 112 words were monosyllabic, 30 words were bisyllabic, and 8 words were trisyllabic. Of the 30 pairs of visual target words, 8 did not match in complexity,

for example, for the priming homonym *draft*, the subordinate target word *recruit* comprises two syllables while the dominant target word *sketch* is monosyllabic. Although a concerted effort was taken to choose balanced target words which were also nouns in order to maintain the balance of noun target words with noun priming homonyms, of the 60 target words appropriately related to the priming noun/noun homonyms, 57 of these were nouns, 2 of these were adjectives (*peace*: *quiet*; *boos*: *taunting*), and 1 of these was a verb (*spring*: *bounce*). For a complete list of stimuli and frequencies used in the semantic condition, please see Appendix 2: List of Stimuli – Semantic Condition Primes with Target Words and Frequencies.

3.4.2.3 Subgroups of Stimuli: Filler Condition

As there were 30 sentences in the syntactic condition and 30 sentences in the semantic condition, 60filler sentences were included. These sentences were considered filler as they were common sentences in English, containing no homonyms whatsoever, such as in (3) below. For a complete list of the filler sentences used in this study, please see Appendix 4: List of Stimuli – Filler Sentences with Pseudowords.

(3) *Zoe really likes her* ***new***▲ *stuffed panda bear.*

The visually-presented target words for this condition were pseudo-words, created to resemble legitimate English words. In the case of (3) above, the pseudo-word target *bulips* appeared. Note that *bulips* contains phonologically permissible consonant clusters and is close in spelling to *tulips*, an actual English word. Pseudo-word targets were included to prevent familiarization with the homonym- and control-condition items described above and to ensure equal expectations of "no" answers to the lexical decision task. For a complete list

of pseudowords used in this condition, please see Appendix 4: List of Stimuli – Filler Sentences with Pseudowords.

3.4.2.4 Subgroups of Stimuli: Questions

To ensure that participants were attending to the sentences, each stimulus sentence was followed by a yes/no question related to the sentence content. To illustrate, the question following example (3) above is "*Does Zoe really hate her new stuffed panda bear?*" The question appeared on the computer screen, and similarly to the lexical decision task, participants were required to answer either *yes* or *no* with a button press. There were an equal number of expected *yes* and *no* answers.

3.4.3 Overall Procedures

Both experiments took place in the Brain and Language Laboratory in the Linguistics Department of the University of Ottawa. Participants came for a one-time experiment lasting approximately 45 minutes (for the behavioural version: Study 1) to 2.5 hours (for the ERP version: Study 2). All participants were required to fill out a consent form (see Appendix 5), language background questionnaire (see Appendix 6), one French cloze task (Tremblay, 2011; Tremblay & Garrison, 2010) and one English cloze task (Brown, 1980) if they participated after 2009. The year 2010 was the year proficiency cloze tasks were implemented as a universal tool for participant group allocation for all bilingual studies being carried out in the lab.

As the goal of this dissertation is to investigate lexical ambiguity resolution, RTs and accuracy were measured to participants' lexical decisions to the visually-presented target word in both Study 1 and Study 2, while ERPs were simultaneously being measured to the

visual target word presentation in Study 2. This enabled the current study to capture and record online homonym processing as primed by auditorily-presented sentential frames.

The precise procedures for the behavioural experiment will be presented in the following section, Chapter 4: Study 1 – The behavioural experiment. Precise procedures for the ERP experiment will be presented in Chapter 5: Study 2 – The ERP experiment.

CHAPTER FOUR: STUDY 1 [6]

4.1 Hypotheses

Study 1 set out to rectify the methodological issues of Folk and Morris (2003) by employing a cross-modal lexical decision task to further test the disambiguation effects that syntactic constraints have on gaze durations that the authors reported. Folk and Morris (2003) claimed that looking time, and therefore access, was shorter, and therefore selective, towards a syntactically-constrained reading of a homonym compared to the control condition. The focus of the current study was on homonyms which are disambiguated with respect to syntactic category (one reading being a noun, the other a verb). The goal of this study was to ascertain whether both meanings of ambiguous homonyms are accessed even when presented in a biasing syntactic context, such as reported by Tanenhaus and Donnenwerth-Nolan (1984). In addition, variations in processing were anticipated according to participants' language groups. Based on the studies discussed above, I speculated that the initial stage of access and processing for all words, ambiguous or not, occurs in a bottom-up manner for monolingual and L2 learners alike. However, it is at the later stages of processing, postulated to occur 500ms after the offset of a stimulus (Elston-Guettler & Friederici, 2007; Friederici, 1995), where differences were expected to lie in each language group's processing of constrained (syntactic) and unconstrained (semantic) homonyms.

As the task was carried out in English, I anticipated the monolingual English speakers to reveal lexical frequency effects when presented with unconstrained homonyms: those of the semantic condition. That is, a homonym placed within a semantically-neutral sentence with no biasing syntactic context, I assumed the dominant meaning would be processed more

[6] An initial version of this chapter has been published as Brien and Sabourin (2012) in Roberts, L., Lindqvist, C., Bardel, C., & Abrahamsson, N. (Eds) EUROSLA Yearbook, 12, John Benjamins.

quickly compared to the subordinate meaning. A shorter reaction time after presentation of a dominant lexical item would be considered evidence of such a frequency effect. In the case of syntactically-constrained homonyms, it was unclear whether this population would reveal clear evidence of syntactic priming or whether their results would support the Reordered Access Model, whereby the syntactic and semantic modules appear to be recruited in a parallel manner resulting in both frequency of items and the syntactically-biasing context to affect processing. That is, the primed and intended yet subordinate reading would be facilitated for access and processing to a similar level as that of the dominant reading, resulting in these two readings appearing to be processed similarly, while possibly competing. A shorter reaction time upon presentation of appropriately-related target words, such as *wrist*, primed by syntactically-constrained homonyms, such as "...*a fine new* ***watch***..." would be considered evidence of syntactic priming. Comparatively, if syntactic priming and frequency effects compete, inappropriately-related target words, such as *view* primed by "...*a fine new* ***watch***...", were expected to have reaction times equal to or shorter than appropriately-related target words as per the Reordered Access Model (Duffy et al., 1988).

The simultaneous bilinguals were anticipated to resemble monolinguals due to the fact that they acquired both their languages as two L1s, and I therefore expected this population to resemble monolinguals in accuracy scores and manner of processing. However, I also hypothesised that the existence of an overlapping lexical store or the possibility that the links between lexical items are weaker than a monolingual's due to reduced frequency could have an effect on L1 lexical ambiguity resolution in the case of all bilinguals, including the simultaneous bilinguals. That is, I anticipated that the acquisition of a L2

would have an effect on lexical ambiguity resolution even though the task is being carried out in the L1. Given earlier postulations (Fabbro, 2001; Paradis 1998, 2001; van Assche et al. 2009) and recent evidence of the activation of multiple lexemes within the mental lexicons of early bilinguals (Elston-Guettler & Friederici, 2005, 2007; among others) coupled with evidence of weaker links between lexical items (Gollan & Silverberg, 2001), I anticipated that all bilingual groups would exhibit a delay in processing compared to the monolingual group, as evidenced by longer reaction times overall. This delay was anticipated to correlate with the age at which the L2 was acquired, thereby having a greater effect on the L1. That is, the earlier the L2 was acquired, the less impact it was expected to have on L1 processing as the L2 was in fact, acquired as a 2L1 rather than being acquired through the L1. The later the L2 was acquired, the greater the expected impact on the L1 as learning the L2 through the L1 is expected to increase the speaker's metalinguistic (albeit unconscious) awareness in the L1. This process of fine-tuning one's attention span involves the L2 learner developing a strategy of recognizing surface cues in the L2 for efficient L2 acquisition, which would carry over into the L1 where efficiency in recognizing and interpreting cues in the L1 would also be improved. Consequently, compared to the monolingual group, the bilingual populations were anticipated to reveal evidence of longer reaction times as additional resources were being recruited to not only resolve competition between lexical frequencies (as the monolingual speakers would have to go through), but also to overcome the weakened links between lexical items due to less-frequent use of each item, as according to the weaker links hypothesis (Gollan & Silverberg, 2001; Gollan et al., 2008). Conversely, the early and late bilinguals were anticipated to reveal an increased sensitivity to surface cues as evidenced in faster RTs in the experimental conditions of priming, relatedness, and frequency. Such evidence is anticipated to support the hypothesis that acquiring an L2 influences lexical

ambiguity resolution in the L1 as acquiring a L2 increases one's sensitivity to strategies to aid in ambiguity resolution. This sensitivity is also anticipated to correlate with the age at which the L2 was acquired, with the later bilinguals showing a more heightened sensitivity relative to the simultaneous bilinguals.

Thus, in the case of the late bilingual group, those who acquired a proficient level of L2 French after the age of six, I anticipated that this group would reveal the greatest L2 effects in their L1 as the acquisition of the L2 was a more recent acquisition compared to the simultaneous and early bilingual groups. Even though the task was being carried out in the L1, I anticipated this group to reveal evidence of differences in processing since this population can no longer be considered monolingual native speakers of English. Indeed, according to Clahsen and Felser (2006) later L2 learners rely more on lexico-semantic information, associative patterns, and other surface cues for interpretation during online sentence processing in their L2 (Neubauer & Clahsen, 2009), which has been found to spill-over into L1 processing strategies for ambiguity resolution (Dussias & Sagarra, 2007). Thus, the late bilingual group was anticipated to show the greatest sensitivity to surface cues such as the sentential frame biasing towards only one appropriate homonym in the syntactic condition, regardless of lexical frequency. that is, in the syntactically-constraining homonym condition, the late bilinguals are anticipated to show the greatest priming effect in the syntactically-constrained appropriately-related and subordinate condition compared to the syntactically-constrained inappropriately-related and dominant condition since the syntactically-constrained appropriately-related and subordinate condition involves a target word that is appropriately-related to the subordinate reading of the priming homonym, whereas the syntactically-constrained inappropriately-related and dominant condition

involves a target word that is inappropriately-related to the dominant reading of the priming homonym. In this way, whereas the monolinguals are anticipated to be influenced by lexical frequency rather than appropriateness (as both readings of the priming homonyms are anticipated to be facilitated for access in this monolingual group), the late bilinguals are anticipated to be influenced by appropriateness rather than lexical frequency. In conditions involving homonyms presented without biasing syntactic context however, this group was expected to reveal frequency effects similar to the monolingual group, whereby a shorter reaction time was expected after the presentation of the dominant meaning compared to the subordinate meaning.

4.2 Method

4.2.1 Participants

One hundred and four lists of results from 99 L1 English L2 French speaking participants were included for the behavioural analysis (78 females). There were 32 sets of monolingual RT and accuracy data, 21 sets of simultaneous bilingual data, 30 sets of early bilingual data, and 21 sets of late bilingual data included in the analysis. For details regarding the language groups, please refer back to Chapter 3 subsection 3.4.1 Participants, and for information on the individual participants, please see Appendix 7: Participant Information – Study 1, and Appendix 8: Participant Information – Study 2.

4.2.2 Design

This cross-modal lexical decision task coupled the auditory presentation of an ambiguous homonym which differed in syntactic category (a noun or a verb) with a visual lexical decision task. The lexical decision was made to a target word that was appropriately-related, inappropriately-related, or unrelated to the priming homonym. The sequential

presentation of the prime and target with the simultaneous recording of participants' reaction occurring during on-line was designed to investigate the effects of syntactic context on participants' automatic associations between homonyms (the prime) and their relevant meanings (the target). For full details of the design of the experiment, please see Chapter 3 section 3.4 Overall Experimental Design and Procedures.

4.2.3 Materials: Experimental Stimuli

The experimental stimuli presented to each participant were the same as presented and discussed above in Chapter 3: Methodology, section 3.4.2 Stimuli. For a complete list of stimuli and frequencies used in each condition, please see Appendix 1: List of Stimuli – Syntactic Condition Primes with Target Words and Frequencies, Appendix 2: List of Stimuli – Semantic Condition Primes with Target Words and Frequencies, and Appendix 4: List of Stimuli – Pseudowords. For a list of stimuli by condition, please see Appendix 3: Stimuli by Condition.

4.2.4 Procedure

The experiment was conducted in the Brain and Language Lab of the Department of Linguistics in the University of Ottawa. There were slight variations of the procedure of the experiment over the course of time. These are presented here as two versions of the experiment, the first is an earlier version occurring from 2008 to 2010, and the second is a later version occurring from 2010 until the completion of this dissertation.

In the earlier version of the experiment, from 2008 to 2010, the experiment was conducted in a private, sound attenuated experiment room with a CRT monitor using the program DMDX (Forster & Forster, 2003). Each participant was positioned comfortably in front of a computer screen, holding the computer mouse in their right hand (all participants

preferred to use the mouse with their right hand). The participants wore headphones which delivered the auditory stimuli while blocking out any distracting environmental noises. Following a brief instruction session with the experimenter, a short practice set consisting of six trial sentences preceded the actual experimental trials. The participants began the experiment by clicking the space bar on the keyboard once at the ready prompt. A "*" symbol appeared for approximately one second as a fixation point just before the onset of each item. Every item consisted of one sentence and one target word, as described above. At the critical point within each sentence (see Chapter 3: Methodology, section 3.4.2 Stimuli), a string of letters appeared on the screen in front of the participant. The timing of the appearance of the letter string would seem random and unpredictable to the participant. When a letter string appeared, the participant indicated whether it was a correct word of English or not by clicking the left mouse button for "*yes"* or the right button for "*no"*. Participants were instructed to respond as quickly as possible after a letter string appeared. Participants then used the yes/no labelled mouse to respond to the content question that followed each item. Responses and response times were recorded by the computer.

The entire behavioural experiment was completed in an average of 45 minutes, including 25 minutes for the completion of the consent form, questionnaire, and interview session, with 20 minutes being spent completing the cross-modal lexical decision task on the computer. There were four self-regulated breaks within the body of the on-line experiment, during which participants were free to stretch and relax but were prohibited from interaction of any kind.

In the later version of the experiment, from 2010 until the completion of this dissertation, the experiment was conducted with a CRT monitor screen using the program

Presentation (Neurobehavioural Systems). This was done so that the EEG recordings could be captured simultaneously. Each participant was positioned comfortably in front of the wall-mounted monitor screen in a sound-proofed room, holding a button box on their lap which was positioned on a cushioned lap desk. The participants wore ear bud headphones which delivered the auditory stimuli. The rest of the procedure for the experiment was identical to the earlier version experiment just described above, except that a button box was used instead of a mouse. In this case, participants pressed a blue button with their right hand to indicate a "*yes*" response to the stimuli and to proceed to the next section, while a yellow button press with the left hand indicated a "*no*" response.

The later version of the experiment was completed in an average of 1.25 hours. This did not include time spent for the fitting and set-up of the ERP cap which will be described in Chapter Five: The ERP Experiment. The 1.25 hours indicated here did include 25 minutes for the completion of the consent form, questionnaire, and interview session, 20 minutes to complete the cross-modal lexical decision task on the computer, and the final 30 minutes being spent on completing the French cloze task and the English cloze task. There were four self-regulated breaks within the body of the on-line experiment, during which participants were free to relax, enjoy their juice and cookies, and were previously encouraged to look away from the computer screen, but were prohibited from getting out of their chair, leaving the room, and interaction of any kind. Refreshments and cookies were offered as compensation for both versions of the experiment.

4.3 Results

4.3.1 Outline of Results

In the first section, 4.3.2, I present and discuss the results of an analysis of accuracy. In 4.3.3, I present and discuss the results of an analysis of reaction times. In section 4.3.4, I present and discuss the results of an analysis of priming effects and 4.3.5 presents and discusses the results of an analysis of frequency effects. Lastly, section 4.4 presents an overall discussion of the findings of Study 1.

4.3.2 Accuracy Effects

4.3.2.1 Analysis

Although incorrect trials were excluded from RT analyses, these were retained for calculations of accuracy. Accuracy was calculated for lexical decisions to all target words, pseudowords, and responses to questions. All participants with scores below 70% accuracy overall were excluded. One early bilingual and two late bilinguals were excluded based on this criterion. A 2-way ANOVA with language group (monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals) and accuracy category (overall, pseudowords, and homonym conditions) as the independent variables (IV) and accuracy score as the dependent variable (DV) was performed. This was done to test my hypothesis that, as the task was carried out in the L1 of all groups, no language group would differ in accuracy overall, nor by pseudowords compared to real words. As expected, there was no overall interaction of language group by accuracy category ($F(3,107)=1.401$, $p=.247$), nor did one-way ANOVAs reveal significant effects of accuracy of pseudowords ($F(3,80)=1.483$, $p=.226$) and of homonym conditions ($F(3, 80)=.945$, $p=.423$).

A 2x4 repeated measures investigating condition (two levels: accuracy of real words vs. pseudowords) by LG (four levels: monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals) found a significant main effect of accuracy condition ($F(1,77)=10.912$, $p=.001$), with responses to homonyms being more accurate than to pseudowords, but this effect was not found by language group ($F(3, 77)=.561$, $p=.643$). Figure 1: Accuracy by Language Group below shows the averages of accuracy in the homonym conditions, pseudowords by language group with standard error bars. For the grand means of accuracy by language group, please see Appendix 10: Means by Language Group.

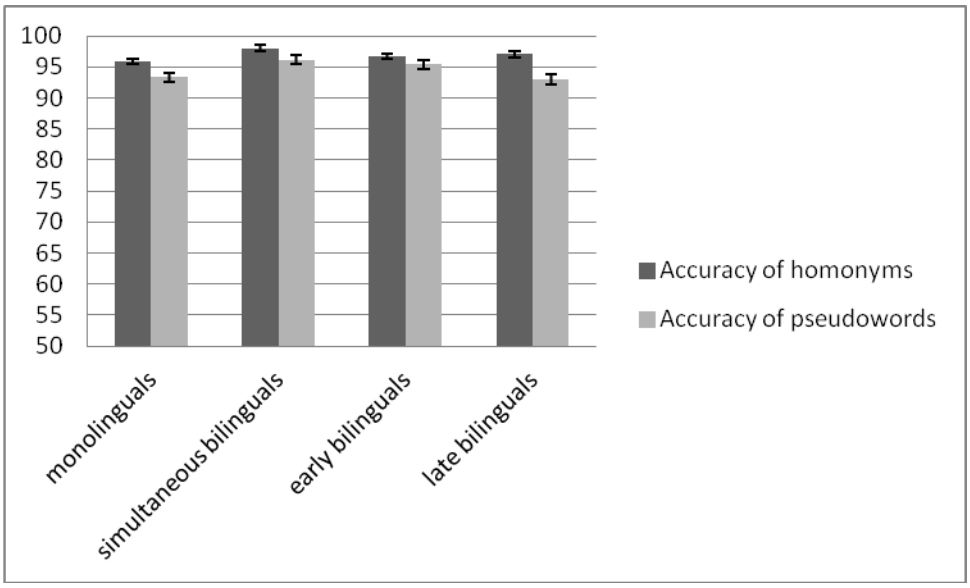


Figure 1: Accuracy by Language Group

4.3.2.2 Discussion

The averaged accuracy rates for each language group was found to be over 90% for each category, that of overall, for the homonym conditions, and for the pseudowords. Consequently, there was no interaction found between language group and accuracy categories. This was expected as the task was carried out in English, the L1 of all participants.

A repeated measures analysis found a significant main effect of accuracy, with responses being more accurate for the homonym conditions compared to the pseudowords. This suggests that real words were easier to process and react to relative to the pseudowords, as previous studies have shown. As there was no difference found between accuracy of pseudowords and language group and between accuracy of homonyms and language group, this suggests that all groups were similar in their decisions to real words and pseudowords.

4.3.3 Reaction Time Effects

4.3.3.1 Analysis

The RTs for only the correct trials were averaged for each condition for each participant grouped according to their predetermined language background. Trials with RTs ±2 standard deviations from each condition mean were removed. This resulted in an overall 4.10% of trials removed. For details of the percentage of all items which were removed because they were plus or minus 2 deviations from the standard in each language group, please see Appendix 9: Percentage of items removed in each condition for each language group in the RT analysis.

A one-way ANOVA of overall RT by Language Group (LG) (4 levels: monolinguals, simultaneous bilinguals, early bilinguals, late bilinguals) did not find that the language groups differed significantly: ($F(3,77)=.544$, $p=.654$) and multiple comparisons showed the groups not differing from each other ($p=.1000$) for all comparisons. The overall RTs of each language group are shown in Figure 2 below with standard error bars.

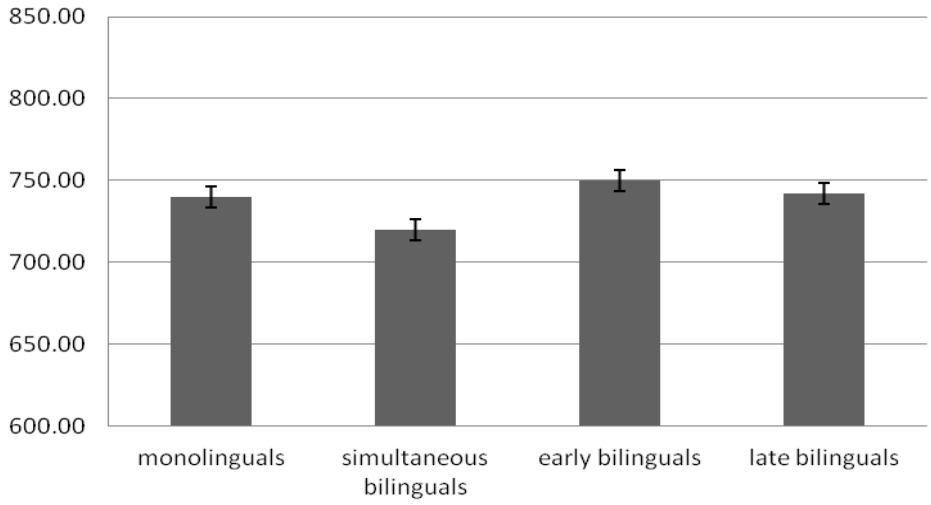


Figure 2: Overall RTs by LG

The averages of each homonym condition (not including the control conditions) were then compared to investigate the effect of homonym type (syntactic vs. semantic) and the effect of relatedness (subordinate and appropriate; dominant and (in)appropriate; unrelated). The mean group RTs for each of these conditions are shown in Table 3.

Table 3: Means by Condition and LG

	MONOLINGUALS		SIMULTANEOUS BILINGUALS		EARLY BILINGUALS		LATE BILINGUALS		TOTAL	
CONDITION	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
synsub	784.06	135.62	727.38	117.05	744.73	122.23	746.75	106.35	753.74	122.71
syndom	714.99	103.50	705.99	105.41	754.38	132.30	772.56	163.79	736.16	127.30
synunr	708.30	107.88	693.25	108.67	716.85	144.93	774.40	133.25	721.08	126.30
semsub	736.91	112.89	735.28	173.32	744.96	141.97	779.76	143.44	747.55	140.06
semdom	703.99	111.53	670.92	96.83	743.80	125.05	695.25	102.98	707.03	112.77
semunr	736.69	125.70	710.66	117.01	720.46	107.05	732.15	117.58	725.84	115.87

The RT data was analyzed using a 3-way repeated measures ANOVA with Homonym Type (2 levels: syntactic & semantic), Relatedness (3 levels: subordinate appropriate; dominant (in)appropriate; unrelated), and LG (4 levels: monolinguals,

simultaneous bilinguals, early bilinguals, late bilinguals) as factors. There was an overall main effect of Homonym Type ($F(1,100)=4.373$, $p=.039$). The effect of Homonym Type revealed the syntactically-constrained and unambiguous homonyms (731.39ms) being processed more slowly than the unconstrained and semantically-ambiguous homonyms (725.80ms).

There was also an overall main effect of Relatedness ($F(2, 200)=11.405$, $p<.001$), showing the subordinate readings of the homonyms being processed more slowly overall, even though the target word in both the syntactic and semantic conditions were appropriately-related to the priming homonym compared to the dominant reading which was processed more quickly yet was inappropriately-related to the priming homonym in the syntactic condition. Indeed, a planned comparison analysis testing the subordinate reading to the unrelated reading found this to be significant in the syntactic condition (synsub vs. synunr) ($p=.007$) as well as a trend toward significance in the semantic condition (semsub vs. semunr) ($p=.070$). A planned comparison analysis testing the subordinate reading to the dominant reading in the semantic condition (semsub vs. semdom) was found to be significant ($p<.001$), illustrating the difference in RTs for these conditions solely based on lexical frequency as the dominant target word was reacted to more quickly compared to the subordinate target word, even though both readings were appropriately-related to the priming homonym. This evidence of lexical frequency effects was also marginally supported in a comparison between the dominant readings to the unrelated readings in the syntactic condition (syndom vs. synunr) ($p=.094$), and the semantic condition (semdom vs. semunr) ($p=.070$). However, a planned comparison between the subordinate reading to the dominant reading in the syntactic condition (synsub vs. syndom) was not found to be significant

(p=.137), suggesting that the syntactic priming did indeed activate the subordinate reading of the priming homonym to the same level of activation as the dominant reading of the homonym, resulting in an equal activation. The RTs of these effects are shown below in Figure 3: RTs of Relatedness in the Collapsed Homonym Conditions (with standard error shown) with the overall RTs of the homonym conditions collapsed into one category for each relatedness condition. That is, the two subordinate conditions (synsub and semsub) combined are indicated below as *appropriate and subordinate*, the two dominant conditions (syndom and semdom) combined are indicated below as *(in)appropriate and dominant*, and the two unrelated conditions (synunr and semunr) are indicated below as *unrelated*.

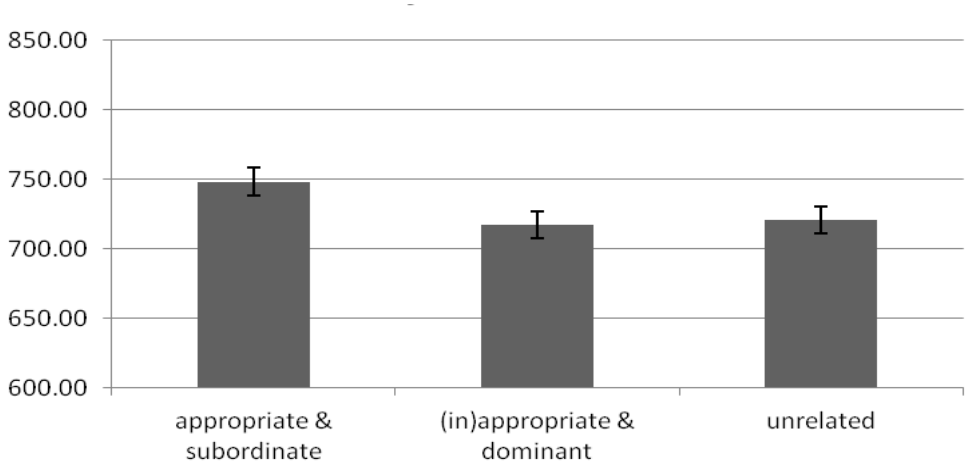


Figure 3: RTs of Relatedness in the Collapsed Homonym Conditions

Significant interactions were found between Relatedness and LG (F(6, 200)=2.596, p=.019). A planned comparison 1-way ANOVA contrasting the subordinate reading in the syntactic condition (synsub) between groups was not found to be significant (F(3,103)=1.053, p=.373) and a planned comparison 1-way ANOVA contrasting the subordinate reading in the semantic condition (semsub) between groups was not found to be

significant (F(3,103)=.482, p=.696), suggesting that all language groups were processing both subordinate readings similarly.

A planned comparison analysis contrasting the two subordinate readings (synsub and semsub) to the two dominant readings (syndom and semdom) found main effects between the subordinate and the dominant readings in the syntactic condition (synsub vs. syndom) (F(1,98)=4.424, p=.038), and in the semantic condition (semsub vs. semdom) (F1,98)=11.306, p=.001), suggesting that the subordinate conditions were processed similarly and the dominant conditions likewise, regardless of homonym type. However, there was a main effect of LG in the subordinate reading in the syntactic condition (synsub) (F(3,98)=3.156, p=.028), but not in the semantic condition (semsub) (F3,98)=1.343, p=.265), suggesting that the language groups may be differing in their processing of the syntactic condition compared to the semantic condition. This may conceivably be due to the constraining nature of the sentence frame of syntactic condition compared to the unconstrained semantic condition.

A planned comparison analysis contrasting the two subordinate readings (synsub and semsub) to the unrelated readings (synunr and semunr) also found main effects in the syntactic condition (synsub vs. synunr) (F(1,98)=15.280, p<.001) and in the semantic condition (semsub vs. semunr) (F1,98)=9.046, p=.003), further supporting the evidence that the constrained and unconstrained subordinate readings were being reacted to more slowly even compared to the target words which were unrelated to the priming homonym. There were no main effects of LG found in the unrelated readings in the syntactic condition (F(3,98)=1.994, p=.120), nor in the semantic condition (F3,98)=.005, p=1.000), which was as expected as these conditions were included as comparison conditions and lack the

frequency effects and priming effects anticipated to have an effect on the processing of the other conditions.

A planned comparison analysis contrasting the two dominant readings (syndom and semdom) to the two unrelated readings (synunr and semunr) was also found to be significant in both the syntactic condition (syndom vs. synunr) ($F(1,98)=56.010$, $p<.001$) and in the semantic condition (semdom vs. semunr) ($F1,98)=15.515$, $p<.001$), supporting my hypothesis that the dominant frequency words would reveal faster RTs compared to the unrelated conditions, regardless of the inappropriate relationship between the target word and the priming homonym in the syntactic condition. As expected, there was a main effect of LG found in the dominant reading of the semantic condition (semdom) ($F3,98)=4.809$, $p=.004$), supporting my hypothesis that some language groups would be more sensitive to lexical frequency given the unconstraining nature of this condition. Indeed, as can be seen in Figure 4 below, the faster RTs of the monolinguals, simultaneous bilinguals, and late bilinguals in the collapsed dominant condition suggest that they were aided by the higher frequency of the target items.

Comparatively, there was no main effect of LG found in the dominant reading of the syntactic condition (syndom) ($F(3,98)=1.470$, $p=.228$), which was unexpected as I had hypothesized that the bilinguals would differ from the monolinguals in their sensitivity to the inappropriateness of the target word in this condition given the constraining nature of the sentence frame.

Figure 4: RTs of Relatedness in the Collapsed Homonym Conditions by LG shows the subordinate reading RTs as the longest compared to the other relatedness conditions for

all language groups except for the early bilinguals. This group appears to show the longest RT for the dominant reading conditions, which is contrary to the other language groups' performances. Overall, the monolinguals, simultaneous bilinguals, and late bilinguals show the longest RTs in the subordinate reading conditions, the shortest RTs in the dominant reading condition, and their RTs to the unrelated target words falls in between these two conditions. The early bilinguals, however, show the shortest RT in the unrelated condition compared to the other relatedness conditions within the group.

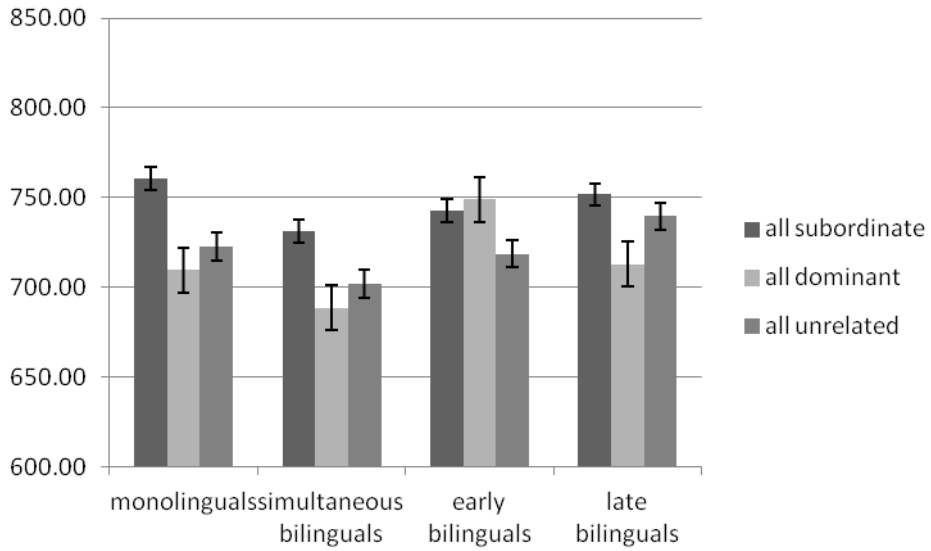


Figure 4: RTs of Relatedness in the Collapsed Homonym Conditions by LG

A significant interaction was also found by Homonym Type and Relatedness and LG ($F(6, 200)=2.277$, $p=.038$), and a trend toward an interaction between Homonym Type and Relatedness ($F(2,200)=2.614$, $p=.076$). Figure 4: RTs of Relatedness in the Collapsed Homonym Conditions by LG shows each group's RTs for each of the Relatedness conditions by Homonym Type, which shows variation between language groups and conditions. It appears that the monolingual group has the longest RT in the syntactically-constrained appropriately-related and subordinate condition (synsub), which was found to be significant

in a planned pair-wise comparison t-test as differences were found between the subordinate and dominant readings in the syntactic condition (synsub vs. syndom) (p=.001), the subordinate and the unrelated readings in the syntactic condition (synsub vs. synunr) (p<.001), the subordinate readings of both conditions (synsub vs. semsub) (p=.019), and the subordinate reading in the syntactic condition versus the dominant reading in the semantic condition (synsub vs. semdom) (p<.001).

As can be seen next in Figure 5, it appears that the late bilinguals reacted fastest to the appropriately-related and dominant reading in the unconstrained semantic condition (semdom), suggesting an effect of lexical frequency in the absence of sentential constraints. A planned pair-wise comparison t-test found this to be significant between the subordinate reading in the syntactic condition versus the dominant reading in the semantic condition (synsub vs. semdom) (p=.036) and the unrelated reading in the syntactic condition versus the dominant reading in the semantic condition (synunr vs. semdom) (p=.009) for this group.

The early bilinguals appear to have the longest RT in the syntactically-constrained inappropriately-related and dominant condition (syndom), and a planned pair-wise comparison t-test found this condition to be marginally different from the unrelated target word in the syntactic condition (synunr) (p=.058). This suggests that the inappropriateness of the relationship between the priming homonym and the target word may be slowing this group down, even in comparison to the unrelated condition which suggests that this group may be undergoing a process of reanalysis for this particular condition. A planned pair-wise comparison t-test investigating this group's longer RT compared to the other groups in the unconstrained appropriately-related and dominant condition (semdom) also found a significant difference between the early bilinguals and the simultaneous bilinguals (p=.030),

but not between the early bilinguals and the monolinguals (p=.190), nor the late bilinguals (p=.150). The reason for this difference found between the early bilinguals and the simultaneous bilinguals is explained next.

As can be seen below in Figure 5: Relatedness of each Homonym Type by Language Group, the simultaneous bilinguals appear to have the fastest RTs in all conditions. The monolinguals and simultaneous bilinguals appear to be faster in the syntactically-constrained inappropriately-related and dominant (syndom) and unconstrained appropriately-related and dominant conditions (semdom) compared to the syntactically-constrained appropriately-related and subordinate (synsub) and unconstrained appropriately-related and subordinate conditions (semsub) which suggest a frequency effect for these groups as it appears they were processing the dominant reading of the homonym more easily than the subordinate reading. These findings are shown in Figure 5 below and to investigate whether or not these observable differences are significant, separate 2-way ANOVAs were run for each language group. The results of which are presented next.

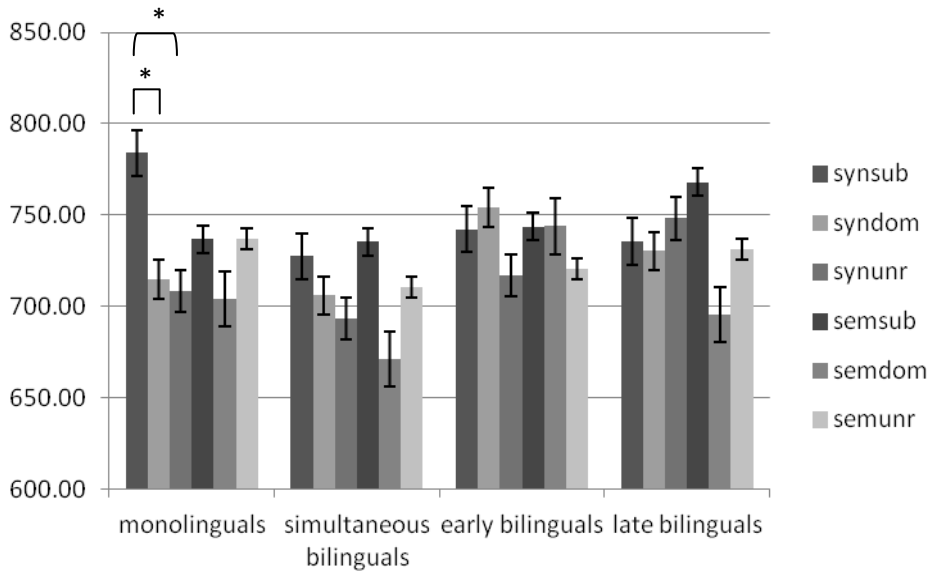


Figure 5: Relatedness of each Homonym Type by Language Group

A 2-way ANOVA comparing Homonym Type and Relatedness for the monolingual group alone revealed a significant effect of Relatedness ($F(2,62)=11.540$, $p<.001$), suggesting that the monolinguals were sensitive to the relationships between the priming homonyms and the target words. This was especially supported in a planned comparison t-test which found a significant difference between the subordinate reading and dominant reading ($p=.001$) and between the subordinate reading and the unrelated target word ($p<.001$) in the syntactic condition, which shows that the monolinguals were slowest in the syntactically-constrained and subordinate reading condition compared to all other conditions. Also, as can be seen above in Figure 5, their RTs to the unconstrained and subordinate reading was just as slow as the unrelated target word in the semantic condition. This shows that the monolinguals are influenced by lexical frequency (with subordinate readings being processed more slowly), and when presented with a subordinate reading coupled with a syntactically-constraining sentence, these two factors appear to be interacting, which can be observed as markedly longer RTs. There was also a significant interaction of Homonym Type and Relatedness ($F(2,62)=4.058$, $p=.022$), suggesting that this sensitivity to the relatedness of the target words to the priming homonyms was not equal between the two homonym types. However, there was no main effect of Homonym Type found ($F(1,31)=1.106$, $p=.301$), suggesting that overall, the monolinguals processed the syntactic condition and semantic condition similarly. This suggests that this group may be more influenced by lexical frequency than by priming. This is explored further in sections 4.3.4 Priming Effects and 4.3.5 Frequency Effects.

The same 2-way ANOVA for the simultaneous bilinguals also revealed a significant effect of Relatedness ($F(2,40)=4.077$, $p=.024$), similarly suggesting that this group was also

sensitive to the relationships between the primes and the target words, which also shows the simultaneous bilinguals responding more slowly to the subordinate readings of the priming homonyms compared to the dominant. There was no main effect of Homonym Type found ($F(1,20)=.076$, $p=.785$), suggesting that overall, the simultaneous bilinguals processed the syntactic condition and semantic condition similarly. As there was no significant interaction between Homonym Type and Relatedness found ($F(2,40)=1.131$, $p=.333$), this suggests that the faster RTs found to the dominant readings were not limited to one or the other homonym type. Indeed, as Figure 5 above shows, the simultaneous bilinguals appear to react more quickly to the dominant readings in both homonym conditions, and more slowly to the subordinate readings, again in both homonym conditions. These findings suggest that the simultaneous bilinguals were more sensitive to lexical frequency than syntactic priming, which will be presented and discussed more in sections 4.3.4 Priming Effects and 4.3.5 Frequency Effects.

The same 2-way ANOVA comparing Homonym Type and Relatedness for the early bilingual group similarly revealed a significant effect of Relatedness ($F(2,58)=3.771$, $p=.029$), suggesting that the subordinate and dominant readings were processed differently, which supports the evidence of the faster RTs for the subordinate readings in Figure 5 above. There was no main effect of homonym type ($F(1,29)=.058$, $p=.811$), suggesting that the two conditions did not differ significantly from each other in RTs for this group. There was no significant interaction between homonym type and relatedness ($F(2,58)=.133$, $p=.876$), suggesting than any difference between the subordinate and dominant conditions between the two homonym conditions was not significant and that the faster RTs to the subordinate readings were not restricted to either the syntactic or semantic condition, even though there

appears to be a greater difference in the syntactically-constrained condition. This suggests that this group was also more sensitive to the relationships between the priming homonyms and the target words than by the presence or absence of a sentential constraint surrounding the homonym. This is evidenced by the RTs of this group as shown above in Figure 5: Relatedness of each Homonym Type by LG. The early bilinguals appear to have consistently longer RTs across conditions, with the longest RT of all of the groups in the unconstrained appropriately-related and dominant condition. In particular, the longer RT in this condition was unexpected as this condition involves an ambiguous priming homonym set in a neutral sentence followed by a target word related to the dominant meaning of the priming homonym. Due to the higher frequency of the target word and the unconstrained nature of the sentence ensuring the target word is appropriately-related to the priming homonym, faster RT results were expected for this condition across all groups, yet the early bilinguals appear to be an exception. Further, although it was anticipated that both the early and late bilinguals would show longer RTs overall, which is shown in Figure 2: Overall RTs by LG, it is not clear why this group specifically would have the longest RT for that particular condition. So, overall, the early bilingual group does indeed show longer RTs overall compared to the monolinguals and simultaneous bilinguals which suggests a delay in processing, perhaps due to this group having to search through a larger store of words, or their delay could be due to the links between the priming homonym and the target word being weaker than those of the monolinguals and the simultaneous bilinguals.

The same 2-way ANOVA comparing Homonym Type and Relatedness for the late bilingual group revealed a significant effect of Homonym Type ($F(1,20)=6.019$, $p=.023$), but not Relatedness ($F(2,40)=1.639$, $p=.207$), and only a trend towards an interaction was found

between Homonym Type and Relatedness (F(2,40)=2.927, *p*=.065). These findings suggest that, in contrast to the other groups, this group appears to be more sensitive to the appropriateness of the target word to the priming homonym as constrained by the sentential frame rather than the frequency of the homonym reading. The late bilinguals appear to be faster in the syntactically-constrained appropriately-related and subordinate reading in the syntactic condition (synsub) compared to the syntactically-constrained inappropriately-related and dominant reading (syndom), but faster in the unconstrained appropriately-related and dominant reading in the semantic condition (semdom) compared to the unconstrained appropriately-related and subordinate reading (semsub), which suggests that they were either facilitated by priming in the subordinate (syntactic) condition or they were slowed down by the inappropriateness of the dominant (syntactic) condition regardless of lexical dominance, yet they appear to be facilitated by lexical dominance in the unconstrained (semantic) condition. These effects are presented and discussed more in depth in sections 4.3.4 and 4.3.5., and for the grand means of reaction times by condition and by language group, please see Appendix 10: Means by Language Group.

4.3.3.2 Discussion

I hypothesised that the three bilingual groups would differ in RTs to the monolingual group based simply on the fact that they had acquired a L2 at some period in life, which might therefore affect their processing time in the L1. However, the overall RT results of all the groups did not support this hypothesis as the bilingual groups did not differ significantly compared to the monolingual group. It appears that acquiring an L2 does not hinder processing time in a lexical decision task overall. Upon closer inspection, it appears that it may be the case that each group differs according to condition, but that their overall averaged

RTs do not differ. Thus, an analysis into specific effects is needed to fully understand the underlying processing mechanisms of each group as they were presented with each condition. For example, it appears that acquiring 2L1s did not hinder processing in the simultaneous bilingual group and provided them with what may be a heightened sensitivity to lexical frequency as their RTs were faster in the dominant conditions than for the subordinate (yet appropriate) conditions This effect of frequency will be examined more in depth in the section 4.3.5 Frequency Effects.

Comparatively, the anticipated delay due to L2 acquisition was supported for certain conditions in the case of the early and late bilingual groups. Whether this may be due to a delay in access to the L1 items within the mental lexicon, or whether this may be due to a reduced ability to inhibit inappropriate items, requires further investigation. Indeed, the early bilingual group show the longest RT overall in the unconstrained semantic conditions, which supports previous postulations that early bilinguals may be searching through a larger store of words (Fabbro, 2001; Murray & Forster, 2004; Paradis, 1998, 2001), as well as having to choose the appropriate word due to a competition of lexical activation (Van Assche et al., 2009). Further, the early bilingual group was found to have the longest RT for the syntactically-constrained inappropriately-related and dominant reading condition (syndom) which suggests that this group may have undergone a process of reanalysis for the inappropriateness of the target word in relation to the priming homonym. If this is the case, this supports my hypothesis that early bilinguals would be sensitive to surface cues such as the priming found in this particular condition. Whether or not this sensitivity also applies to lexical frequency will be examined next. Lastly, the late bilinguals also revealed longer RTs in the syntactically-constrained inappropriately-related and dominant condition (syndom),

which suggests that this group may also be sensitive to the priming cues of this condition. The late bilinguals also revealed shorter RTs for the unconstrained appropriately-related and dominant condition (semdom), suggesting that they responded more quickly to the higher frequency words than the lower frequency words in the absence of syntactic constraints. Taken together, these findings fully support my hypothesis that the recent acquisition of the L2 heightened this group's sensitivity to surface cues for easier homonym processing. Evidence of this group thus being influenced by priming in the syntactic condition and lexical frequency in the semantic condition appears to indicate a processing of surface cues in the L1 due to the influence of a heightened sensitivity to surface cues used as a strategy for acquisition of the L2. These surface cues include syntactic constraints for priming and lexical frequencies which are discussed next.

4.3.4 Priming Effects

4.3.4.1 Syntactic Conditions Analysis

For this analysis, the data points of a subset of participants were used. This was due to the method used for data analysis during the earlier version of the experiment between the years 2008 and 2010, in which the priming data were compiled from the raw data, but not the non-priming control condition data. The method for data analysis in the later version of the experiment involved compiling all of the data for all of the conditions. Consequently, for this analysis comparing the priming conditions and the non-priming control conditions, only the data from the later version of the experiment was used. This resulted in 16 sets of data included in the monolingual group, 8 sets of data in the simultaneous bilinguals, 13 in the early bilinguals, and 13 in the late bilinguals.[7]

[7] I intend to reanalyse the raw data of the earlier version to include the non-priming control condition results for a larger analysis before submission to a peer-reviewed journal.

A 3-way repeated measures ANOVA examined the effect of priming (2 levels: priming homonym conditions, non-priming control conditions) and relatedness (2 levels: appropriately-related and subordinate (synsub), inappropriately-related and dominant (syndom)) in the syntactically-constrained condition for the four language groups (monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals). There was a main effect of priming ($F(1,46)=5.510$, $p=.023$) and a main effect of relatedness ($F(1,46)=11.860$, $p=.001$). There was a trend towards a significant interaction between priming effect and LG ($F(3,46) =2.545$, $p=.068$). There was a significant 3-way interaction between priming, relatedness, and LG ($F(3,46)=3.658$, $p=.019$). There was no significant interaction found between relatedness and LG ($F(3,46)=1.496$, $p=.228$), nor between priming and relatedness ($F(1,46)=1.658$, $p=.204$). There was no main effect of group ($F(3,46)=.266$, $p=.849$). To further investigate the significant 3-way interaction and the main effects presented here, these conditions were separated and 2-way ANOVAs were run comparing just the subordinate priming to the non-priming conditions and the dominant priming to the non-priming conditions. The results of these analyses are presented in subsections of the appropriate headings.

The overall mean RTs of responses in the priming homonym, non-priming control conditions, and the appropriately-related and subordinate, and inappropriately-related and dominant conditions in the syntactically-constrained condition for the four language groups are presented below in Figure 6: RTs in the Priming and Non-priming Syntactic Conditions by LG. In particular, this shows the monolingual group reacting more slowly to subordinate target words that are appropriately-related to the preceding priming homonym compared to the presentation of the same target word preceded by a sentence not containing any homonym. In contrast, the bilingual groups appear to respond more quickly to a target word

which is of subordinate frequency and appropriately-related to the priming homonym than when presented with sentences containing no homonyms at all. This suggests that the relationship between the prime and the target facilitated faster reaction times for the bilingual groups, but not for the monolingual group. The extent of the priming effect across groups is discussed in the next two subsections, the first investigating the appropriately-related and subordinate condition (synsub) compared to the non-priming control condition (synsub control) and the second investigating the inappropriately-related and dominant condition (syndom) compared to the non-priming control condition (syndom control). For the grand means of RTs in these conditions by language group, please see Appendix 10: Means by Language Group.

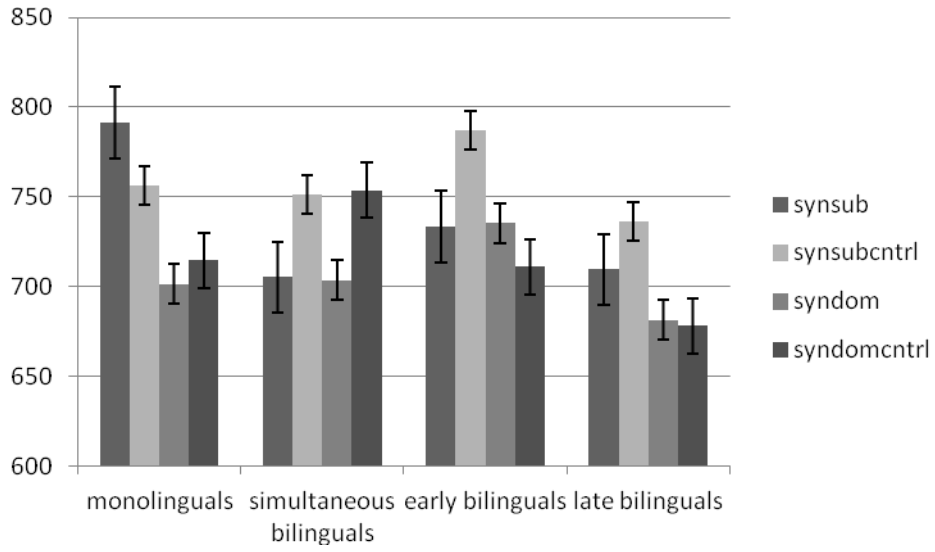


Figure 6: RTs in the Priming and Non-priming Syntactic Conditions by LG

SYNSUB CONDITIONS

In order to investigate the proposed priming effects in the syntactically-constrained appropriately-related and subordinate condition, a 2-way ANOVA of RTs in the

syntactically-constrained appropriately-related and subordinate condition (synsub) and the syntactically-constrained appropriately-related and subordinate control condition (synsub control) were compared by LG. There was a main effect of priming found ($F(1, 46)=5.097$, $p=.029$) which suggests that overall the primed subordinate meaning (mean RT) was quicker to access than the unprimed control condition (mean RT). There was also a significant interaction between priming and language group ($F(3, 46)=3.936$, $p=.014$). This interaction revealed that the syntactically-constrained appropriately-related and subordinate condition (synsub) was slower for the monolinguals and quicker for the 3 bilingual groups, although a planned pair-wise comparison of this condition did not find the monolinguals differing significantly from any of the other groups: the monolinguals vs. the simultaneous bilinguals ($p=.123$), the monolinguals vs. the early bilinguals ($p=.236$), and the monolinguals vs. the late bilinguals ($p=.293$).

SUBTRACTED DIFFERENCES BETWEEN SYNSUB AND SYNSUB CONTROL CONDITIONS

To investigate the evidence of differences between the syntactically-constrained appropriately-related and subordinate condition and the syntactically-constrained appropriately-related and subordinate control condition, a 1-way ANOVA comparing language groups for the priming effect (the RT to the synsub condition minus the synsub control condition) was performed. All priming effects are shown below in Figure 7 with a negative value (such as -52.77), indicating a shorter RT, and therefore a priming effect, for the syntactically-constrained homonym relative to the control condition. The monolinguals clearly show a difference of RTs relative to the bilingual groups as they show a positive value, indicating a lack of priming. A main effect of priming between groups

(F(3,49)=3.936, p=.014) was found. A multiple comparison found the early bilinguals differed significantly from the monolinguals (p=.010), while there was no significant difference between the other groups.). The bilingual groups all show negative values, indicating faster RTs relative to the control condition, and these priming effects did not differ across the bilingual groups (p=1.000). Statistical significance between the monolingual and the early bilingual group is indicated with a bracket and an asterisk in Figure 7: Priming Effects in the Appropriate and Subordinate Syntactic Condition by Language Group.

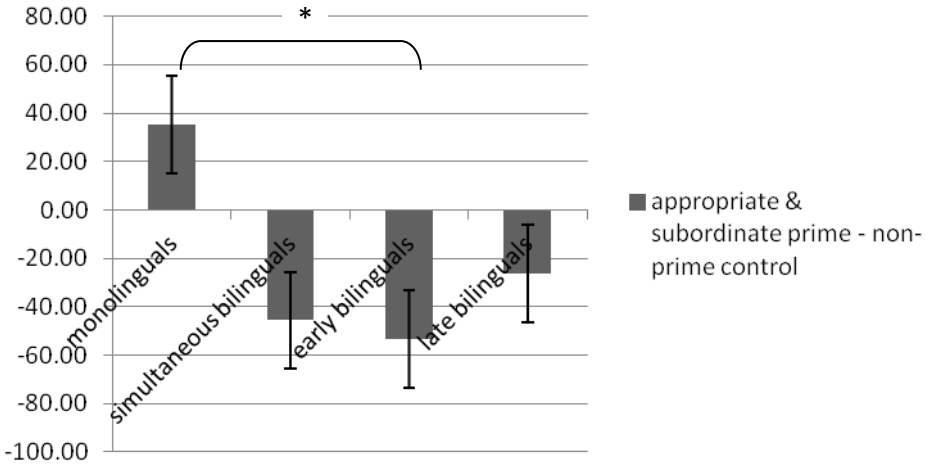


Figure 7: Priming Effects in the Appropriate and Subordinate Syntactic Condition by LG

SYNDOM CONDITION

A 2-way ANOVA did not find a significant effect of priming in the syntactically-constrained inappropriately-related and dominant condition compared to syntactically-constrained inappropriately-related and dominant control condition (F(1,46)=.125, p=.725). A trend toward a significant interaction between priming and LG (F(3,46)=2.395, p=.080) was found. Figure 8: RTs in the Inappropriate & Dominant Syntactic Priming Condition shows that the simultaneous bilinguals are the only group to show an associative priming effect, whereas the early bilingual group appears to be slowed down by the presentation of a

target word that is inappropriately related to the priming homonym, and the other two groups appear to show no effect either way. Indeed, a planned pair-wise comparison t-test found a trend towards a main effect between the primed dominant reading in the syntactic condition compared to the non-priming control condition for the simultaneous bilinguals (p=.078) and the early bilinguals (p=.073), but not the monolinguals (p=.549), nor the late bilinguals (p=.824).

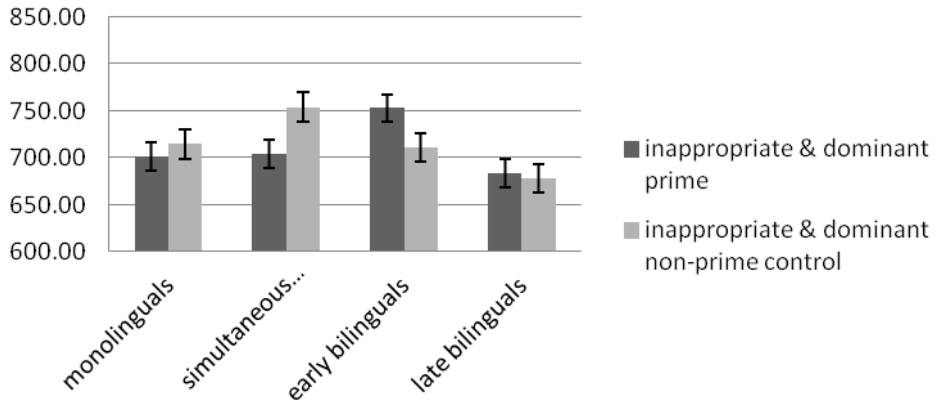


Figure 8: RTs in the Inappropriate and Dominant Syntactic Priming Condition

SUBTRACTED DIFFERENCES BETWEEN SYNDOM AND SYNDOM CONTROL CONDITIONS

To investigate the evidence of differences between the syntactically-constrained inappropriately-related and dominant condition and the syntactically-constrained inappropriately-related and dominant control condition, a 1-way ANOVA comparing language groups for the priming effect (the RT to the syndom condition minus the syndom control condition) was performed. All priming effects are shown below in Figure 9 with a negative value (such as -13.19), indicating a shorter RT for the syntactically-constrained homonym relative to the control condition. A trend towards an interaction between priming

and language groups (F(3,49)=2.395, p=.080) was found. A planned pair-wise comparison t-test found the early bilinguals differing from the simultaneous bilinguals (p=.012), and a trend towards a difference between the early bilinguals and the monolinguals (p=.084), while there were no significant differences among the other groups. This is illustrated in Figure 9: Priming Effects in the Inappropriate and Dominant Syntactic Condition by Language Group with significance indicated with a bracket and an asterisk.

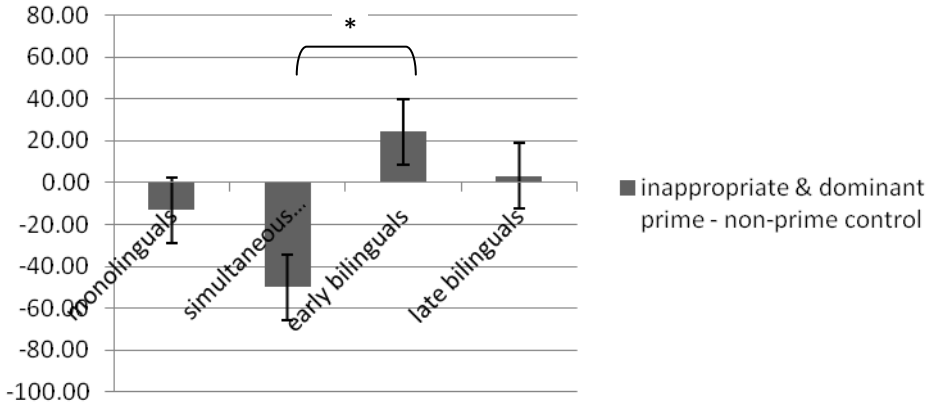


Figure 9: Priming Effects in the Inappropriate and Dominant Syntactic Condition by LG

COMPARISON OF SUBTRACTED DIFFERENCES: SYNSUB VS. SYNDOM PRIMING

To investigate the differences between the two subtracted differences in priming effects discussed above, a 2-way ANOVA comparing priming effects (subtracted difference of synsub priming effect vs. subtracted difference of syndom priming effect) and language group (monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals) was performed. A main effect of priming (F(1,46)=11.860, p=.001) was found, as was a main effect of relatedness (F(1,46)=5.510, p=.023). There was a trend towards an interaction between relatedness and LG (F(3,46)=2.545, p=.068). There was also a main interaction found between priming, relatedness and LG (F(3,46)=3.658, p=.019). There was no

interaction between priming and LG ($F(3,46)=1.496$, $p=.228$). The subtracted differences for the two priming conditions in the syntactic category are shown together next in Figure 10: Priming Effects of the synsub and syndom Conditions. This figure shows the differences of priming effects side-by-side by language group. As already discussed above, the dominant condition shows the early bilinguals and late bilinguals as having no significant priming effect, whereas the monolinguals and simultaneous bilinguals do show priming in this condition, even though the relationship between target word and priming homonym was inappropriate. The subordinate condition (presented above in Figure 7) shows all bilingual groups as having priming effects, whereas the monolinguals do not show significant priming effects in this condition even though the relationship between target word and priming homonym was appropriate. Therefore, the monolingual group does not appear to be sensitive to the appropriateness of the relationship between the target word and the priming homonym in either condition. Indeed, a planned pair-wise comparison between the subtracted difference in the subordinate priming condition and the subtracted difference in the dominant condition was not found to be significant ($p=.274$). In contrast, the simultaneous bilinguals showed an effect of priming for both conditions, again, regardless of the appropriateness of the relationship between the target word and the priming homonym. Indeed, a planned pair-wise comparison between the subtracted difference in the subordinate priming condition and the subtracted difference in the dominant condition was not found to be significant ($p=.274$) for the simultaneous bilinguals. Contrastively, the early and late bilinguals showed similar evidence of priming effects as they showed priming effects for the appropriate relationship between the target word and priming homonym, but no priming effects for the inappropriate relationship between the target word and priming homonym. The same planned pair-wise comparison between the subtracted difference in the subordinate priming condition and the

subtracted difference in the dominant condition for the early bilinguals revealed a significant difference between these two priming conditions (p=.002), but not the late bilinguals (p=.307). This suggests that overall, the bilinguals were more sensitive to syntactic priming relative to the monolingual group, and the later bilinguals (the early and late bilingual groups) appear to better distinguish between the appropriateness of the relationships between the target and the prime. Furthermore, the early bilinguals show the greatest difference between these two priming effects, the significance of which is shown in Figure 10 below with a bracket and asterisk.

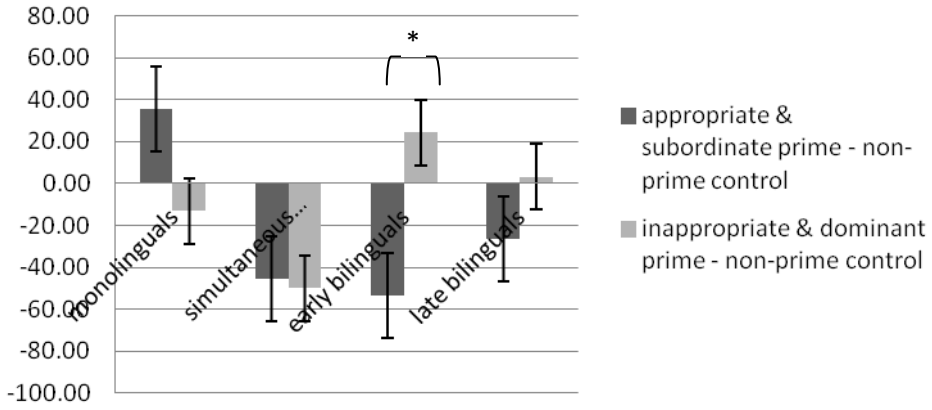


Figure 10: Priming Effects of the Appropriate & Subordinate and the Inappropriate & Dominant Syntactic Conditions

4.3.4.2 Semantic Conditions Analysis

In order to test whether or not the priming in the syntactic conditions described above was facilitated primarily by syntactic constraints, the same analyses were carried out on the semantic conditions, with a comparison of the two priming conditions to follow. In the semantic condition, only associative priming was anticipated due to the sentences lacking a semantic priming context, with the relationship between priming homonyms and target words being an associative one.

A 3-way repeated measures analysis examined the effect of priming (priming homonym conditions vs. the non-priming control conditions) and relatedness (appropriately-related and subordinate vs. appropriately-related and dominant), and language group (monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals) in the unconstrained semantic condition. A main effect of priming was found ($F(1,46)=17.560$, $p<.001$). This was the only effect found. A multiple comparison analysis did not find any differences between groups ($p=1.000$). For the grand means of RT in this condition by language group, please see Appendix 10: Means by language group.

SEMSUB CONDITION

A 2-way repeated-measures analysis contrasted the unconstrained appropriately-related and subordinate condition to the unconstrained appropriately-related and subordinate control condition by group. No significant effect of associative priming in the appropriately-related and subordinate semantic condition was found ($F(1,46)=.014$, $p=.907$), nor was there an interaction between priming and LG ($F(3,46)=.792$, $p=.505$). The lack of a main priming effect was unexpected since the target word is appropriately-related to the priming homonym. However, these results may reflect the fact that the target word is related to the subordinate reading of the priming homonym. Consequently, whether or not there was a difference in effects found between the subordinate reading and the dominant reading will be discussed next in Section 4.3.5: Frequency Effects, as these conditions deal with frequency effects. Figure 11: RTs in the Appropriate and Subordinate Priming and Non-priming Semantic Conditions shows the mean RTs of all groups as they reacted to target words which were appropriately related to the subordinate reading of the priming homonym. Although it appears that there are differences in RT between the language groups and according to the

condition, these differences were not found to be significant. Indeed, a multiple comparison analysis did not find any significant differences between language groups (p=1.000), nor did planned pair-wise comparisons find differences between these conditions for any language group.

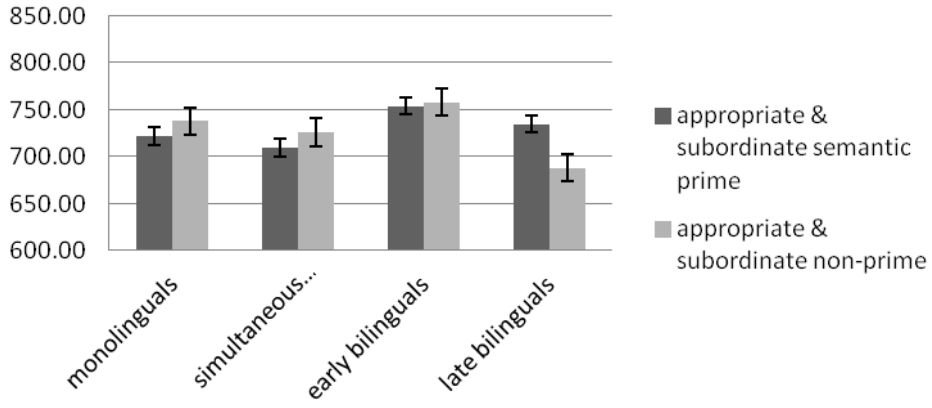


Figure 11: RTs in the Appropriate and Subordinate Priming and Non-priming Semantic Conditions

A 1-way ANOVA comparing language groups in the subtracted difference between the semantic subordinate prime and control conditions did not find a main effect of priming between groups (F(3,49)=.792, p=.505). A multiple comparison likewise did not find any significant differences between the groups (monolinguals vs. late bilinguals (p=.992) all others (p=1.000)). This is illustrated below in Figure 13: Priming Effects in the Appropriate Semantic Condition by Language Group which shows a comparison of priming effects of the appropriately-related subordinate and dominant semantic conditions.

SEMDOM CONDITION

A 2-way repeated-measures analysis contrasted the unconstrained appropriately-related and dominant condition to the unconstrained appropriately-related and dominant

control condition by LG was performed. Similar to the subordinate condition, no significant effect of associative priming in the appropriately-related and dominant semantic condition was found ($F(1,46)=.017$, $p=.898$), nor was there an interaction found between priming and LG ($F(3,46)=1.672$, $p=.186$). Likewise, a multiple comparison did not find the language groups differing significantly from each other in either the unconstrained appropriately-related and dominant or the unconstrained appropriately-related and dominant control condition ($p=1.000$). Figure 12: RTs in the Appropriate and Dominant Priming and Non-priming Semantic Conditions shows the simultaneous and early bilinguals differing from the monolinguals, however in this condition the monolinguals and late bilinguals show evidence of priming in their reactions to target words which were appropriately-related to the dominant reading of the priming homonym. The simultaneous and early bilinguals unexpectedly do not show such an advantage for the appropriately-related dominant readings compared to the target words unrelated to the non-homonymous word they are presented with. However, any differences found in the graph below were not found to be statistically significant ($p=1.000$). Indeed, a planned pair-wise comparison did not find any differences between these conditions for the monolinguals ($p=.757$) the simultaneous bilinguals ($p=.470$), early bilinguals ($p=.136$), nor the late bilinguals ($p=.136$).

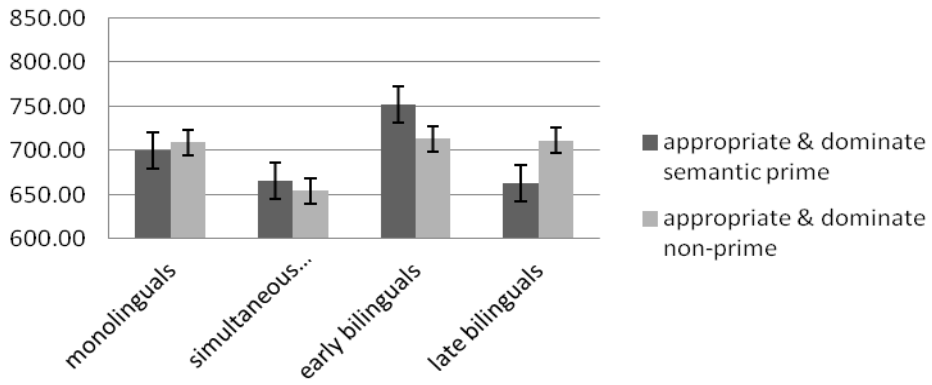


Figure 12: RTs in the Appropriate and Dominant Priming and Non-priming Semantic Conditions

A 1-way ANOVA comparing language groups in the subtracted difference between the appropriately-related and dominant semantic priming and non-priming control conditions did not find a main effect of Priming between groups ($F(3,49)=1.672$, $p=.186$). A multiple comparison revealed no significant differences between the groups (early bilinguals vs. late bilinguals ($p=.203$) all others ($p=1.000$)). This is illustrated below in Figure 13: Priming Effects in the Appropriate Semantic Conditions by Language Group which shows a comparison of priming effects of the appropriately-related subordinate and dominant semantic conditions.

SUBTRACTED DIFFERENCES BETWEEN SEMSUB AND SEMDOM CONDITIONS

A 2-way ANOVA did not find any significant priming effects between the subtracted differences of the priming and non-priming (both subordinate and dominant) semantic conditions ($F(1,46)=.029$, $p=.865$), nor was there an interaction by LG ($F(3,46)=1.909$, $p=.141$). Multiple comparisons likewise did not find the language groups differing from each other ($p=1.000$). Even though Figure 13below shows the monolinguals differing in the direction of priming from the bilingual groups, this difference was not found to be significant. Nor were the actual priming effects found to be significant between the subordinate and dominant priming conditions. This indicates that, regardless of lexical frequency, the RTs of all the groups were similarly not significantly influenced either way by the appropriate relationship between the target words and the unconstrained priming homonym relative to target words which were unrelated to the non-homonymous priming conditions. Indeed, a planned pair-wise comparison did not find a main difference between the subtracted differences of the subordinate semantic priming conditions and the subtracted

differences of the dominant semantic priming conditions for the monolinguals (p=.871), simultaneous bilinguals (p=.441), early bilinguals (p=.150), and late bilinguals (p=.153).

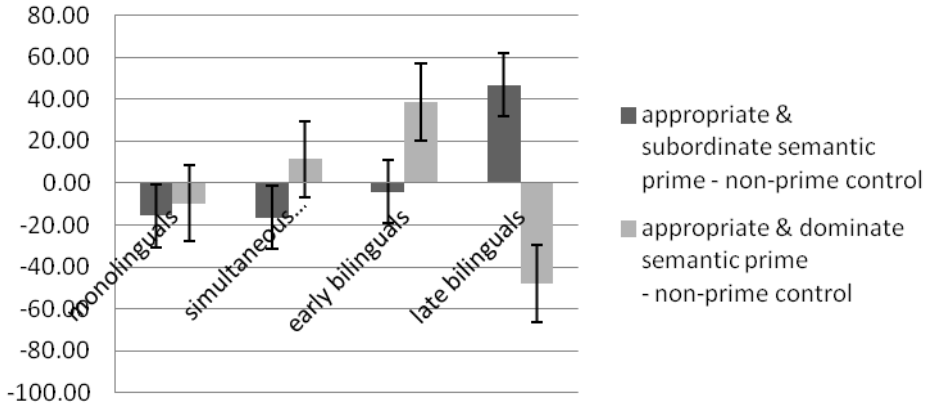


Figure 13: Priming Effects in the Appropriate Semantic Conditions by LG

4.3.4.3 Syntactic vs. semantic priming analysis

Using the subtracted differences between the priming condition and the non-priming control conditions, a 3-way repeated measures analysis investigating homonym type (syntactically-constrained and unconstrained semantic homonym conditions), relatedness (appropriately-related and subordinate; (in)appropriately-related and dominant; unrelated conditions), and language group (four levels: monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals) was performed. There was an interaction found between relatedness and LG ($F(6,92)=2.559$, p=.024), suggesting that the language groups differed by how they were processing the relatedness between the priming homonym and the target word. Indeed, this is shown above in the findings of the syntactically-constrained and inappropriately-related dominant condition (syndom – syndom control) as the early and late bilinguals do not show evidence of priming due to the inappropriateness of the target word to the priming homonym, whereas the monolinguals and simultaneous bilinguals do show

evidence of priming regardless of this inappropriate relationship. This is further supported by evidence of a trend towards an interaction between priming, relatedness, and LG ($F(6,92)=1.900$, $p=.089$). However, there was no main effect of language group ($F(3,46)=.266$, $p=.849$) and a multiple comparison did not find any differences between groups ($p=1.000$), suggesting that overall, no one language group differed from another. Consequently, to investigate whether or not this was an indication of the different language groups processing homonyms differently compared to the unrelated condition, a 3-way repeated measures analysis of the priming effects involving only homonym type (syntactic and semantic), frequency (subordinate and dominant) and LG (the same four levels) was performed. A significant interaction between frequency and LG was found ($F(3,46)=3.088$, $p=.036$) and there was a trend toward a significant interaction between homonym type, frequency, and LG ($F(3,46)=2.380$, $p=.082$), but no main effect of homonym type ($F(1,46)=1.516$, $p=.224$), nor of frequency ($F(1,46)=.579$, $p=.451$). These findings suggest that some language groups were more sensitive to the lexical frequencies of the target words than to the appropriateness of the relationships between the priming homonym and target words, which is investigated next in section 4.3.5 Lexical Frequency Effects.

4.3.4.4 Discussion

The goal of the priming analysis was to investigate whether or not both meanings of a homonym are facilitated for access regardless of sentential bias. It was hypothesised that the presentation of syntactically-constrained homonyms followed by appropriately-related and subordinate target words would reveal a greater effect of syntactic priming compared to the inappropriately-related and dominant target word. This priming effect was expected to be evidenced as an RT equal to or slightly shorter than the RT found in the dominant condition

due to the subordinate and dominant meanings being made available simultaneously. My hypothesis was upheld as there was a main effect of priming found for the syntactic condition as well as a significant interaction found between priming effects and language group, as well as an interaction between priming, target word relatedness, and language group. However, only the three bilingual groups appear to reveal syntactic priming with shorter RTs for target words appropriately-related to the priming homonym due to the biasing sentential frame, suggesting that these groups were more sensitive to the surface cues of the constraining sentential information relative to the monolingual group.

Based on the Reordered Access Model (Duffy et al., 1988) and the Subordinate Bias Effect (Rayner, et al., 1994), which suggest that the difficulty processing a subordinate and biased meaning does not necessarily negate syntactic priming, but rather, the subordinate meaning is available earlier than usual to compete with the dominant and unbiased meaning, my hypothesis was uncertain as to the results of the monolingual group. I hypothesised that 1) a shorter RT to the items in the syntactically-constrained appropriately-related and subordinate condition would be evidence of syntactic priming, thereby suggesting serial processing is unaffected by a competing dominant meaning, whereas 2) an equal or longer RT to the same items would be evidence of parallel processing and the Subordinate Bias Effect as both syntactic priming and lexical frequency would be competing. The results of the monolingual group's RTs support the latter hypothesis as the syntactically-constrained items resulted in significantly longer RTs compared to the control condition. This suggests that the monolinguals were slowed down due to the Subordinate Bias Effect, whereby the subordinate meaning of the syntactically-biased target word became available for processing at the same time as the dominant meaning. The ensuing competition resulted in the

significantly longer RT for this group, which will also be discussed as an effect of frequency in the next section. This lack of priming for the appropriately-related and subordinate reading in the syntactic condition (synsub) but priming found for the inappropriately-related and dominant reading (syndom) also supports the results found by Tanenhaus and Donnenwerth-Nolan (1984) who suggest that listeners access all readings of an ambiguous word even when one of the readings is inappropriate given the preceding syntactic context.

I hypothesized that the simultaneous bilingual group would resemble the monolingual group in manner of processing. This was not supported as this group did not show the syntactic constraints slowing them down as significantly as did the monolinguals. Whereas the monolingual group show syntactic priming and lexical frequency competing, the simultaneous bilingual group appears to be aided significantly by the syntactic constraints, as their RTs for the syntactically-constrained homonyms are shorter than for the control conditions. Indeed, the early and late bilinguals also show priming effects in this condition, which suggests that acquiring French as an L2 at any age results in an increase in sensitivity to surface cues for homonym processing in the L1. Unexpectedly, the simultaneous bilinguals also showed priming for the inappropriately-related and dominant condition similarly to the monolinguals, which suggests that these groups had the dominant meaning of the homonym facilitated for access regardless of the syntactic cues biasing towards the alternative. The early and late bilingual groups do not show priming in this condition, suggesting that their reactions were guided by sentential bias.

As expected, the monolinguals showed slightly faster RTs for the dominant reading of the priming homonyms in the semantic condition relative to the subordinate reading, which suggests frequency effects due to the absence of syntactic constraints. These

frequency effects will be discussed next in the section involving the Frequency analysis. However, the bilinguals did not show such clear-cut effects of frequency in the unconstrained conditions. The simultaneous and early bilingual groups showed priming effects for the appropriate and subordinate reading in the syntactic condition, but not for the appropriate and dominant reading in the semantic condition. As they are not showing a processing advantage for the dominant readings of the homonyms, this suggests possible effects supporting the weaker links hypothesis. The late bilinguals show a strong priming effect for the dominant reading, but not for the subordinate reading in the semantic condition, suggesting an effect of lexical frequency in the absence of sentential context. Consequently, these findings require further research and do suggest that not all native speakers be considered equal without taking into consideration the possible effects that acquiring an L2 may have on the L1, regardless of age of L2 acquisition.

My second hypothesis was that the late bilinguals would contrast the most in RT and manner of processing from the other groups, revealing L2 effects on the L1. Specifically, I hypothesised syntactic priming effects to be a substantiation of a reliance on lexico-semantic information and surface cues. Thus, if such reliance were found, this would reveal an effect of an L2 learning strategy influencing lexical ambiguity processing strategies in the L1. A facilitating effect of syntactic priming was found, but it was not limited to the late bilingual group. This supports the hypothesis that 1) functional bilinguals do indeed rely on lexico-semantic information and other surface cues to aid in lexical ambiguity resolution. Thus, syntactic context facilitated the appropriately-related target word following the priming homonym compared to a sentence without surface cues. This not only supports the findings of Goodman, McClelland, and Gibbs (1981) and Folk and Morris (2003) who found that

syntactic context affects lexical decisions without influence of semantic context effects, but also suggests that the bilingual groups show serial processing since syntactic and semantic information do not appear to be competing. On the other hand, the unexpected priming effects in the unconstrained semantic condition, that of priming found for the subordinate reading rather than the dominant reading, requires looking into. This is the focus of the next section: an analysis of frequency effects.

4.3.5 Frequency Effects

4.3.5.1 Analysis

A 3-way repeated measures analysis investigating homonym type (syntactic and semantic), frequency (subordinate and dominant), and LG (the same four levels: monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals) was performed to compare and contrast the effects of frequency across conditions. There was a main effect of homonym type ($F(1,100)=6.761, p=.011$), suggesting that the sentential constraints found in the syntactic condition but not in the semantic condition may be a factor. There was no interaction found between homonym type and LG ($F(3,100)=.708, p=.550$), which suggests that all four groups were processing the differences between the homonym types similarly. There was a main effect of frequency ($F(1,100)=18.542, p<.001$), as well as an interaction between frequency and LG ($F(3,100)=3.676, p=.015$), suggesting that one or some of the groups was/were more sensitive to the effects of frequency compared to the other groups. There was a trend toward a significant interaction between homonym type and frequency ($F(1,100)=3.393, p=.068$), where again the priming effect may be a factor. There was a significant 3-way interaction between homonym type, frequency, and LG ($F(3,100)=3.147, p=.028$), which is investigated further. Figure 14: RTs in the Frequency Conditions by LG

shows an overall view of each language group's responses to the subordinate and dominant readings in both the syntactic and semantic conditions. Each one of these effects, subordinate and dominant, will be presented and discussed more in depth in the following subsections categorised by the homonym type, either syntactic or semantic. In Figure 14 below, the error bars represent standard error. For this overall analysis, a multiple comparison did not find any language group differing significantly from the others (p=1.000). These results suggest that the language groups were processing the subordinate and dominant conditions differently, and that there was an interaction between the homonym conditions in which these frequency effects were found. To investigate this, and any condition-specific differences that might be found by language group, repeated measures analyses were performed on each homonym condition separately and are presented next. For the grand means of RT for frequency, please see Appendix 10: Means by Language Group.

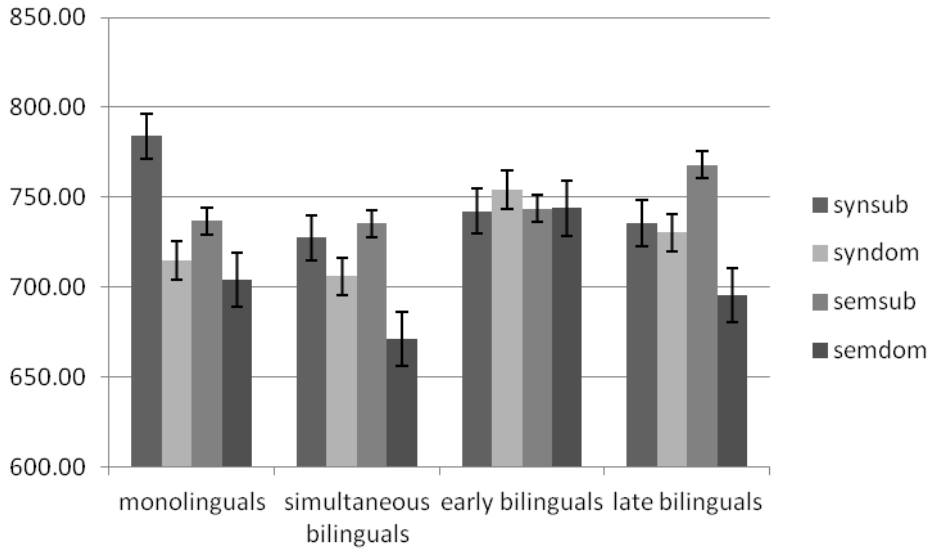


Figure 14: RTs in the Frequency Conditions by LG

SEMANTIC CONDITION

To further investigate the frequency effects found and presented above, as well as the unexpected priming effects found in the semantic condition and reported in the previous subsection, a 2-way repeated measures analysis was performed comparing frequency effects in RTs by LG in the semantic condition (unconstrained appropriately-related and subordinate (semsub) vs. unconstrained appropriately-related and dominants(semdom)) alone. This analysis found a significant main effect of frequency ($F(1,100)= 18.412$ $p<.001$) and an interaction between frequency and LG ($F(3,100)=2.958$, $p=.036$), but no main effect of LG ($F(3,100)=.620$, $p=.604$). Even though both types of target words are appropriately-related to the priming homonym, Figure 15: Frequency Effects in the Semantic Conditions by LG shows the monolingual, simultaneous bilingual, and late bilingual groups responding more quickly to target words that are appropriately-related to the dominant reading of the priming homonym than the subordinate reading. These frequency effects are as expected since words that are used more frequently within one's language are expected to be processed more easily than those words which are used less frequently. With higher frequency, a faster RT is expected, which is what these groups show. Indeed, a planned pair-wise comparison found a main difference between these two conditions for the monolinguals ($p=.022$), the simultaneous bilinguals ($p=.030$), and the late bilinguals ($p=.025$), but not the early bilinguals ($p=.923$). The early bilingual group were found to respond equally to target words that are appropriately-related to the dominant reading of the priming homonym as to the subordinate reading. This suggests that the early bilingual group was not as sensitive to lexical dominance. Given the ambiguity of the priming homonym placed within a neutral sentence with no syntactic or semantic context to bias the meaning of the homonym towards

either reading, it is possible that the early bilingual group processed both readings of the homonyms equally, and therefore do not show an effect of lexical frequency. This may be due to the links between lexical items within the mental lexicon for this group being weaker than those links within the mental lexicons of the other groups. Significant differences between these conditions are indicated in the Figure below with a bracket and an asterisk.

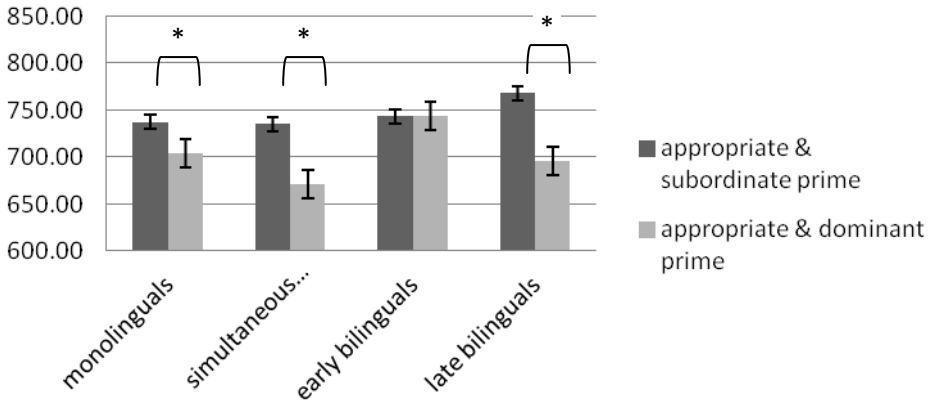


Figure 15: Frequency Effects in the Semantic Conditions by LG

SYNTACTIC CONDITION

A 2-way repeated measures analysis investigating frequency (subordinate vs. dominant) and LG in the syntactically-constrained condition found a significant interaction between frequency and LG ($F(3,100)=3.690$, $p=.014$), but there was no significant main effect of frequency ($F(1,100)=1.426$, $p=.235$). Figure 16: Frequency Effects in the Syntactic Conditions by LG shows the monolinguals and the simultaneous bilinguals responding more quickly to target words which are related to the dominant reading of the priming homonym, regardless of the appropriateness of the relationship between the target word and the priming homonym. This suggests that both readings of the homonym are facilitated for access

regardless of the syntactic constraints biasing the meaning of the sentence towards only the subordinate reading. Indeed, a planned pair-wise comparison found a difference between the subordinate and dominant syntactic conditions (synsub vs. syndom) for the monolinguals (p=.001). However, the same pair-wise comparison did not find a significant difference between these two conditions for the simultaneous bilinguals (p=.330). The early and late bilinguals, on the other hand, do not show faster RTs to the dominant reading of the priming homonym, which suggests that these two groups were more sensitive to the surface cues of the sentential frame rather than lexical frequency of the target words, as the subordinate reading and the dominant reading appear similar. Indeed, a planned pair-wise comparison did not find a difference between the subordinate and dominant syntactic conditions (synsub vs. syndom) for the early bilinguals (p=.634), nor for the late bilinguals (p=.412). The significant difference found between these conditions for the monolinguals is indicated in Figure 16 below with a bracket and an asterisk.

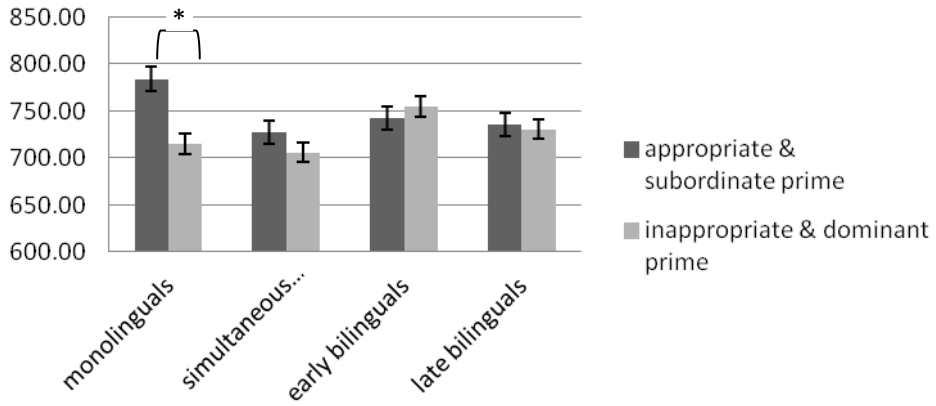


Figure 16: Frequency Effects in the Syntactic Conditions by LG

4.3.5.2 Discussion

I expected all groups to show shorter RTs for dominant frequency items in the semantic condition since these items were not constrained by cues to one reading over the other, and would therefore conceivably be free of competition. My hypothesis was supported by the monolingual, simultaneous bilingual, and late bilingual groups as they were faster in their responses to the dominant readings relative to the subordinate readings. This supports the findings of Bilenko and colleagues (2008), who found longer RTs and an increase in neural recruitment for the subordinate meaning of an ambiguous word. The findings of Study 1 support their suggestion that additional neurological resources may be recruited to overcome lexical competition when accessing the subordinate meaning of an ambiguous word. The early bilinguals, on the other hand, did not show any effect of lexical frequency in the semantic condition. Perhaps as a result of both the subordinate and dominant frequency items being appropriately-related to the priming homonym, the early bilingual group showed equal RTs to both. Although this was unexpected, this may in fact be due to an effect suggested by the weaker links hypothesis. That is, as this bilingual group use both their languages half the time compared to monolinguals, this results in the links between items being weaker relative to a monolingual's. These proposed weaker links may not reveal the same effects of frequency that the monolinguals display. Thus, an item which is dominant in the mental lexicon of a monolingual may not be dominant in the mental lexicon of a bilingual, and vice versa. This may explain the lack of frequency effects found in the semantic condition for the early bilinguals in Study 1.

Frequency effects within the syntactic condition confirmed my hypothesis that syntactic and semantic processing occurs in a parallel manner at this higher level of processing, as syntactic priming and lexical frequency were found competing: specifically

for the monolinguals and the simultaneous bilinguals. For these groups, the main effect of Frequency shows that the faster processing of the more dominant reading is maintained even when inappropriately-related to the priming homonym. This also suggests that both meanings of homonyms are accessed, which supports the Reordered Access Model (Duffy et al., 1988) as both the subordinate meaning and the dominant meaning of the target word become available simultaneously and compete. However, this effect was not found for the early bilinguals and the late bilinguals, suggesting that syntactic priming appears more influential for these two groups.

As such, my hypothesis that both meanings of ambiguous homonyms are accessed even when presented in a biasing syntactic context was supported in the results of the monolingual and simultaneous bilingual groups. This was evidenced as longer RTs were found for target words that are appropriately-related to the subordinate reading of the priming homonym (the syntactically-constrained appropriately-related and subordinate condition), suggesting that access and inhibition of the inappropriate and dominant target word was also occurring. This competition supports the suggestion that higher level processing, such as with lexical ambiguity resolution, occurs in a parallel manner within the mental lexicons of these groups.

The results of the early and late bilinguals, on the other hand, support the hypothesis suggesting that the acquisition of an L2 may affect processing in the L1. While not showing significantly longer RTs overall, this group showed effects of syntactic priming over lexical frequency in the syntactic condition, suggesting that these two were not in competition. Thus for this group, the effects of frequency cannot be considered an overall strategy as they were not found in conditions where both lexical frequency and syntactic priming were present.

Under these circumstances, the early and late bilinguals did not show effects of competition. This suggests that these groups processed syntactic homonyms not in a parallel manner as evidenced by the monolingual and simultaneous bilingual groups in this study, but rather in a serial manner of processing which is not influenced by the subordinate access effect. I suggest this is due to the early bilinguals and late bilinguals homonym processing in the L1 being influenced by acquiring an L2 after the proposed sensitive period of language development.

Lastly, the syntactic condition results show the simultaneous bilinguals resembling monolingual speakers in the manner of processing homonyms, with no significant delay in RTs as hypothesised. As such, contrary to our hypothesis, there was no evidence that this group accessed any translation equivalents as they accessed both the dominant and subordinate meanings of the homonyms.

4.4 General Discussion of Study 1

This study found that the acquisition of an L2 does indeed result in differences in homonym processing in regards to accuracy and RTs in regards to the relationship between prime and target, and sensitivity to priming and lexical frequency. Although this study did not find that the acquisition of an L2 increased the overall RTs in any condition, there were indications that the later the L2 is acquired, the more the L2 is found to influence the L1, by evidence of serial processing rather than parallel. These findings support claims by Cook (2003) that bilinguals naturally focus their attentional skills on linguistic structure, resulting in an increased sensitivity to surface cues and possible interactions between the two languages, and by van Hell and Dijkstra (2002) who found that foreign language knowledge affects L1 target word processing even in an exclusively native language context.

Specifically, the results of the bilingual groups counter the Subordinate Access Effect suggested by Duffy, Morris, and Rayner (1988) as these groups showed a greater sensitivity to surface cues as they were influenced by syntactic priming compared to the control condition where the monolinguals were not. Further evidence of the early bilinguals showing a lack of facilitation for the dominant reading suggests that this group may have been more sensitive to the sentential information to aid in their processing of the homonyms. This may be that as these bilinguals acquired the L2 through the L1 and relied on surface cues as a strategy for processing in the L2, they may unconsciously have become more aware of and aided by surface cues existing in the L1. This suggests that any speaker who has recently acquired an L2 may process their L1 differently, due to a more heightened metalinguistic awareness to language overall, albeit unconscious. One of these ways may be that lexical access is not as automatically exhaustive, but rather the order in which meanings of words are accessed is determined either by preceding contextual information or by meaning dominance, but not by both (as was found with the monolingual speakers). This leads to the surprising and perhaps controversial conclusion that any speaker proficient in an L2 should not be considered as equal to monolingual native speakers given the evidence of L2 effects on ambiguity resolution in the L1.

It is this suggestion which motivates the second study, which is the first of its kind to utilise ERP methodology to investigate lexical ambiguity resolution in real-time at the level of neurological processing. Using both the behavioural technique of Study 1 and ERPs of Study 2, this dissertation aims to conclude in a comparison and discussion of processing differences between monolingual and bilingual speakers as well as the possible correlations which are anticipated to correspond to the age at which the L2 was acquired. Specifically, the

age at which the L2 was acquired is anticipated to have had an effect on the mental lexicon. The results of Study 2 are anticipated to reveal such evidence in the timing, generalised scalp distribution, and amplitude of wave forms representative of electrical activity of the brain which occurs with language processing. Such evidence is anticipated to correlate with later AoL2A as evidence of lexical items being stored and accessed in separate but integrated mental lexicons for each language. Reflective of the results found in Study 1, I anticipate finding neurophysiological evidence of the two languages interacting due to the recently-acquired strategy of relying on surface cues for lexical ambiguity resolution. That is, I expect to find ERP evidence supporting the claim of Study 1 that the integration of the two languages within the bilingual mental lexicon affects L1 language processing to a greater extent for the later bilinguals and to a lesser extent for the simultaneous bilingual group.

CHAPTER FIVE: STUDY 2

5.1 Event Related Brain Potentials

Since the 1980s, researchers have been investigating established theories of language processing by using neurophysiological methods. These methods are thought to be able to more accurately record unconscious and automatic language processing as it occurs. Event-related potentials (ERPs) is one of the electrophysiological techniques used to do so (see Sabourin, Brien, & Tremblay, 2013), and is arguably one of the best methods available to date to be used for the current study. Although ERPs are unable to determine the source loci of the brain's reactions to stimuli, this methodology is able to determine the timing and stages of processing as it occurs in real time (Luck, 2005). In other words, ERPs tell us the when and the how of processing, but not the where. Thus, this is an ideal method to be used for the second part of the study being presented here as it is a complimentary technique to the behavioural measurements of speed and accuracy involved in the first study. ERPs consist of a technique which couples electroencephalography (EEG) with the presentation of stimuli (the events), which provokes responses (the potentials) from the individual involved. EEG is a non-invasive recording technique which uses a snug-fitting cap containing electrodes which are filled with a saline-based conductive gel. Via the conductive gel, the electrodes of the cap capture the ongoing fluctuations of electrical activity from specific locations on the scalp of the individual. The patterns of this electrical activity are represented as continuous waveforms. ERPs then indicate and measure specific electrical activity which reflects the individual's neurological responses to stimuli.

ERPs have been found that are thought to represent the earlier and later stages of language processing and are often referred to by their polarity and the time at which they are

recorded post-stimulus. In the current study, negative peaks are referred to as "N" plus the number of milliseconds from stimulus onset, such as the N400, and positive peaks are represented as "P" plus the number, such as the P600.

Language processing is known to occur at the level of milliseconds (Friederici, 1995) and thus, due to the excellent temporal resolution of this particular neurophysiological measure, ERPs make it possible to determine the different processes that occur in real-time as participants undergo tasks such as the cross-model lexical decision task presented and discussed in Study 1.

Many ERP studies have investigated lexical processing (in masked or unmasked priming, association tasks, etc. (Kluender & Kutas, 1993; among others)) and sentence processing (Kaan & Swaab, 2003; among others) in the L1. This provides a referential background for the current study as it involves both lexical and sentence processing in the L1 of all participants, regardless of some participants having acquired a L2 at some point in their development. Where the current study differs from the existing literature however, is in its combination of a cross-modal lexical decision task and ERPs in order to specifically investigate L2 effects on L1 syntactically-constrained homonym processing: a specification which has yet to be investigated. Further, my study uses these specifications to investigate and pinpoint neurophysiological differences in such syntactically-constrained homonym processing between participants who have only one L1, 2L1s, and bilinguals who are grouped according to the age at which they acquired the L2.

The following subsections present and discuss the ERP components which are anticipated to be relevant for the current study. Subsection 5.1.1 presents the N400 which is related to lexical and semantic processing, and subsection 5.1.3 presents the P600 which is

related to syntactic processing and the garden path effect within sentence processing. Other ERP components, such as the ELAN and the LAN have also been found for sentence processing, but these are not anticipated for the current study and are therefore, for reasons of thoroughness, only briefly mentioned in subsection 5.1.2.

5.1.1 Lexical processing and the N400

The N400 is a negative-going deflection which peaks at approximately 400ms after the onset of a stimulus. It is possibly one of the most commonly investigated language-related components of ERPs and is considered to be a default part of electrophysical responses to potentially meaningful representations (Luck, 2005). The classic example of an N400 effect was found by Kutas and Hillyard (1980) who reported finding N400 responses to words presented at the end of a sentence which were semantically incongruent to the preceding sentential information. They also found that the greater the incongruence, the greater the N400 effect. The sentences they used were of the kind "*The pizza was too hot to eat / drink / cry"*. The target word c*ry* (in the provided example) produced a larger N400 than *drink* which produced a larger N400 than *eat*. The authors suggested that the N400 may reflect a range of processes which guide access to semantic memory, such as the connections of information from the stimulus input to representations from short and long term memory, thereby gleaning meaning from the current context (Kutas & Hillyard, 1980).

Most importantly for the current study, the N400 appears to be sensitive to processing lexical properties, such as word frequency, with lower frequency words eliciting larger amplitude negativities compared to words with higher frequency (Barber, Vergara, & Carreiras, 2004; Van Petten, 1993; Van Petten & Kutas, 1990), and the relationships between items, where related items show reduced N400 amplitudes relative to unrelated items (for a

review, see Kutas & Federmeier, 2011; and Kutas & Van Petten, 1988). The N400 also appears to reflect integration within a context, where reduced N400 amplitudes are found when word pairs match as opposed to a mismatch between primes and predicted targets based on the accrued contextual information (De Long, Urbach, & Kutas, 2005; Van Petten & Kutas, 1990). It is these sensitivities to lexical frequency, lexical relationships, and the integration of target words into accrued context which suggest that ERPs may be the best technique to investigate effects on target words in a cross-modal priming paradigm such as the one in the current study. Indeed, Brown and Hagoort (1993) have suggested that the N400 ERP component occurs late in the processing stream and reflects the integration of a word's meaning into the preceding context.

The location of the priming word within the sentence appears to be crucial for language processing and has been found to affect the amplitude of an elicited N400 component, the amplitude of which has been suggested to be dependent upon the stored representation itself and the retrieval cues provided by the preceding context (Chwilla, Brown, & Hagoort, 1995; Chwilla, Kolk, & Mulder, 2000). With semantic congruence, the amplitude of the N400 has been found to decline progressively according to the ordinal position of the eliciting word within the sentence. This has been argued as a reflection of a build up of contextual information as sentences unfold, since this has not been found in cases where scrambled sentences provide a stream of lexical information, but no opportunity to build a coherent message-level representation (Van Petten & Kutas, 1990). As such, predictable sentences would be expected to elicit smaller N400s and therefore, in the context of the current experiment, congruent (or appropriate) sentence and target word pairings would be expected to elicit smaller N400s than incongruent sentence and target word

pairings. Further, it has been suggested that the interpretation of sentences is immediate, yet computed incrementally (Van Petten, Coulson, Rubin, Plante, & Parks, 1999). This suggests that even in the case where a priming word is presented at the midpoint of a sentence and therefore arguably results in little build up of contextual information, participants can be expected to predict the sentence interpretation as if they had been presented with complete sentences.

ERPS are sensitive to the timing at which electrical activity occurs, but not localization. Even so, recent studies have suggested trends towards generalised areas where the N400 can be found. Further theories do exist as to the underlying regions believed to be involved and supporting these N400 areas, but due to the limitation of the ERP technique in reporting subcortical activity, this dissertation will present and discuss the evidence of evoked potentials at scalp level only. Van Petten and Luka (2006), have reported scalp recorded N400s in areas over a large portion of the temporal lobes, typically with a larger contribution from the left hemisphere than the right hemisphere. On the other hand, Holcomb, Kounios, Anderson, and West (1999) have found the N400 within centroparietal (CP) areas, with an anterior distribution for concrete words (Holcomb, Kounios, Anderson, & West, 1999). Further studies have suggested that the input modality of auditory priming results in a more centralized N400 (Holcomb & Anderson, 1993; McCallum, Farmer, & Pocock, 1984).

5.1.2 Sentence processing and the (E)LAN

Recent studies utilising the ERP methodology to investigate sentence processing have posited that the processing of sentences occurs in three phases which apply consecutively for each word within the given sentence. Each of these three phases is reflected by distinct ERP

components, early left anterior negativities (ELANs), left anterior negativities (LANs) and/or N400s, and finally P600s (for a review, see Steinhauer & Drury, 2012). Although the current study anticipates only finding a P600 effect, each of these effects will be discussed briefly.

The first phase, occurring between 100-300ms post-stimulus onset (Friederici, Pfeifer, & Hahne, 1993; Neville, Nicol, Barss, Forster, & Garrett, 1991), involves initial phrase structure building which is typically based on syntactic word category information. It is during this phase and latency window that first-pass structure identification (van Hell & Tokowicz, 2010), phrase structure violations (Ingram, 2008; Pakulak & Neville, 2010), and violations of word category have been reflected in ELAN effects (Steinhauer & Drury, 2012). An ELAN effect refers to the amplitude difference between the averaged waveforms of two conditions. That is, there is an increased negativity in one condition compared to another condition, and this negative increase is largest over left frontal sites. These negativities are correlated to areas of the left frontal cortex (i.e., Friederici, 2002) and have appeared as the first of a two-part response as they often precede elicited P600s. In a recent study by Pakulak and Neville (2010), phrase structure violations elicited a bilateral and prolonged ELAN with the onset beginning at 100ms, followed by a P600 effect. Similarly, Rossi and colleagues (2005) also found ELANs to precede P600 effects in a word category violation task. ELANs have been found to be similar in distribution and latency to the standard LAN (Friederici, Hahne & Mecklinger, 1996), a negative ERP component typically found being elicited during Phase 2 of sentence processing.

Phase 2 occurs between 300-500ms, and involves morpho-syntactic processing as well as lexical/conceptual-semantic integration. Difficulties in processing morpho-syntactic information such as violations of inflections tend to elicit LANs or N400s. However, lexical-

semantic difficulties typically elicit only N400 components. Disparate from the N400, LANs have been reported to be larger over the left than the right hemisphere, in more anterior loci than N400s, and to be elicited by syntactic processing rather than semantic integration. Tasks involving the processing of grammatical violations (Friederici et al., 1993; Neville et al., 1991), automatic grammatical processing (e.g., Friederici, 2002), and outright syntactic violations have elicited LANs preceding elicited P600s (e.g., Angrilli et al., 2002).

Phase 3 occurs between 500-1000ms or later and involves the integration of information. It is at this stage of processing that anomalies involving sentence structure elicit reanalysis and repair processes which are reflected in P600 components (Osterhout & Holcomb, 19992; Steinhauer & Drury, 2012). The P600 component is presented and discussed more in-depth next.

5.1.3 Sentence processing and the P600

The P600 is a positive-going deflection which is generally found at about 500ms after the perception of a sentence violation and lasts for approximately 500ms. The polarity and latency of this effect caused it to be referred to as the P600, but it has also been known as the Syntactic Positive Shift, or SPS, based on its functional characteristics (Hagoort, Brown, & Groothusen, 1993). For example, Hagoort and colleagues (1993) found that for a violation of the syntactic requirement of number agreement between the grammatical subject of a sentence and its finite verb, a positive-polarity shift is elicited to the word that renders the sentence ungrammatical. The P600 has been observed in the centroparietal areas, typically in correlation with secondary syntactic processes such as syntactic integration (Elston-Guettler & Friederici, 2005), aspects of syntactic complexity (Kaan & Swaab, 2003; Osterhout &

Holcomb, 1992), processes of reanalysis involving garden path sentences (Kaan & Swaab, 2003; Osterhout & Holcomb, 1992), and reanalysis and repair (Friederici, 2004).

The P600 has been reported for more than syntactic violations alone. Kuperberg, Caplan, Sitnikova, Eddy, and Holcomb (2006) reported a P600 elicited by morphosyntactic violations as in the phrase, "*For breakfast the boys would only eats*...." as well as a smaller P600 effect found for thematic role animacy violations such as in the phrase, "*For breakfast the eggs would only eat*". As unexpected as these findings were since they were of a different calibre of violations, they also unexpectedly found that the two effects had similar latency, morphology, and scalp distribution. The authors point out that these patterns of ERP effects evoked by verbs such as "*eat*" in the above example, were unexpected and at odds with the literature at the time. Not only did the semantic violations fail to evoke an N400 effect, but they also produced a robust P600 effect, which has been associated with violations of syntax. In a subsequent study, Kuperberg, Kreher, Sitnikova, Caplan, and Holcomb (2007) similarly reported a broadly distributed P600 to the verb "*plant*" when participants were presented with the phrase, "*At breakfast the eggs would plant*....". Furthermore, the P600 has also been reported for cases involving the reversal of expected pragmatic plausibility relations (Kolk, Chwilla, van Herten, & Oor, 2003; van Herten, Kolk, & Chwilla, 2005), with the word "*hunted*" eliciting a P600 in the phrase, "*The fox that hunted the poachers stalked through the woods*". These findings have been explained as suggesting that some degree of semantic association between a verb and it argument or arguments may trigger a P600 effect. Further, when these semantic associations are particularly close (such as *eggs* and *eat*), they may semantically prime the critical verb leading to an attenuation of the N400.

This leads to the question of whether a P600 can be evoked by such semantic violations between the verb and its argument(s) without the existence of a semantic

association between them. Indeed, some studies have reported that non-associated verb and argument pairing violations fail to evoke a P600 effect. This was investigated in a two-part study by Kim and Osterhout (2005) who found a significant P600 effect to verbs such as "*devouring*" in sentences such as "*The hearty meals were devouring.....*" in Experiment 1. In Experiment 2 however, they did not find the same effect for sentences of exactly the same structure as in Experiment 1, but with no semantic association between the critical verbs and their preceding arguments, such as "*The dusty tabletops were devouring….*" In these sentences, verbs such as "*devouring*" evoked an N400 effect rather than a P600 effect relative to non-violated verbs (Kim & Osterhout, 2005). Another two-part study by van Herten, Chwilla, and Kolk (2006) found similar results involving sentences which had been manipulated as to the degree of semantic association between the critical verb and one of its arguments. They found that verbs such as "*pruned*" in sentences such as "*John saw that the elephants the trees pruned…*" evoked a P600 effect as "*pruned*" is semantically associated with the argument "*trees*". However, verbs such as "*caressed*" in the same sentence "*John saw that the elephants the trees caressed…*", failed to evoke a P600 effect as caressed is not semantically associated with any of the arguments in the sentence. Together, these two studies suggest that a P600 is evoked by semantic violations between the verb and its argument(s) only where there is a semantic associative relationship between the verb and its argument(s).

Such evidence of the P600 effect in the absence of syntactic violations has led some researchers to posit that the P600 reflects a process of revision and reanalysis, such as is found with garden path sentences. Garden path sentences are known as such because the parser follows one interpretation of a sentence, only to realise later that this initial interpretation was wrong and he or she must backtrack to properly interpret the sentence's

actual meaning. Literally, the initial part of the sentence leads them “down the garden path”. Such sentences which must be parsed in a different way than first expected, have revealed P600 effects even though the sentences contain no outright grammatical errors (Gouvea, Phillips, Kazanina, & Poeppel, 2009). For example, Osterhout and Holcomb (1992) found P600s elicited by the word *to* in sentences such as “*The broker persuaded to sell the stock was tall”.* In this particular case, "*persuaded*" is initially interpreted as the main verb of the sentence (as in, "*the broker persuaded me to sell the stock*"), consequently, the word *to* causes the reader to re-analyze the sentence and reinterpret the meaning of the sentence to be "*the broker who was persuaded to sell the stock was tall*" (Coulson, King & Kutas, 1998). The process of revision typically occurs in cases where a sentence contains structural errors which cause the parser to try to rescue the interpretation of the sentence. This process of reanalysis is also likely to occur in cases of garden path sentences which cause the parser to rearrange the structure of the sentence in order to interpret it correctly (Friederici, 2002; Kaan & Swaab, 2003). On the other hand, others have suggested that the P600 may simply reflect the time and effort it takes a parser to build up the interpretable structure of a sentence (Hagoort, 2003), or the process of creating or destroying syntactic structure (Gouvea et al., 2009). Yet another suggestion is that the P600 is a reflection of a parser encountering improbable stimuli. As Coulson, King, and Kutas (1998) point out, ungrammatical sentences are relatively rare in natural speech, and so they suggest that the P600 effect may not be a linguistic response, but simply a reflection of the subject's surprise upon encountering an unexpected stimulus (Coulson, King, & Kutas, 1998).

5.2 Hypotheses

Study 2 of this over-arching study investigating the effects of an L2 on homonym processing in the L1, employs the novel complementary combination of a cross-modal lexical decision task with ERP measures. As ERPs are being measured to a visual target (lexical) item, which is appropriately related, inappropriately related, or completely unrelated to a (noun or verb) homonym or a control word, lexical effects are expected. These lexical effects are anticipated to be reflected in N400-like deflections occurring around 400ms post-stimulus onset. Secondly, as the sentence frame is being presented auditorily, sentence processing effects are also anticipated due to the relationship between the target lexical item and the word in the priming sentence frame. These lexical effects are anticipated to be reflected in P600-like deflections occurring at the later stages of processing, and only in the cases of unexpected stimuli due to the accrued contextual information. I do not anticipate finding evidence of ELAN or LAN effects as the current study does not require phrase structure identification nor does it contain any word category or phrase structure violations. The specific details of what is expected to be found in the current study are explained next.

Given the input modality of an auditory prime followed by a visual target word, both being concrete words, I expect a more centralized N400 with an anterior distribution (Holcomb, Kounios, Anderson, & West, 1999). I anticipate N400s for all items included in the current study, but the amplitude will be modulated for certain conditions based on the predicted interpretations of the sentence frame including the prime. It has been suggested that the interpretation of sentences is immediate, yet computed incrementally (Van Petten, Coulson, Rubin, Plante, & Parks, 1999), building up contextual information. As Van Petten and colleagues (1999) suggest, participants can be expected to predict the sentence interpretation as if they had been presented with complete sentences. As such, participants

should automatically predict the appropriate reading of the homonym based on the sentential information, which should consequently reveal larger N400 effects for those target words which do not match the predicted sentence interpretation compared to those that do match the predicted interpretation. That is, sentences presented with the predicted congruent (or appropriate) target word would be expected to elicit smaller N400s than incongruent sentence and target word pairings. Further, due to the sensitivity to semantic incongruity found by Kutas and Hillyard (1980), I anticipate the proposed study to reveal an N400 effect corresponding to the relationship of appropriateness of the target word in relation to the priming word embedded within identical sentential frames. For example, upon presentation of the auditorily-presented sentence "*Often times, the news would puzzle John for no apparent reason*", the pairing of the priming homonym *puzzle* with the inappropriately-related target word *assemble* would be expected to elicit the greatest N400 because the inappropriately-related target word violates the predicted interpretation of the sentence. It is the incorrect reading of the homonym based on the sentence it is presented with. The unrelated target word *sprinkle* would be expected to elicit a greater N400 than the appropriately-related target word *mystify* because there is no relationship between the priming homonym and the unrelated target word. As the unrelated target word is not related to an incorrect interpretation of the priming sentence, but is more neutral, it is anticipated to elicit a smaller N400 effect compared to the inappropriately-related target word *assemble*. The appropriately-related target word *mystify* is anticipated to elicit the smallest N400 effect as the target word correctly matches and is related to the predicted interpretation.

As ERP evidence appears to support findings of lexical frequency effects (Barber, Vergara, & Carreiras, 2004; Van Petten, 1993; Van Petten, & Kutas, 1990), I anticipate

finding N400 evidence of frequency effects in the current study. In particular for the semantic condition, there is no context to aid the disambiguation of the homonym and consequently both readings are appropriate (the sentences are ambiguous as to which reading is intended), I anticipate finding frequency effects for the subordinate reading compared to the dominant reading. That is, I anticipate a greater N400 effect in the unconstrained appropriately-related and subordinate condition relative to the unconstrained appropriately-related and dominant condition.

In contrast, I anticipate finding evidence that the sentential context reduces the N400 effect for the lower frequency items in the syntactically-constrained condition or equalises them to comparable amplitudes as to the higher frequency items of the same condition due to recent ERP evidence of sentential context reducing the N400 effect for low-frequency items (Kutas, Van Petten, & Kluender, 2006). These findings would support the Reordered Access Model (Duffy, 1988), as the subordinate reading is expected to be facilitated to the same level as the dominant frequency reading in the syntactically-constrained homonym condition.

Recent evidence of speakers' sensitivity to the unexpected (Coulson, King, & Kutas, 1998; Kolk, Chwilla, van Herten, & Oor, 2003; van Herten, Kolk, & Chwilla, 2005) is motivation for anticipating evidence of larger positivities corresponding to a reanalysis of the presentation of the inappropriately-related visual target word with the preceding priming stimulus. In effect, I anticipate a "garden path effect" even though the sentences contain no syntactic violations. That is, as previous studies have suggested that syntactic context effects are due to special-purpose strategies such as predicting the target word (Tanenhaus & Donnenworth-Nolan, 1984), it is plausible that a P600 effect might be found for the syntactically-constrained inappropriate and dominant condition (syndom) compared to the

unconstrained appropriate and dominant condition (semdom) since the syntactically-constrained inappropriate and dominant condition (syndom) is a combination of a sentential frame priming for the syntactically-constrained appropriate and subordinate homonym (such as *Richard had a shed in the back of the garden*) followed by the target word which is related to the syntactically-constrained inappropriate and dominant homonym (such as *skin*). In this way, in the case where the target word (*skin*) is inappropriately-related to the priming homonym (*a shed*), the combination is expected to elicit a surprise reaction and/or an automatic attempt to reanalyse the already-presented sentential frame. In essence, a P600 effect is expected to correspond to the experimental conditions containing syntactic priming compared to semantic priming and non-priming conditions, with a greater P600 for the inappropriately-related target words within the syntactic priming conditions. This would also support the Reordered Access Model (Duffy et al., 1988) since the prior disambiguating context increases the availability of the appropriate meaning without influencing the alternative.

The results of the behavioural study, Study 1, found that the three bilingual groups differed from the monolingual group in a number of ways. All three bilingual groups showed RT evidence of a heightened sensitivity to syntactic priming whereas the monolinguals did not. The simultaneous bilinguals were more accurate overall relative to the results of the monolingual group, the early and late bilingual groups appeared to be more aware of the inappropriate relationship between target and prime in the syntactically-constrained inappropriately-related and dominant condition as their RT results were slower in this condition compared to the other groups. Further, the late bilingual group showed the strongest effect of lexical dominance facilitating their responses in the semantically neutral

and syntactically-unconstrained sentences. Based on these findings, I anticipate all three groups of bilingual speakers to differ from the monolinguals in ERP measures as a reflection of the RT and accuracy differences found in Study 1. These neurophysiological differences are anticipated to support the idea postulated in Study 1 that processing differences are being found due to L2 effects on the L1, and these differences are postulated as being due to an increased metalinguistic awareness.

In the current neurophysiological measures, I anticipate the bilinguals will show evidence of processing strategies such as a heightened sensitivity to surface cues (priming) compared to the monolinguals. Evidence of this is anticipated to be reflected in greater P600 effects for the target word that is inappropriately-related to the priming homonym given the sentential context, but is appropriately related to the dominant reading for the bilinguals. Due to the early and late bilinguals having acquired the L2 through the L1, they are anticipated to show evidence of an increased metalinguistic awareness of the L1 due to acquiring the L2 after the L1 had been acquired. Such evidence is anticipated to be found as they follow the priming frame and access only the one appropriate reading of the homonym. Consequently, when presented with the inappropriately-related target word (syntactically-constrained inappropriately-related and dominant), they will realize that it is inappropriate and will show a greater N400 effect, which is also anticipated to support the slower RT results found in Study 1. Then, at the later stages of lexical processing suggested by Elston-Guettler and Friederici (2005), the early and late bilinguals may attempt to reassess or reanalyze what they have just heard and have stored in memory. This reanalysis will be reflected in a positivity for the syntactically-constrained inappropriately-related and dominant condition but not syntactically-constrained appropriately-related and subordinate. Comparatively, I

anticipate the monolinguals to show a small overall N400 effect for lexical processing in the relatedness conditions, but no P600 effect. I anticipate a reduced N400 for this condition as the priming effect of the syntactically-constrained and appropriately-related target word condition raises the activation of the subordinate reading to the same level of activation as the dominant reading, thereby resulting in a reduced N400 for both homonyms in the syntactic condition. Based on the findings of Study 1, I do not anticipate monolinguals to show a positive effect because they do not appear to be as sensitive to the surface cues as the bilingual groups. They are consequently not anticipated to show a garden path effect when presented with the inappropriately-related target word in the syntactically-constrained inappropriately-related and dominant target word condition as there will be no attempt to reanalyze the sentential frame.

5.3 Method

5.3.1 Participants

Data from 39 L1 English L2 French speaking participants (27 females) were included (5 of these participants did 2 separate lists of the experiment) for the ERP analysis. There were 10 monolinguals (13 lists analysed), 7 simultaneous bilinguals (8 lists analysed), 12 sets of early bilingual data, and 10 late bilinguals (11 lists analysed) included in the analysis. For details regarding the language groups, please refer back to Chapter 3 subsection 3.4.1 Participants, and for information on the individual participants, please see Appendix 6: Participant Information – Study 2.

5.3.2 Design

The complimentary and novel combination of cross-modal lexical decision task and ERP methodology of Study 2 allowed me to investigate the effects of syntactic context on

the associations between the homonym (the prime) and its relevant meanings (the target) while simultaneously recording the ongoing brain waves of each participant. For full details of the design of the experiment, please see Chapter 3 section 3.4 Overall Experimental Design and Procedures.

5.3.3 Materials: Experimental Stimuli

The experimental stimuli presented to each participant were the same as presented and discussed above in Chapter 3: Methodology, section 3.4.2 Stimuli, except for a few revisions. For a complete list of stimuli and frequencies used in each condition, please see Appendices 1-4 representing the different conditions. The revisions which were made to the stimuli for Study 2 are as follows. There were two typos found within the visual questions which were corrected, from "*Is it probably that Lindsay will tie the green laces later?*" to "*Is it probable that Lindsay will tie the green laces later?*" The following visual target words occurred twice and thus one of the targets was therefore changed to a different word: *baseball* to *sport*; *computer* to *machine*; *animal* to *cheese*. Six visually-presented questions were shortened because they were found to be too long for the screen display – the content of the questions were not altered.

5.3.4 Procedure

The procedure for the ERP experiment is as outlined in Chapter 4, section 4.2.4 Procedure, along with the following details which are unique to the ERP version. Before beginning the experiment in the sound-proofed ERP room of the Brain and Language lab of the University of Ottawa, each participant was seated in a comfortable chair of the main room of the BALL lab, where he or she was prepared to be fitted with a close-fitting ERP cap. The cap used was a 64 channel Compumedics Quick Cap, Model C190, in either small

or medium size. Six additional electrodes were also used. Four of these six electrodes were placed above and below the left eye (to measure vertical eye movement) and one each on the left and right temple (to measure horizontal eye movements), The remaining two additional electrodes were placed on each mastoid (the jutting bone behind the ear) as a baseline comparison for external electrical activity being recorded. Each participant's head was measured and fitted with the most appropriately-fitting ERP cap, such that the cap fit snugly but not so tight as to render the participant uncomfortable. Measurements were taken to ensure that the central electrode within the midline was aligned with the exact top of the participant's head by measuring from the nasion to the inion and from ear to ear. All electrodes were then gently topped-up or filled with a saline-based gel specifically designed for the purpose of efficiently measuring low amplitude electrical activity at the surface of the skin and scalp. Wooden dowels were gently used to remove hair and air from the gel inside each electrode, thus decreasing impedances of the measures. Impedances were 8 kOhms or lower. The participant was then positioned comfortably about 3 feet in front of a 15 inch monitor screen in the sound attenuated booth of the BALL lab with a button box on top of a cushioned lap desk on their lap. The Compumedics Quick Cap was connected to a SynAmps 2 amplifier which was connected to a Pentium 4 CPU. Participants received instructions for the experiment and prepared to complete a short trial run of the cross-modal lexical decision task. Participants were instructed to sit still in a relaxed position and not to blink or move unnecessarily, but if they needed to blink, they were to try to blink simultaneously with the presentation of the fixation point preceding each set of experimental stimuli. After all instructions were given and understood, the participants were then fitted with disposable ear bud headphones, STIM 10 Ohm insert earphones, which delivered the auditory stimuli while blocking out any possible environmental noises. Presentation software (Version 12.2,

www.neurobs.com) presented all stimuli and recorded the button press responses of the participants. A short practice set consisting of six trial sentences preceded the actual experimental trials. The participants began the experiment by pressing the blue button once on the button box at the ready prompt. The "*" symbol fixation point also served as a blink point for this experiment. Responses and response times were recorded by the program Presentation while the program Scan 4.3 simultaneously recorded the continuous electrical activity of the participant's brain as they carried out the cross-model lexical decision task. The visual presentation of target stimuli was time-locked within the continuous wave recording for later ERP analysis. There were four self-regulated breaks within the body of the on-line experiment, during which participants were instructed to relax, look away from the monitor, and blink as much as they would like. Participants were prohibited from interaction of any kind unless they decided not to complete the experiment or in the case of computer or equipment malfunction. One participant interrupted the experiment to request an enlargement of the stimuli font size, and two participants interrupted the practice run to request a reduction of volume. With each of these interruptions, a new task was presented and none of the interrupted trials were used in the analysis of the experiment. The cloze tasks testing English and French proficiency were completed after the cross-model lexical decision task.

5.3.5 Analyses

The adaptive artefact correction model by Sherg, Ille, Bornfleth, & Berg (2002) was used for off-line correction of eye movement using the BESA software program (Version 5.3, MEGIS Software, Munich, Germany). The recordings were scanned as a first-pass visual inspection of the entire file to observe any noisy channels or problems. Averaging of the

recordings was based on 1650ms epochs from 150ms pre-stimulus onset until 1500ms post-stimulus onset. All averages were filtered with a 30Hz, 6db/oct slope low-pass filter enabled for scan and averaging. Individual participants' data were analyzed separately for artefacts. Artefact rejection was conducted using fixed thresholds on the BESA software; amplitude 115 to 120 gradient of 75. In addition, each file was scanned and any channel with a mean amplitude range over 75 was marked as bad and rejected in an attempt to include 100% of conditions in the averaging. Electrode sites FP1, FP2, FPz, AF3, and AF4 were rejected for all participants and were therefore not included in any analyses. The following further electrodes were excluded due to noise: the number reported beside the electrode name is the percentage of participants who had this electrode excluded. For example, 41 of the 44 data files included for analysis had FP1 excluded from the analysis due to noise: FP1 (93.181%), FP2 (93.18%), FPz (79.5445%), P8 (2.27%), T7 (4.54%), TP8 (2.27%), O1 (4.54%), AF4 (49.99%), AF3 (49.99%), F7 (29.54%), F6 (11.36%), Oz (2.278%), C3 (2.27%), T8(4.54%), TP7(6.82%), M1(9.09%), PO5(2.27%), T8(2.27%), CB2(2.27%) F3(4.54%), F8(18.18%), FT8(2.27%), PO8(9.09%), P2(4.54%), FC2(2.27%), M2(9.09%), PO7(2.27%), FT7(2.27%), F5(9.09%), F1(2.27%).

Grand averages were conducted for each condition for each language group as an initial assessment. These are presented in Figures in the respective subsections for each analysis within section 5.4 Results. Statistical analyses were carried out using the SPSS programme. The results of all statistical analyses are presented in the respective subsections for conditions in section 5.4 Results.

Averaged waves for each condition were then exported from BESA into Excel for averaging 33 different 50ms time windows from 150ms pre-stimulus onset to 1500ms post stimulus onset. For analyses of these different time windows, the averaged data per subject,

per condition, per time window were exported from Excel into SPSS. Only significant results and trends with a *p* value of 0.1 or lower are reported. A Greenhouse-Geisser correction for sphericity was used when there was more than one degree of freedom in the numerator. Details and results of the analyses carried out for each factor are presented in their respective results sections.

5.3.5.1 Relatedness and frequency conditions analyses – Negative effects

A visual evaluation of negativities in the grand averages for the relatedness and frequency conditions of the subordinate, dominant, and unrelated target words in both the syntactic and semantic conditions (synsub, syndom, synunr, semsub, semdom, semunr) was carried out. This was an examination of observable differences in amplitude, scalp distribution, or latency between the conditions for the four language groups (monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals). The results of which are presented as images along with the grand averaged waveforms for these conditions which are presented in the series Figure 17-24 in section 5.4.2.1 of the Results section.

Two analyses were carried out for the relatedness and frequency conditions analyses, the factors for which are outlined below in section 5.4.2.1. Figure 25 within section 5.4.2.1 illustrates the approximate location of electrodes (indicated in light grey) used in the analyses.

5.3.5.2 Priming conditions analyses – Negative effects

A visual evaluation of negativities in the grand averages for the syntactic priming conditions (synsub – synsub control, syndom – syndom control) and semantic priming conditions (semsub – semsub control, semdom – semdom control) examined observable differences in amplitude, scalp distribution, or latency between the conditions for the four

language groups (monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals). The results of which are presented as images along with the grand averaged waveforms for these priming conditions which are presented in the series Figure 26-33 in section 5.4.3.1 of the Results section.

A series of 4-way ANOVA analyses were carried out for the Priming conditions analyses. The factors were condition (four levels: synsub, synsub control, syndom, syndom control), laterality (seven levels), anteriority (six levels), and language group (four levels). These were conducted for each 50ms time window of interest. These analyses are described below in section 5.4.3.1 and Figure 34 in section 5.4.3.1 illustrates the approximate location of electrodes (indicated in light grey) used in the analysis.

5.3.5.3 Priming condition analyses – Positive effects

A visual evaluation of positivities in the grand averages for the inappropriately-related syntactic priming conditions (syndom – syndom control) examined observable differences in amplitude, scalp distribution, or latency between these two conditions for the four language groups (monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals). The results of which are presented along with the grand averaged waveforms for these conditions which are presented in the series Figure 35-42 in section 5.4.5.1 of the Results section.

A series of 4-way ANOVA analyses were carried out for the positive effects found in the priming conditions analyses. The factors were condition (two levels: syndom, syndom control), laterality (seven levels), anteriority (six levels), and language group (four levels). These were conducted for two 50ms time windows of interest. These analyses are described

below in section 5.4.5.1 and Figure 43 in section 5.4.5.1 illustrates the approximate location of electrodes (indicated in light grey) used in the analysis.

5.4 Results

5.4.1 Outline of Results Section

In each subsection of this section, the averaged ERP waveforms by language group and by condition are provided as figures. In all of these figures, negative is plotted up. The coloured label at the top of each figure identifies the condition being analysed in the same colour as the EEG wave in each ERP representation. Where applicable, an arrow indicates the peak of any found effects. The latency of any found effects is indicated at the bottom right of each of the ERP representations, while electrode sites are indicated at the top left of each ERP representation. The observations and analyses of effects found for the conditions of relatedness and frequency are presented and discussed in section 5.4.2, while section 5.4.3 presents and discusses the same for the priming conditions. These are followed by a brief summary of all negative effects found. The observations and analyses of positive effects found for the inappropriately-related condition are presented and discussed in section 5.4.5. Lastly, section 5.5 presents an overall discussion of the findings of Study 2. The results of Study 1 and Study 2 will be discussed together in the next Chapter, Chapter Six: General Discussion and Conclusions.

5.4.2 Relatedness and Frequency Conditions

5.4.2.1 Observations and analyses of relatedness and frequency conditions

ERPs analysed here for the syntactic conditions included those to the target words which are appropriately-related to the subordinate reading of the syntactically-constrained priming homonym (synsub), the target words which are inappropriately-related to the

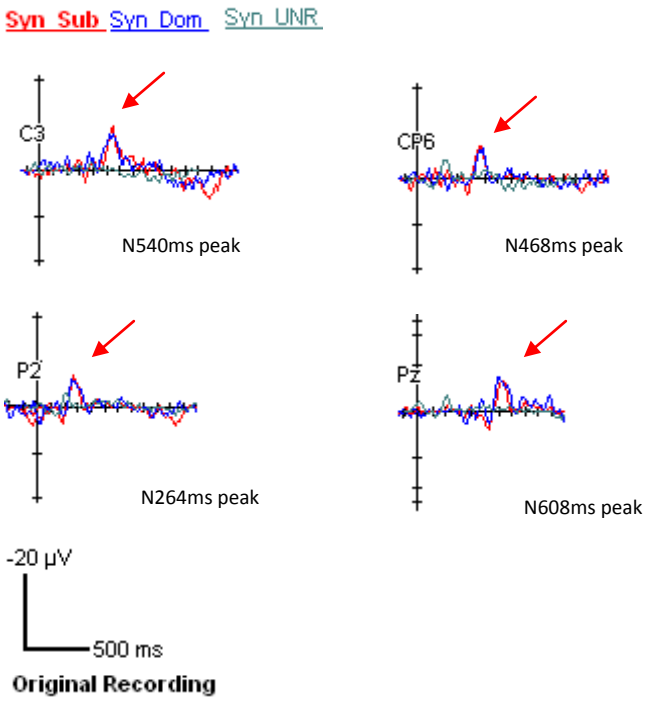
subordinate reading of the syntactically-constrained priming homonym, but are appropriately-related to the dominant reading of the homonym (syndom), and the target words which are unrelated to the syntactically-constrained priming homonym (synunr). The semantic conditions included in these analyses are the target words which are appropriately-related to the subordinate reading of the unconstrained priming homonym (semsub), the target words which are appropriately-related to the dominant reading of the unconstrained priming homonym (semdom), and the target words which are unrelated to the unconstrained priming homonym (semunr).

A visual inspection of the grand averages reveals all language groups showing negativities being elicited in similar locations on the scalp (C3, CP6, Pz, and P2) with slightly different times of elicitation (222ms – 864ms). These can be seen in Figures 17 through 24 which also show the grand averaged wave forms for all electrodes and all conditions with priming homonyms for each language group.

As can be seen in Figure 17 and 18 for the monolingual group, both homonym conditions (syntactic and semantic) and the subordinate and dominant conditions (synsub, syndom, semsub, semdom) elicited similar responses. The latencies of these negative-going deflections varied, with an early time window showing a negative peak at 264ms post-stimulus onset at electrode P2, and later time windows showing negative peaks at 468ms at CP6, at 540ms at C3, and 608ms at Pz. The unrelated conditions did not appear to elicit the same N400-like effects compared to the related conditions, suggesting that the unrelated conditions were easier to process compared to the primed and related conditions. However, there do appear to be early negativities for the unrelated conditions at CP6 for both the syntactic and semantic conditions, and a small negativity at Pz for the syntactic condition.

These particular effects are shown below in Figure 17: Monolingual Negativities, with both the syntactic homonym conditions shown above the semantic and in Figure 18: Monolingual Grand Averages for Relatedness and Frequency Conditions.

SYNTACTIC RELATEDNESS AND FREQUENCY CONDITIONS



SEMANTIC RELATEDNESS AND FREQUENCY CONDITIONS

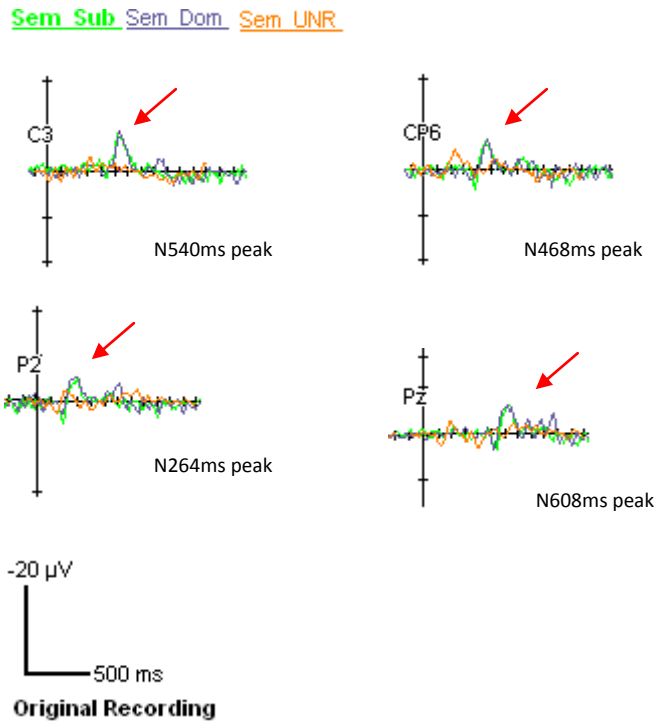


Figure 17: Monolingual Negativities for Relatedness and Frequency Conditions

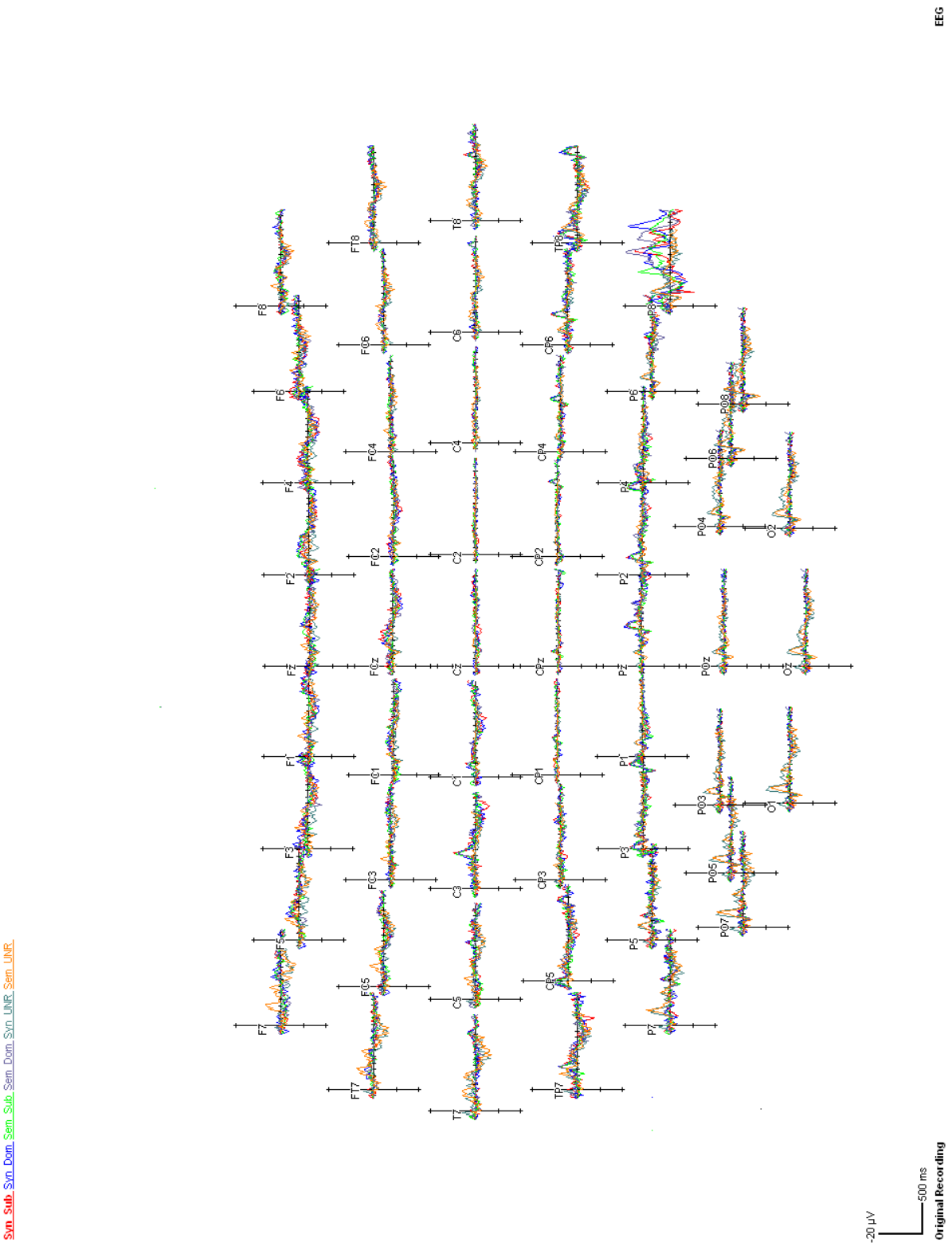
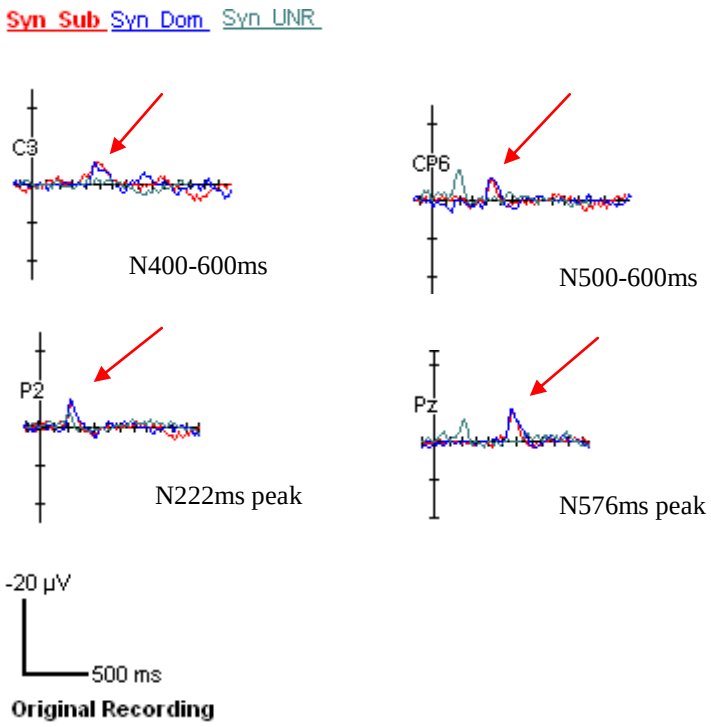


Figure 18: Monolingual Grand Averages for Relatedness and Frequency Conditions

As can be seen in Figure 19 and Figure 20, the simultaneous bilingual group also shows both homonym conditions and the subordinate and dominant conditions eliciting similar responses as more negative-going deflections compared to the unrelated conditions. The latencies of these negative effects varied, with an early time window showing a negative peak 222ms post-stimulus onset at electrode P2, and later negative peaks occurring at 445ms at electrode CP6, at 507ms at C3, and at 576ms at Pz. The unrelated condition did not appear to elicit large negativities, although again there is evidence of early negativities at CP6 for both homonym conditions and a small negativity at Pz for the syntactic condition. These negative effects are shown more clearly next in Figure 19: Simultaneous Bilingual Negativities and in Figure 20: Simultaneous Bilingual Grand Averages for Relatedness and Frequency Conditions.

SYNTACTIC RELATEDNESS AND FREQUENCY CONDITIONS



SEMANTIC RELATEDNESS AND FREQUENCY CONDITIONS

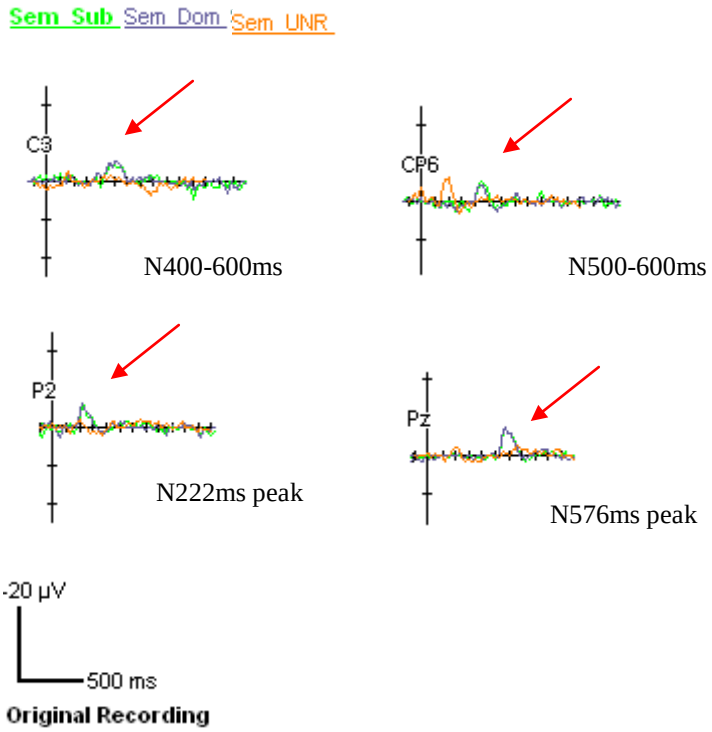


Figure 19: Simultaneous Bilingual Negativities for Relatedness and Frequency Conditions

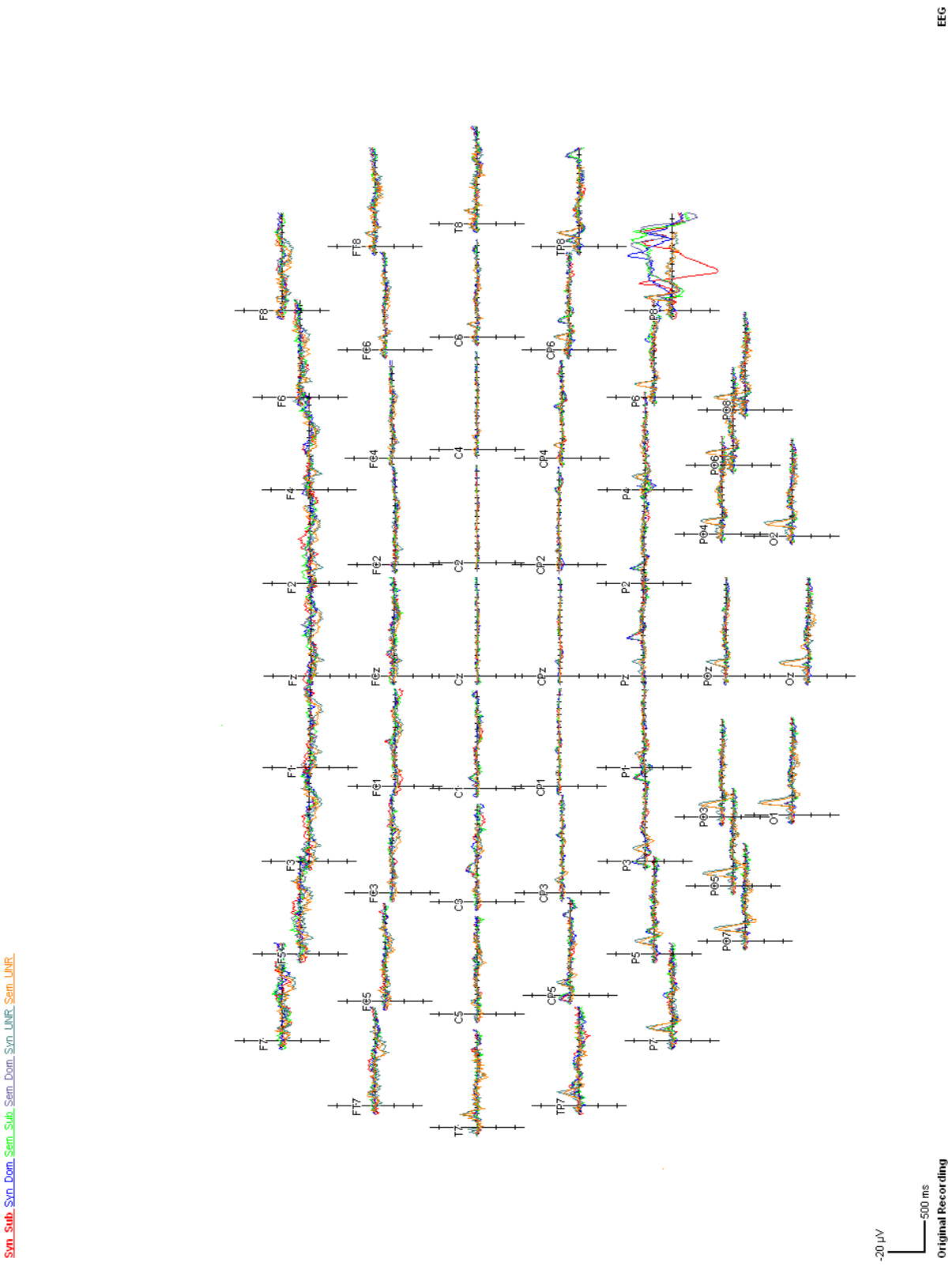
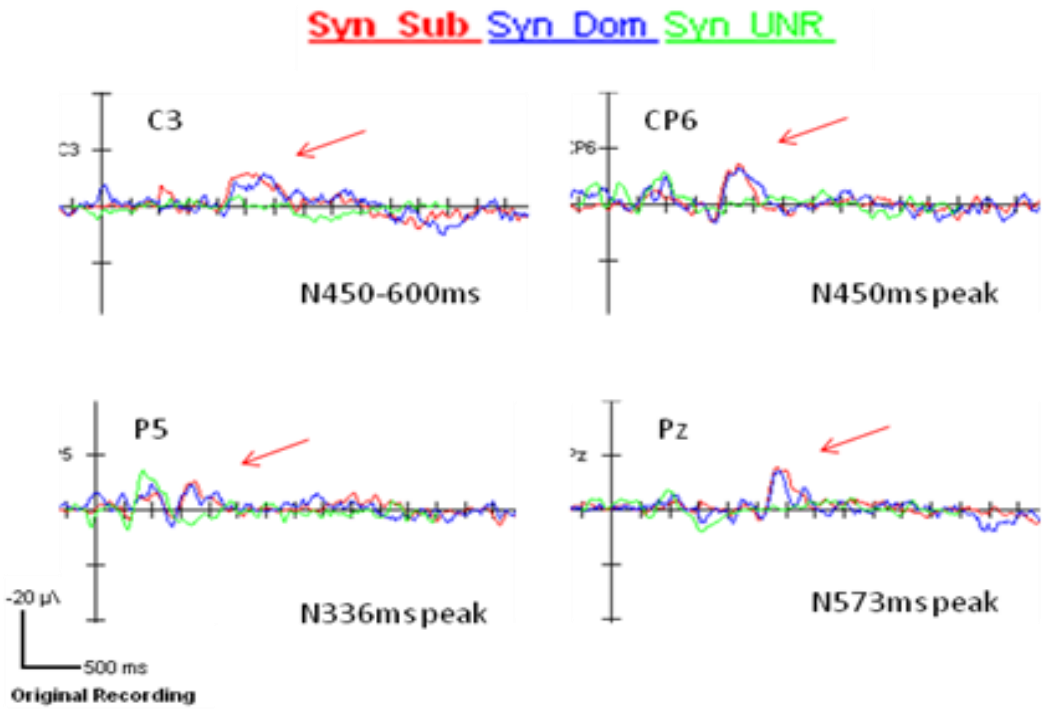


Figure 20: Simultaneous Bilingual Grand Averages for Relatedness and Frequency Conditions

As can be seen in Figure 21 and Figure 22, the early bilingual group show negative-going responses with what appears to be a little more widespread distribution and slightly different times of elicitation compared to the monolinguals. The semantic condition appears to elicit a slightly larger negativity compared to the syntactic condition. The syntactic conditions elicited varying latencies of negative responses, although there were no early time windows of negative-going deflections found. There was a negative peak at 336ms post-stimulus onset at electrode P5, at 450ms at electrode CP6, there was a window of negativity at 450-600ms at electrode C3, and a peak at 573ms at Pz. The unrelated conditions did not appear to elicit any negativity compared to the related syntactic conditions.

The semantic conditions similarly elicited varying latencies of negative responses, with an early time window negative peak occurring at 227ms post-stimulus onset at electrode P2. There were later time windows of negative responses peaking at 352ms at electrode P5, at 438ms at CP6, there was a window of negativity at 450-600ms at C3, and a negative peak at 590ms at Pz. Similarly to the syntactic condition, the unrelated condition did not elicit any negativity. These effects are shown below in Figure 21: Early Bilingual Negativities and in Figure 22: Early Bilingual Grand Averages for Relatedness and Frequency Conditions

SYNTACTIC RELATEDNESS AND FREQUENCY CONDITIONS



SEMANTIC RELATEDNESS AND FREQUENCY CONDITIONS

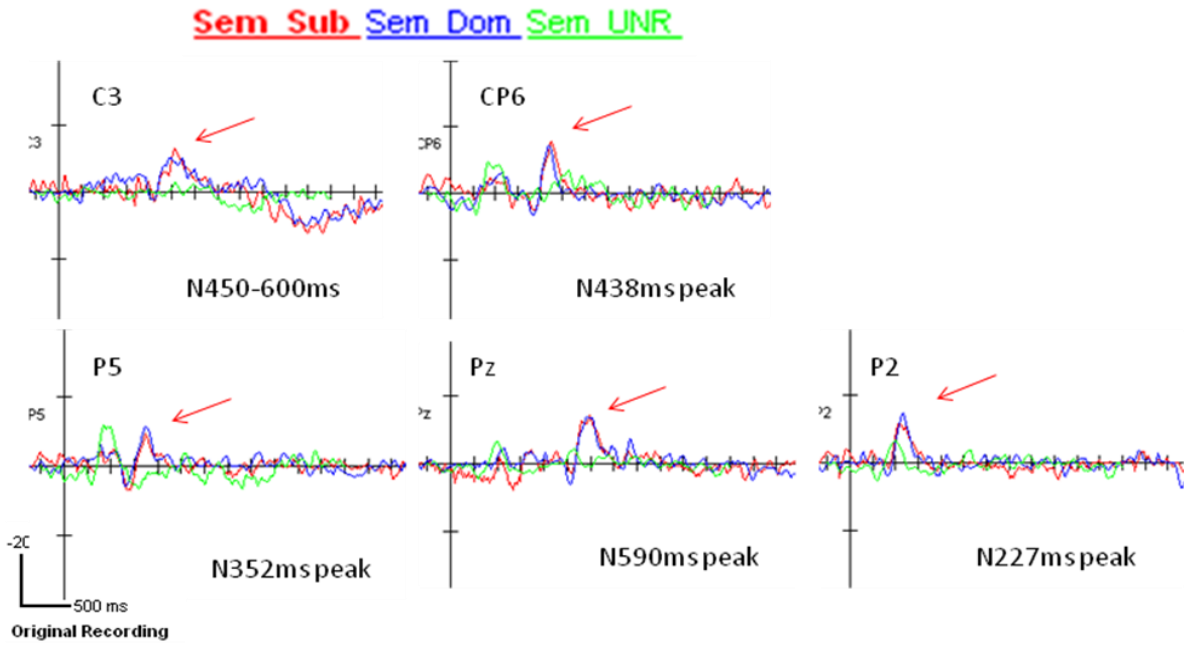


Figure 21: Early Bilingual Negativities for Relatedness and Frequency Conditions

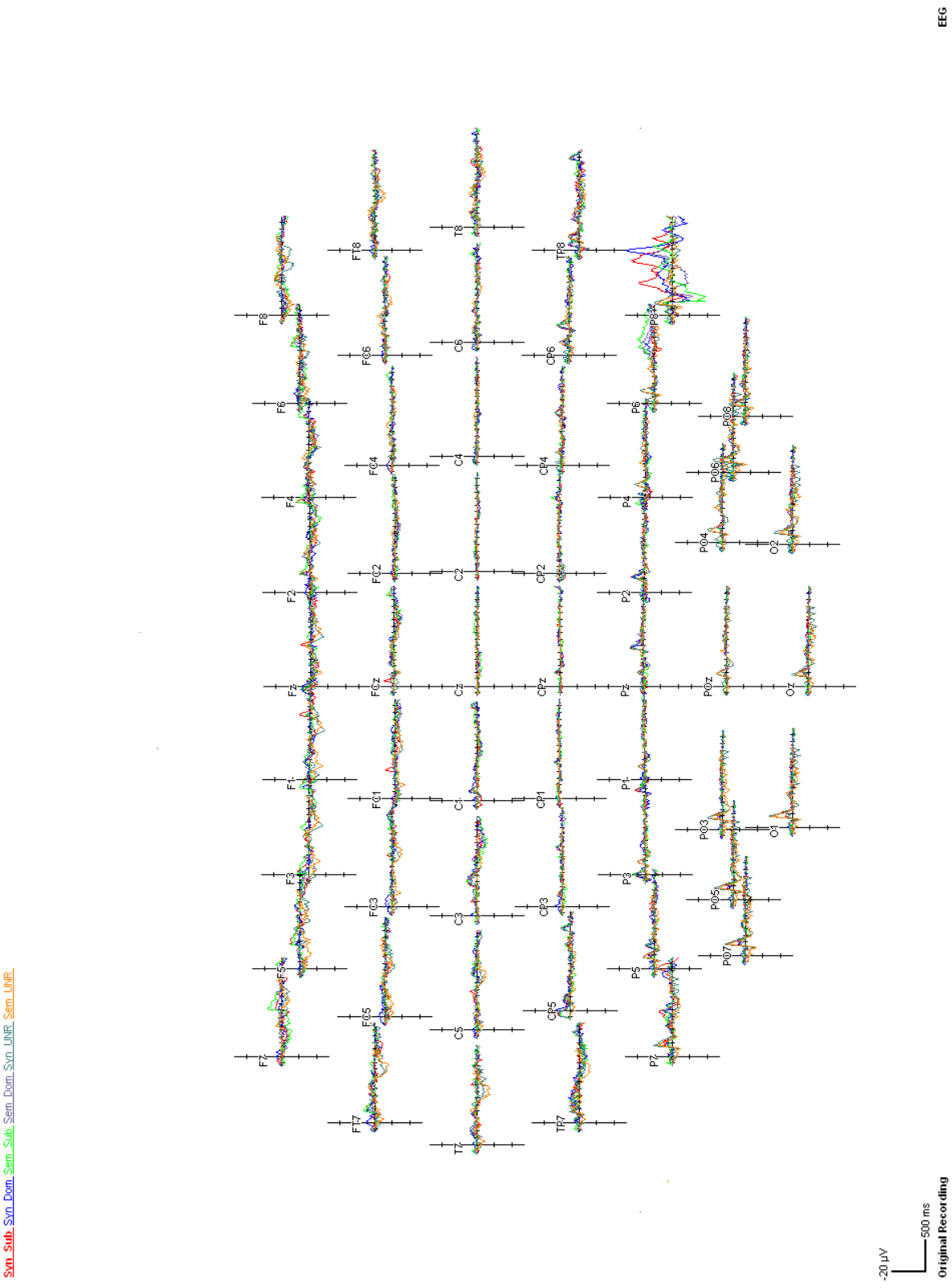
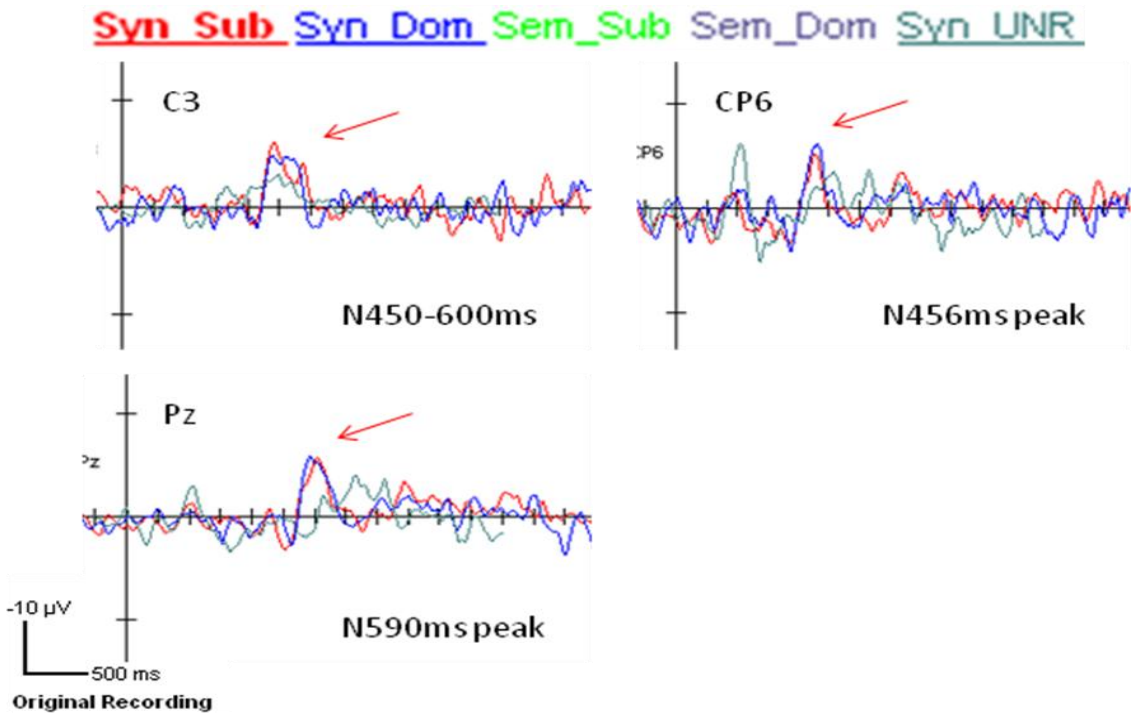


Figure 22: Early Bilingual Grand Averages for Relatedness and Frequency Conditions

As can be seen in Figure 23 and Figure 24, for the late bilingual group, the homonym conditions and the subordinate and dominant conditions elicited similar negativities. The negativities appear to have slightly different times of elicitation compared to the other groups. For the syntactic condition, the latencies of the negative-going deflections varied, with a negative peak found at 456ms post-stimulus onset at electrode CP6, a window of negativity at 450-600ms at electrode C3, and a negative peak at 590ms at Pz. The unrelated condition did not appear to elicit any negativity.

The latencies of the negative responses for the semantic condition were very similar to those in the syntactic condition, with a negative peak at 453ms post-stimulus onset at electrode CP6, a window of negativity at 450-590ms at C3, and a peak at 600ms at Pz. Similarly to the syntactic condition, the unrelated condition did not appear to elicit any negativity. These effects are shown below in Figure 23: Late Bilingual Negativities with the results of the syntactic condition shown above the results of the semantic condition and in Figure 24: Late Bilingual Grand Averages for Relatedness and Frequency Conditions.

SYNTACTIC RELATEDNESS AND FREQUENCY CONDITIONS



SEMANTIC RELATEDNESS AND FREQUENCY CONDITIONS

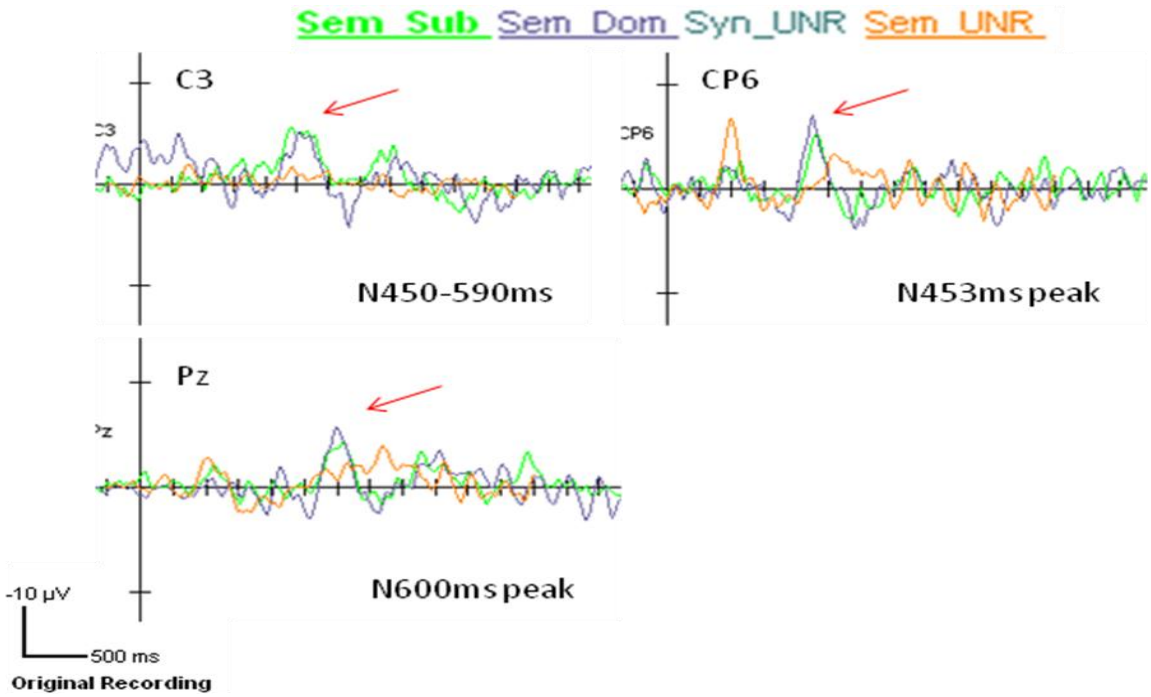


Figure 23: Late Bilingual Negativities for Relatedness and Frequency Conditions

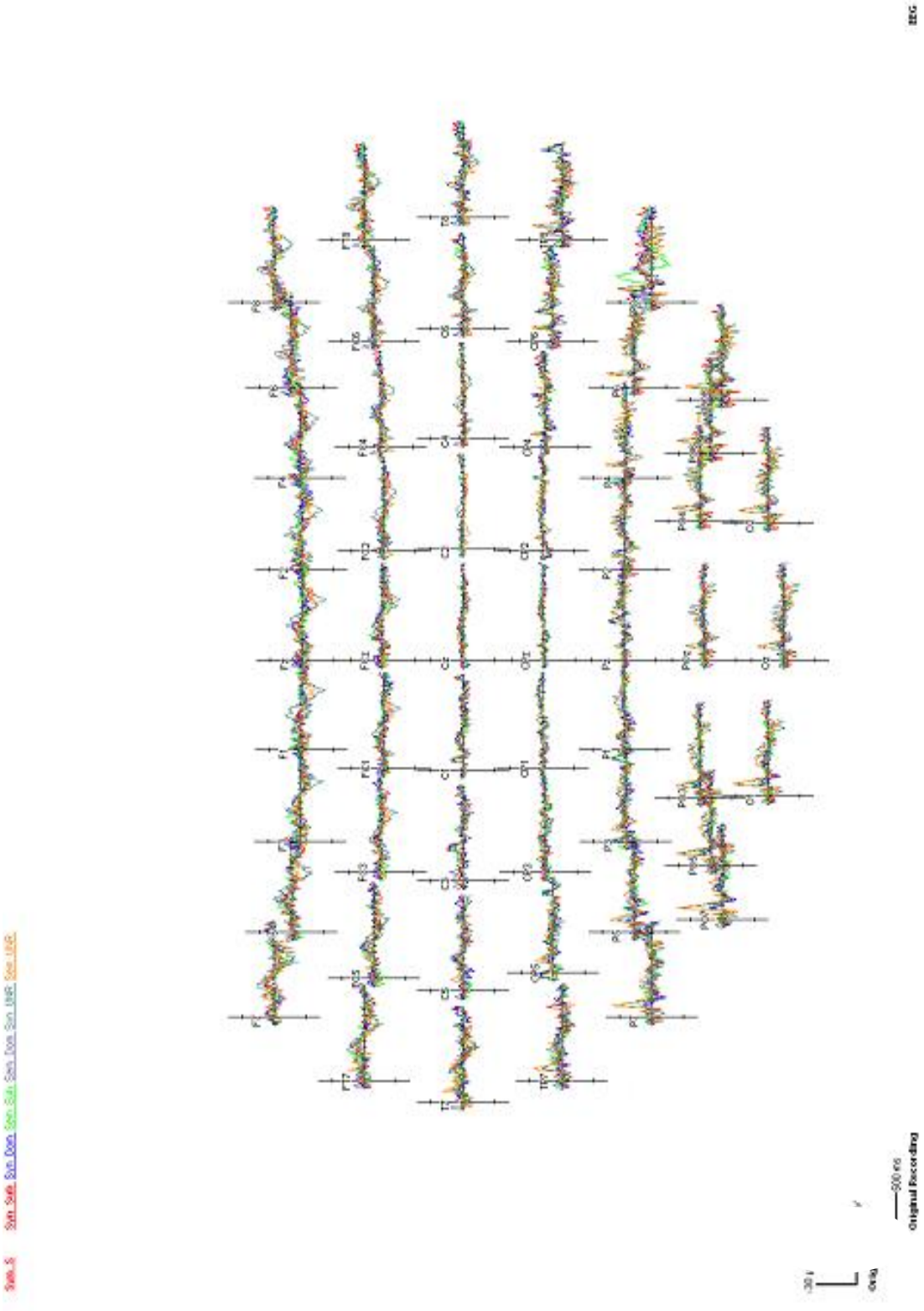


Figure 24: Late Bilingual Grand Averages for Relatedness and Frequency Conditions

Statistical analyses were then performed in order to determine whether any of the differences that were apparent upon visual inspection of the averaged waves could be confirmed statistically. The results of the statistical analyses are reported next.

Statistical Analysis 1

The factors for Statistical Analysis 1 were condition (six levels: synsub, syndom, synunr, semsub, semdom, semunr), laterality (seven levels from left to right), anteriority (six levels from front to back), and language group (four levels: monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals). Figure 25 below illustrates the approximate location of electrodes used in the experiment and light grey circles indicate electrodes chosen to examine the distribution of effects using Statistical Analysis 1. This analysis was run on seven 50ms time windows, that of 200-250ms and between 400-700ms as exploratory statistical analyses. No significant effects were found in these analyses. Below I present results of Statistical Analysis 2 for time windows where significant effects occurred and for the time windows mentioned above in section 5.4.2.1 where differences were found in the visual inspection.

Statistical Analysis 2

A further subset of central and posterior electrodes was selected for Statistical Analysis 2. These electrodes were analysed for the same six levels of condition, laterality (five levels), and anteriority (three levels). The reduced subset of electrodes used for Statistical Analysis 2 is circled in Figure 25 below. ANOVAs were performed for the following time windows expected to show changes in amplitude over time: 350-400ms, 400-450ms, 450-500ms, 500-550ms, 550-600ms, 600-650ms, and 650-700ms.

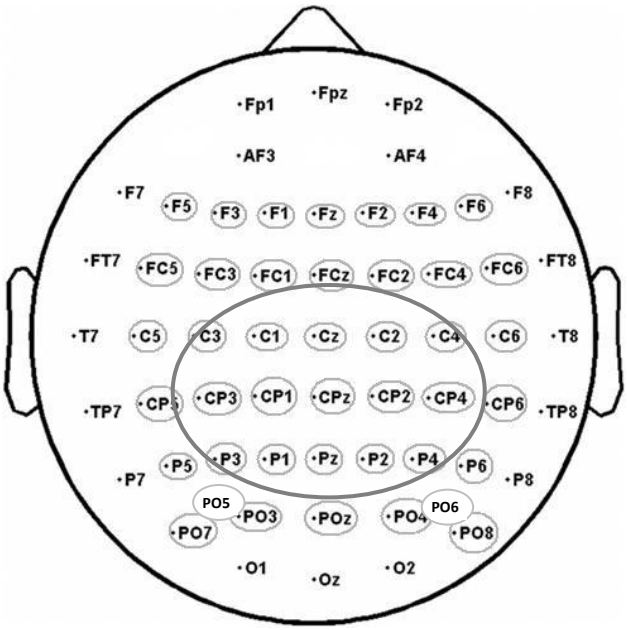


Figure 25: Electrodes Included for Statistical Analysis 1 and the Circled Subset of Electrodes for Statistical Analysis 2

Although there were main effects of anteriority and laterality for most time windows, for the purpose of this dissertation, I will only report the main effects found to correspond to the given conditions and interactions with condition and/or group. These are presented as *p*-values only in Table 4 and are discussed more in-depth following the table. There were no main effects of language group found for any time window.

Table 4: Results of Relatedness and Frequency Conditions Statistical Analysis 2

factors / time windows	anteriority x LG	laterality x LG	condition x anteriority x LG	condition x laterality	condition x laterality x LG	condition x anteriority x laterality	condition x ant. x lat. x LG
350-400ms			(p=.046)		(p<.001)	(p=.011)	(p=.011)
400-450ms	(p=.063)		(p=.011)	(p=.071)		(p=.020)	(p=.002)
450-500ms	(p=.076)		(p=.002)		(p=.046)	(p=.067)	(p=.002)
500-550ms		(p=.020)	(p=.006)			(p=.017)	(p=.002)
550-600ms		(p=.017)			(p=.064)	(p=.004)	(p=.004)
600-650ms		(p=.028)				(p=.005)	(p=.006)
650-700ms						(p=.026)	(p=.006)

For all time windows, there were significant 3-way interactions found between condition, anteriority, and laterality (although this interaction was only a trend toward significance for the time window 450-500ms (p=.067)), suggesting that the related and unrelated, and subordinate and dominant conditions were being processed differently overall and that these differences were found at anterior and lateral scalp distributions. This 3-way interaction was further found to differ across language groups in a significant 4-way interaction found between condition, anteriority, laterality, and language group for all time windows.

There was a trend towards a significant interaction between anteriority and language group found between 400ms-500ms, which was further found to differ significantly by condition as a 3-way interaction was found between condition, anteriority, and language group between the time windows 350-550ms, suggesting that not only did the groups differ in their anterior locations of processing during these time windows, but they differed by condition within a slightly longer time frame. An interaction between laterality and language group was found at later time windows occurring between500-650ms, whereas condition appears to interact with laterality and language group at earlier time windows, as there are significant 3-way interactions found at the time windows 350-400ms (p<.001) and 450-500ms (p=.046). The fact that the language groups differed in anteriority at earlier time windows and in laterality at later time windows suggests that the language groups differed from each other in the locations of their scalp recorded responses, and these differences were confined to the earlier and later stages of processing.

A separate 1-way ANOVA on each condition testing the factor language group in order to investigate the 4-way interaction found between condition, anteriority, laterality, and

language group found significant differences between language groups for each condition at the electrode sites presented above which were observed to show negative effects. These main effects are presented in Table 5 below and are discussed here. Table 5 also includes the results of post-hoc comparison analyses comparing the language groups at each time window for each condition. The language groups have been abbreviated to fit within the table, please see the Abbreviations section (page 8) for any needed clarification. There were no significant effects found by language group for the syntactically-constrained dominant condition (syndom) and for the unrelated target word in the semantic condition (semunr).

At the combined early time windows 350-450ms, there were consistent main effects for the two subordinate conditions, both syntactic and semantic, and post-hoc comparisons found most of the four language groups differing from each other. The only groups not found to differ from each other at these time windows were the monolinguals and the early bilinguals, suggesting that these two groups processed the subordinate conditions similarly. The later time windows show a main effect in the syntactically-constrained unrelated condition and post-hoc comparisons reveal the monolinguals differing from the late bilinguals consistently, and from the other two groups in the latest time window, that of 600-650ms post-stimulus onset. This suggests that the monolinguals were consistently processing the syntactically-constrained unrelated condition differently from the bilinguals, conceivably due to this group not being as sensitive to the priming sentential cues compared to the bilingual groups.

Table 5: Results of 1-way ANOVA Examining Condition by LG

condition / time	synsub	synunr	semsub	semdom
350-400ms	P2: (p=.075) Post-Hoc comparison: LG2* vs. LG3 (p=.094)		C3: (p=.026 Post-Hoc comparison: LG4* vs. LG1 (p=.073), LG4* vs. LG2: (p=.058)	P5: (p=.008 Post-Hoc comparison: LG3* vs. LG4 (p=.008)
400-450ms	P2: (p=.065) Post-Hoc comparison: LG1 vs. LG2* (p=.063) CP6: (p=.041)	Pz: (p=.083)	C3: (p=.060)	
450-500ms		Pz: (p=.082) Post-Hoc comparison: LG1 vs. LG4* (p=.092)		P2: (p=.087)
500-550ms		C3: (p=.031) Post-Hoc comparison: LG1 vs. LG4* (p=.022)		
550-600ms		Pz: (p=.082) Post-Hoc comparison: LG1 vs. LG4* (p=.034).		
600-650ms		C3: (p=.002) Post-Hoc comparison: LG1 vs. LG2* (p=.031), LG1 vs. LG3* (p=.002), LG1 vs. LG4* (p=.074).		

"*" indicates the group with the greater negative effect

To further investigate the results of the 1-way ANOVA reported above, planned pair-wise comparisons at electrode site C3 for 13 time windows between 350-1000ms were performed for each language group. The results are presented for each language group in Tables 6-9 and discussed below.

Table 6 below shows the unrelated conditions being processed mainly during the earlier time windows and being elicited at all three electrode sites for the monolinguals. These differences support the observable early N400-like effects for the unrelated target words in both the syntactic and semantic conditions even though these are visible at electrode sites CP6 and Pz, not at C3 which the table suggests. In comparison, the subordinate and dominant conditions appear to elicit only the parietal electrodes at later time

windows. This suggests that the relationships between primes and targets may have been harder to process and occurred during earlier stages of processing, whereas lexical frequency effects appear more locally in parietal sites (at the level of the scalp) at later stages of processing. These results suggest that the monolinguals were processing the related conditions differently compared to the unrelated conditions. The lack of difference found in the subordinate and dominant conditions between the syntactic and semantic conditions suggests that the monolinguals did not process the inappropriately-related target word any differently compared to the appropriate target words. This suggests that this group does not appear to be sensitive to the syntactic contextual information constraining the meaning of the priming homonym toward the subordinate target word rather than the dominant.

Table 6: Monolingual Responses at Electrodes C3, Pz, and P2 - a Planned Comparison

LG1	synsub-syndom	synsub-synunr	syndom-synunr	semsub-semdom	semsub-semunr	semdom-semunr
350-400						P2(p=.067)
400-450		C3 (p=.014) Pz (p=.063) P2 (p=.021			C3 (p=.091)	C3 (p=.080)
450-500		Pz (p=.017)		P2(p=.070)		Pz(p=.047) P2(p=.025)
500-550		C3 (p=.093), Pz (p=.055), P2 (p=.062)				
550-600		Pz (p=.053),		Pz (p=.081), P2 (p=.034)		Pz(p=.088), P2 (p=.072)
600-650		Pz (p=.067)	C3 (p=.016)			
650-700		Pz (p=.092)			C3 (p=.078)	
700-750					C3 (p=.030)	
750-800	Pz (p=.051), P2 (p=.058)					C3 (p=.005)
800-850				P2 (p=.083)		C3 (p=.024)
850-900	Pz (p=.073),			Pz (p=.053), P2 (p=.067)		
900-950						
950-1000	P2 (p=.016)	Pz (p=.090), P2 (p=.081)		P2 (p=.084)		

For the simultaneous bilinguals, Table 7 below shows that the electrode site P2 does not appear to reveal significant differences for any of the conditions compared to C3 and Pz. The subordinate and dominant conditions appear to show differences at both of these sites (at scalp level) and at both early and late time windows. The electrode site C3 reveals differences mainly during the earlier time windows between 350-700ms post-stimulus onset, whereas the parietal electrode shows differences between time windows 550-700ms and between the 800-1000ms time windows, suggesting that these sites may reflect different stages of processing. The fact that a comparison of subordinate reading and dominant reading in the syntactic condition (synsub and syndom) shows the most significant differences in time windows and electrode sites suggests that not only was this group sensitive to the lexical frequency differences between the subordinate and dominant target items, but they were also sensitive to the appropriateness of the relationship between the priming homonym and the target word, shown by the longer and later processing time of the syntactic condition compared to the semantic condition.

Table 7: Simultaneous Bilingual Responses at Electrodes C3, Pz, and P2 - a Planned Comparison

LG2	synsub-syndom	synsub-synunr	syndom-synunr	semsub-semdom	semsub-semunr	semdom-semunr
350-400	C3(*p*=.064)	C3(*p*=.067)		C3(*p*=.027)		
400-450	C3(*p*=.024)			C3(*p*=.065)	C3(*p*=.023)	
450-500	Pz(*p*=.090)		C3(*p*=.049)	C3(*p*=.092)	C3(*p*=.017)	
500-550	C3(*p*=.055)					
550-600	C3(*p*=.065)			Pz(*p*=.055)		Pz (*P*=.040)
600-650	C3(*p*=.041)			Pz(*p*=.036)		Pz (*P*=.052)
650-700	C3(*p*=.021)			Pz(*p*=.097)	C3(*p*=.075)	Pz (*P*=.009)
700-750						
750-800						
800-850						Pz(*p*=.042)
850-900	Pz (*p*=.059)					
900-950	Pz (*p*=.020) **P2** (*p*=.083)				C3(*p*=.014)	
950-1000	Pz (*p*=.085)					

Table 8 illustrates the early bilingual group revealing the most differences for the semantic conditions, in particular for the subordinate target word compared to the unrelated. This suggests that for this group, the unconstrained and therefore ambiguous nature of the priming homonym was harder to process compared to the syntactically-constrained homonyms. As the subordinate items in the semantic condition appear to show differences at all three electrode sites fairly consistently from 400ms post-stimulus onset until 950ms, this suggests that the unconstrained and low frequency items were harder to process. In comparison, the syntactically-constrained conditions do not show such differences, and the dominant conditions in both the syntactic and semantic conditions likewise.

Table 8: Early Bilingual Responses at Electrodes C3, Pz, and P2 - a Planned Comparison

LG3	synsub-syndom	synsub-synunr	syndom-synunr	semsub-semdom	semsub-semunr	semdom-semunr
350-400		P2 (*p*=.081)		C3(*p*=.075)		C3(*p*=.004)
400-450					C3(*p*=.079)	C3(*p*=.045)
450-500					C3(*p*=.087)	C3(*p*=.033)
500-550					Pz (*p*=.092) P2(*p*=.084)	C3(*p*=.037) P2 (*p*=.087)
550-600						C3(*p*=.059)
600-650					Pz(*p*=.068) P2 (*P*=.059)	
650-700				Pz(*p*=.012)	Pz (*P*=.004) P2 (*p*=.024)	
700-750				Pz(*p*=.013)	Pz (*P*=.004) P2 (*p*=.004)	
750-800	C3(*p*=.040)			Pz(*p*=.037)	Pz (*P*=.026) P2 (*p*=.038)	
800-850		Pz(*p*=.063) P2(*p*=.033)		Pz(*p*=.035)	Pz (*P*=.033) P2(*p*=.091)	C3(*p*=.031)
850-900		P2(*p*=.035)		C3(*p*=.023)	Pz (*P*=.048) P2 (*P*=.075)	
900-950		P2(*p*=.059)		Pz(*p*=.043)	Pz (*P*=.039) P2 (*P*=.019)	
950-1000						

For the late bilinguals, Table 9 shows very little variation, with no differences found at all in the syntactically-constrained subordinate versus dominant condition (synsub – syndom). The semantic conditions appear to show the most wide-spread differences as all

three electrode sites are found sporadically between the time windows 350-800ms post-stimulus onset. This suggests that the unconstrained and ambiguous conditions were harder to process compared to the syntactically-constrained conditions. The central electrode site C3 (at scalp level) appears to show activity between the earlier time windows, those of 350-500ms, suggesting that lexical frequency processing was occurring during this earlier stage of processing. The lack of effects found in the comparison between the subordinate and dominant target words within the syntactic condition suggests any reanalysis that might be occurring between these two conditions is not revealed at these three electrode sites for this group.

Table 9: Late Bilingual Responses at Electrodes C3, Pz, and P2 - a Planned Comparison

LG3	synsub-syndom	synsub-synunr	syndom-synunr	semsub-semdom	semsub-semunr	semdom-semunr
350-400				C3(p=.005)		
400-450				C3(p=.057)	Pz (p=.099)	
450-500				C3(p=.093)		
500-550						
550-600		P2 (p=.079)				C3(p=.081)
600-650			Pz (p=.039)		Pz (p=.082)	C3(p=.013)
650-700			Pz (p=.081)			
700-750			Pz (p=.062)		Pz (p=.048) P2 (p=.064)	
750-800				C3(p=.066)	P2 (p=.069)	
800-850						
850-900			P2 (p=.075)			
900-950						
950-1000						

5.4.2.2 Discussion of negativities for relatedness and frequency

The observable N400-like effects for the related conditions compared to the unrelated conditions indicate that all the language groups were processing the relationships between the priming homonyms and the target words. These observations are supported by the 4-way

interaction that was found between condition, laterality, anteriority, and language group for all time windows within Statistical Analysis 2. Similar amplitudes and latencies of N400-like effects can be seen in the images for the monolinguals (in Figure 6 above) and the simultaneous bilinguals (in Figure 7 above) for the subordinate and dominant readings of both homonym conditions. This suggests that these two language groups were processing these relationships equally, at least at this initial stage of homonym processing. For the monolinguals, the planned comparisons between conditions showed differences in waves between the subordinate and dominant syntactic condition within late time windows, between 750-900ms, whereas the subordinate and dominant readings in the semantic condition first appear at 450-500ms. This suggests that this group may not be as sensitive to the priming condition or the inappropriateness of the target word to the priming homonym in the syntactic condition, at least not at the earlier stages of homonym processing. At the later stages of processing, there is no difference between the comparisons of the subordinate and dominant conditions of the syntactic and semantic conditions, which further support the idea that the monolinguals may not be showing effects of priming, but rather, these late effects may reflect lexical frequency effects.

The simultaneous bilinguals, on the other hand, show greater differences over many time windows for the subordinate syntactic condition compared to the dominant syntactic condition. These differences further vary by electrode site, and this variance corresponds to differences found between the subordinate and dominant readings in the semantic conditions. These correlations may indicate the different processes of lexical frequency and syntactic priming effects. Indeed, it may be that the differences found at the earlier time windows for the electrode site C3 may reflect lexical frequency effects, while the differences found at the later time windows for the electrode site Pz may reflect syntactic priming effects and lexical

integration with sentential context, which is hypothesized to occur at later stages of processing compared to frequency effects.

The early bilinguals show the most differences for the semantic conditions, which suggest that the unconstrained and ambiguous target words were harder to process. Similarly to the simultaneous bilinguals, this group also appears to show lexical frequency effects at the earlier time windows for the electrode site C3, and the later time windows reveal differences at the parietal electrode sites. This group further shows a greater difference for the subordinate conditions, which suggests that the low frequency words elicited the most processing activity.

The late bilinguals, on the other hand, show very few differences overall. However, the differences that were found also occur in the semantic conditions, suggesting that the unconstrained and ambiguous conditions resulted in more processing activity compared to the syntactically-constrained conditions. For this group as well, the early time windows reveal differences found at the electrode site C3, conceivably reflecting lexical frequency effects in the unconstrained semantic conditions. This is the only group to not show any differences in the comparison of the subordinate and dominant target words in the syntactic condition, which suggests that if this group is undergoing the hypothesized process of reanalysis for the inappropriately-related target word in relation to the priming homonym, this reanalysis is not being reflected at these particular electrode sites.

Indeed, the significant interactions found between condition, anteriority, laterality, and language group suggest that each language group may be processing some conditions differently in terms of scalp distribution and latency. One of these conditions may be of priming which is analysed and discussed next.

5.4.3 Priming Conditions

5.4.3.1 Observations and analyses of negativities for the priming conditions

The conditions included in these analyses involve only the syntactic conditions: the target words which are appropriately-related to the subordinate reading of the syntactically-constrained priming homonym (synsub), the target words which are appropriately-related to the subordinate reading of the syntactically-constrained priming homonym, but the sentence frame contains no priming homonym (synsub control), the target words which are inappropriately-related to the subordinate reading of the syntactically-constrained priming homonym, but are appropriately-related to the dominant reading of the homonym (syndom), and the target words which are inappropriately-related to the subordinate reading of the syntactically-constrained priming homonym, but are appropriately-related to the dominant reading of the homonym, but the sentence frame contains no priming homonym (syndom control).

A visual inspection of the grand averages reveals all language groups again showing negativities being elicited in similar locations on the scalp (electrode sites C3, CP6, CP4, P2, and Pz)with slightly different times of elicitation (200ms to 800ms) for all four conditions, that of synsub, synsubcontrol, syndom, and syndomcontrol. However, the monolinguals and the early bilinguals show reduced amplitudes of negative-going deflections in the frontal regions for all conditions compared to the simultaneous bilinguals and the late bilinguals. These can be seen in Figures 26 through 33 which show the subset of these electrodes more clearly as well as the grand averaged wave forms for all electrodes for the syntactic priming conditions (synsub and syndom) and the non-priming control conditions (synsubcontrol and syndomcontrol) for each language group. These are shown and discussed next by language group.

As can be seen in Figure 26, the N400-like effects for all the priming conditions were similar for the monolinguals. This was unexpected as the control conditions did not contain any homonyms within the sentential frame and were therefore not expected to elicit any N400-like effect. There is a difference in the electrode sites that show negative effects for the priming conditions compared to the relatedness and frequency conditions. The priming conditions reveal an N400-like effect at electrode site CP4 as well as CP6, suggesting that this may be a region of interest to be further analysed in the analysis section.

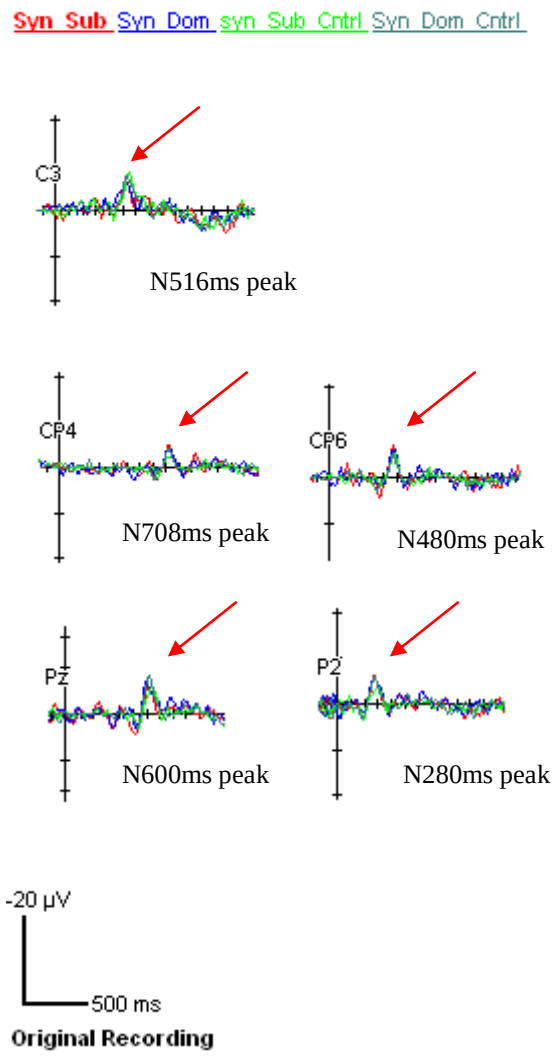


Figure 26: Monolingual Negativities for the Priming Conditions

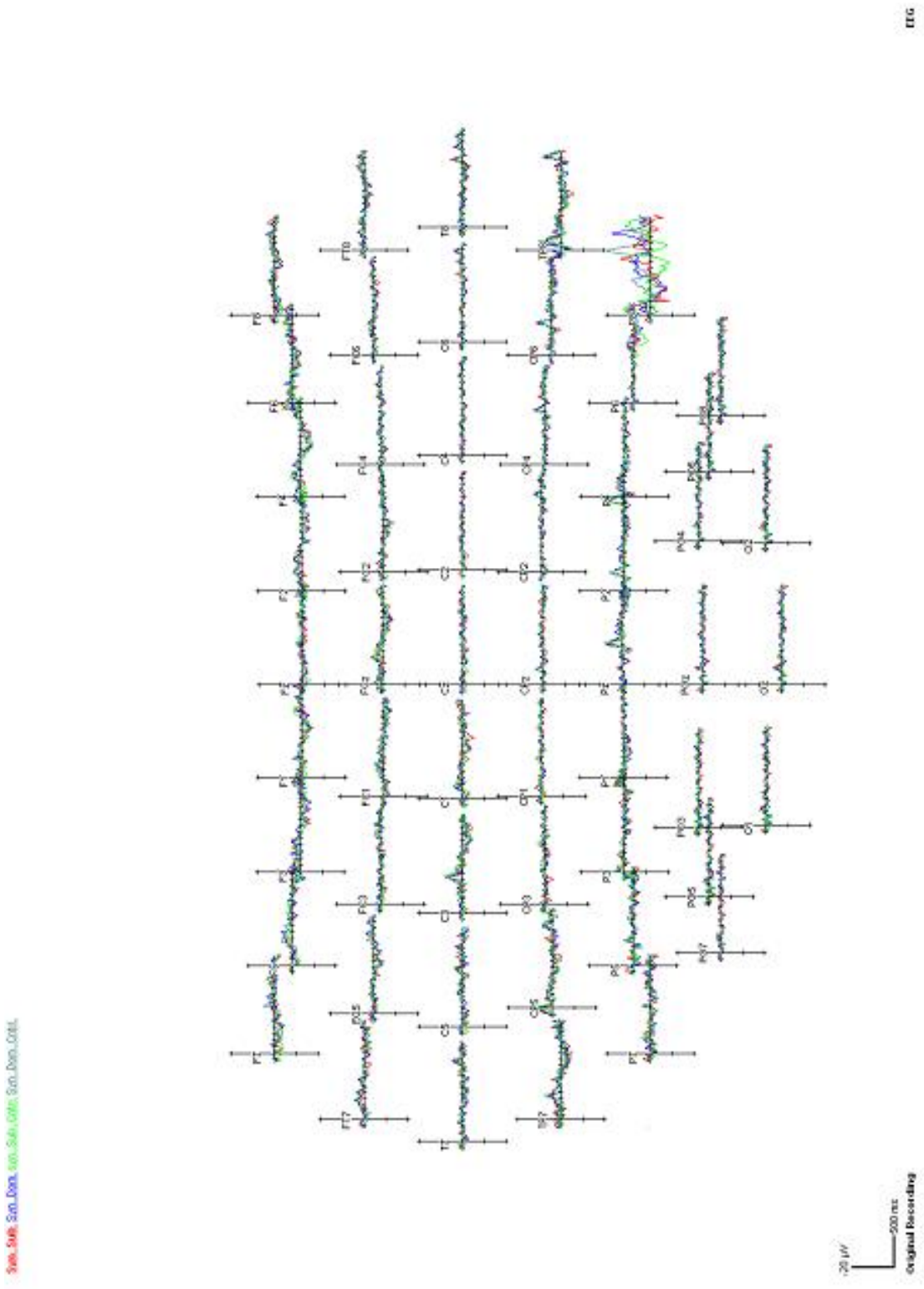


Figure 27: Monolingual Responses in the Syntactic Priming Conditions

Figure 28 shows the N400-like effects for all the priming conditions for the simultaneous bilinguals. This group shows negative effects at electrode site CP4 and CP6, whereas this effect was not found for the relatedness and frequency conditions. The amplitudes for the simultaneous bilinguals appear to be reduced compared to the monolinguals. Electrode site C3 differs from the monolinguals with a slightly earlier-going wave and evidence of a second negative peak found occurring between 800-900ms post-stimulus onset for the target word that is inappropriately related to the priming homonym (but is appropriately related to the dominant reading). This suggests that this group may have undergone a process of reanalysis for the inappropriately-related target word, consequently suggesting that the simultaneous bilinguals may have been more sensitive to the sentential bias compared to the monolinguals who do not show this second late negative peak.

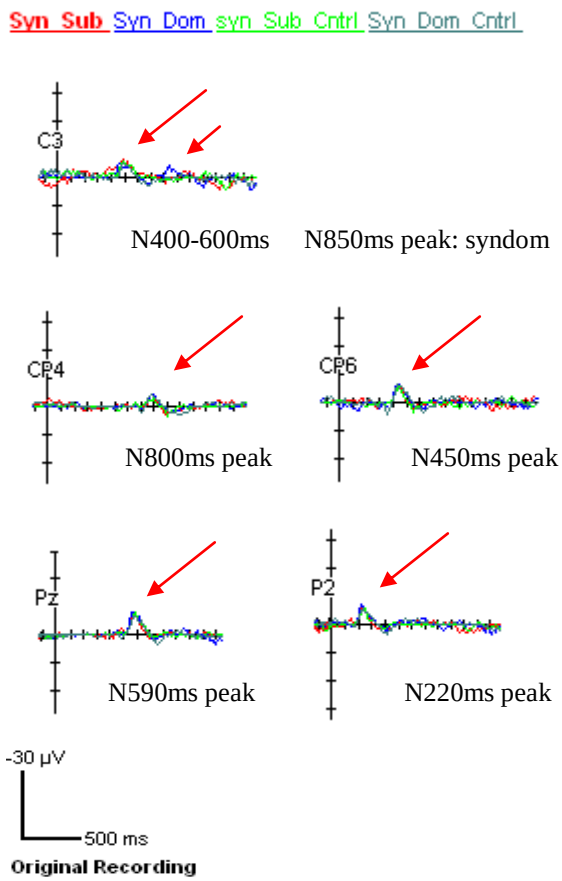


Figure 28: Simultaneous Bilingual Negativities for the Priming Conditions

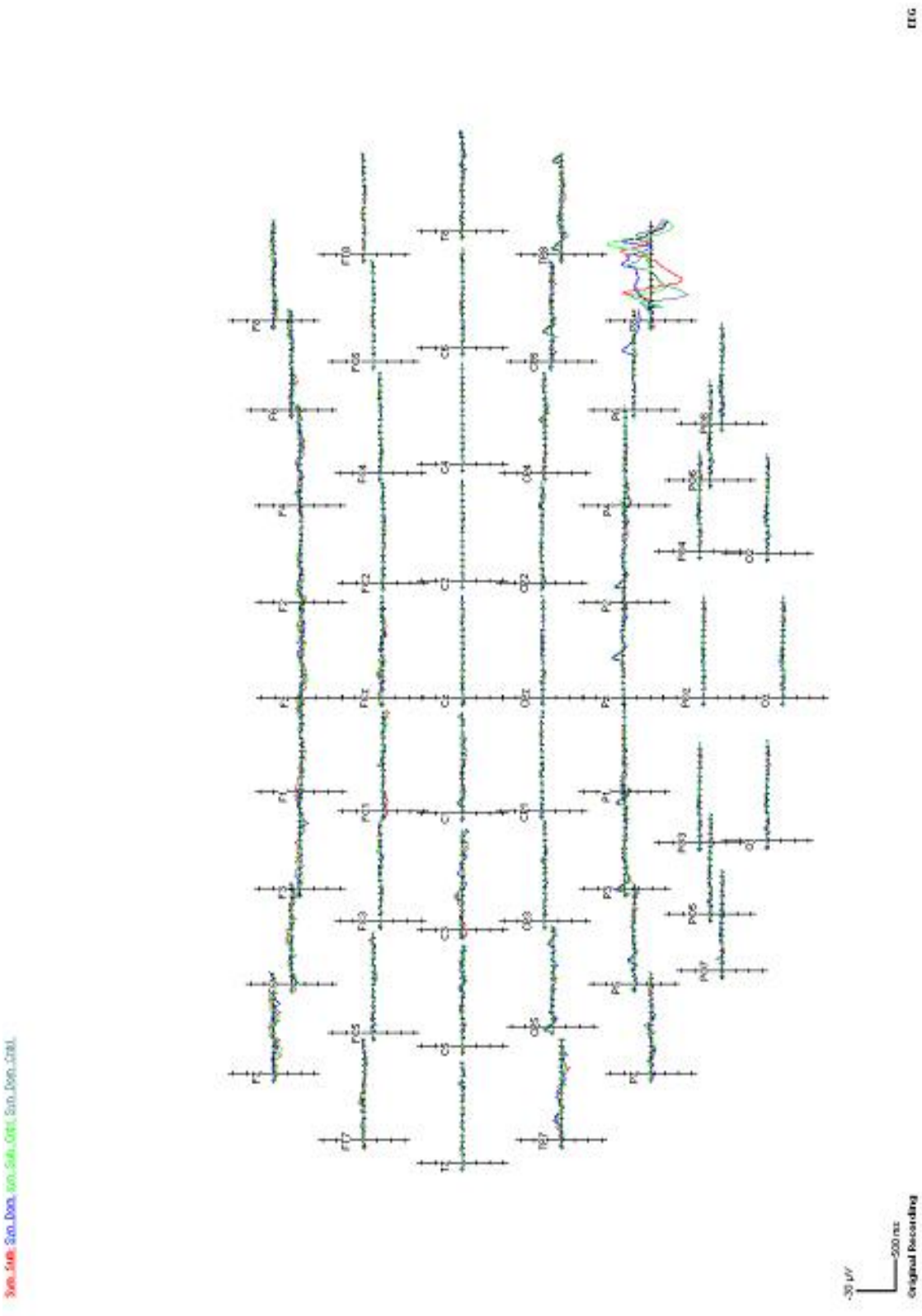


Figure 29: Simultaneous Bilingual Responses in the Syntactic Priming Conditions

As can be seen in Figure 30, the N400-like effects for all the priming conditions were also similar for the early bilinguals. This group also shows negative effects at electrode site CP4 as well as CP6, whereas this effect was not found for the relatedness and frequency conditions. This group does not show as great amplitudes as the monolinguals, but not as reduced amplitudes as the simultaneous bilinguals. Although the early bilinguals do not show a second negative peak for the inappropriately-related condition, there is possible evidence of this condition eliciting a late positivity in CP6 and P2. This is explored further in section 5.4.5 which investigates evidence of P600-like effects.

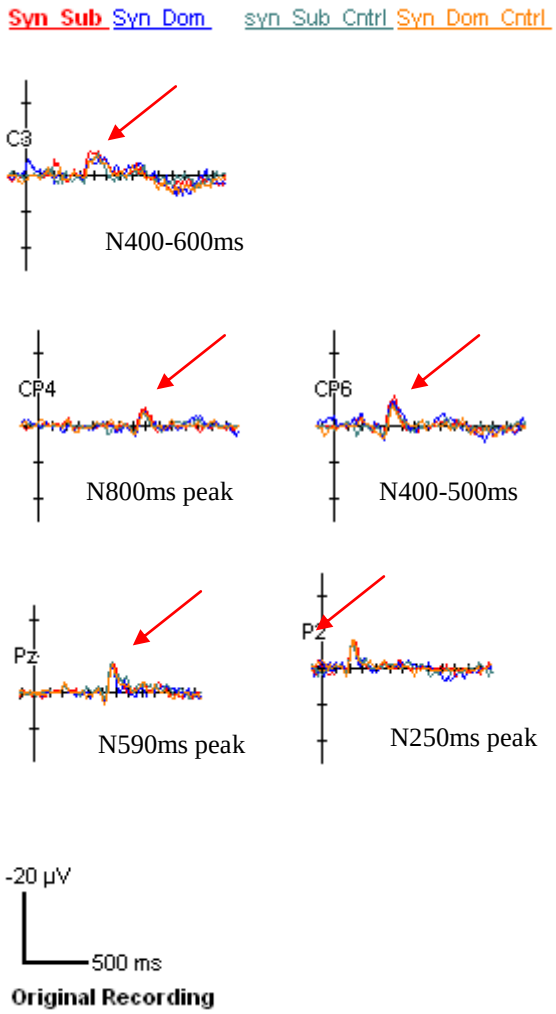


Figure 30: Early Bilingual Negativities for the Priming Conditions

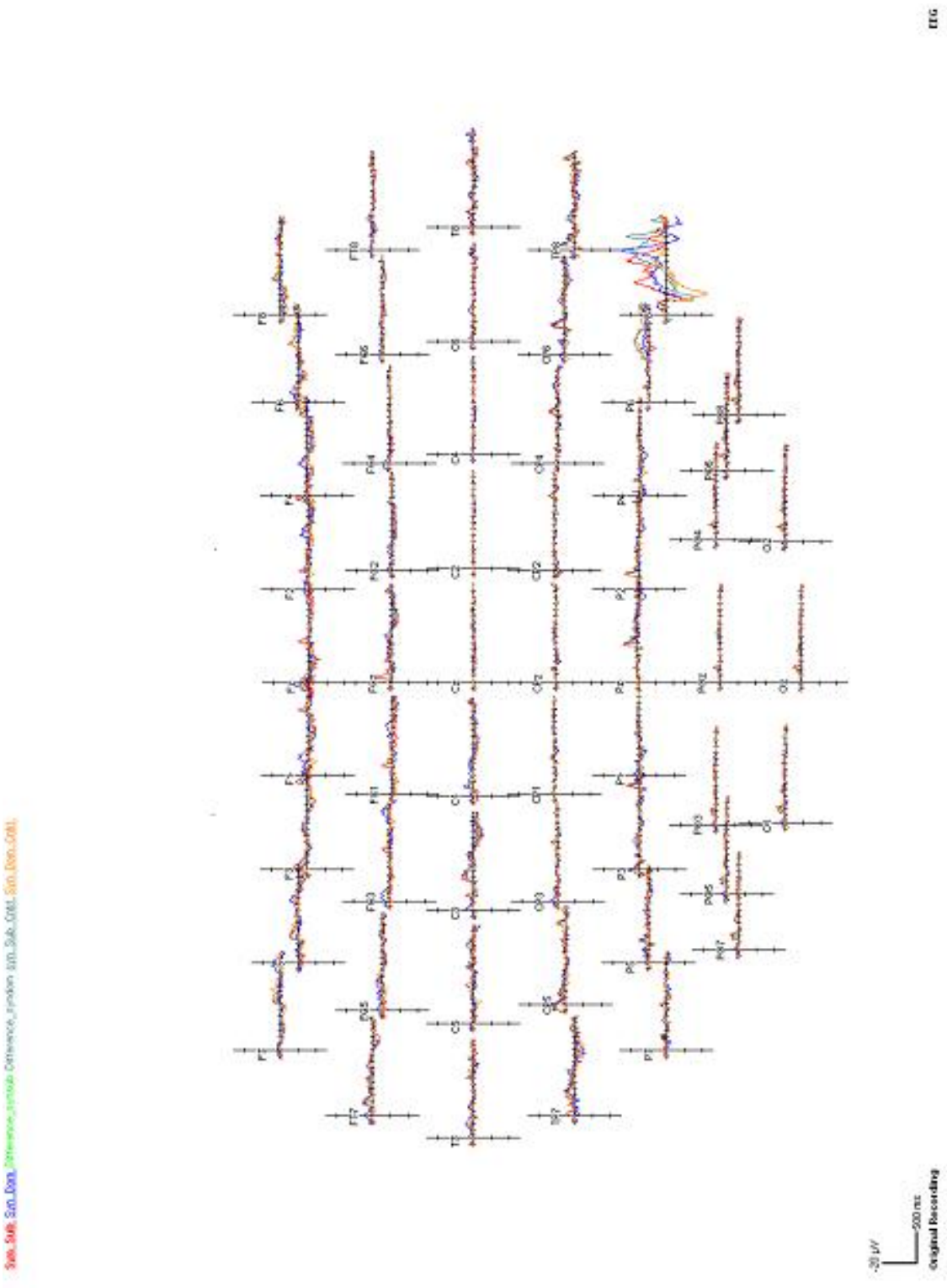


Figure 31: Early Bilingual Responses in the Syntactic Priming Conditions

As can be seen in Figure 32, the N400-like effects for all priming conditions were also similar for the late bilinguals. This group also shows negative effects at CP4 and CP6, whereas this effect was not found for the relatedness and frequency conditions. This group shows the most reduced amplitude of waves, most particularly at CP4 and P2. This group does not appear to reveal any modulations for the inappropriately-related condition at any of these electrode sites, suggesting that it does not appear that this group underwent a process of reanalysis for the inappropriately-related condition as the other bilingual groups did. Nor does this group reveal as strong amplitudes of N400-like effects as the monolinguals, suggesting that this group requires further analysis to understand how, why, and to what extent this group is differing from the others.

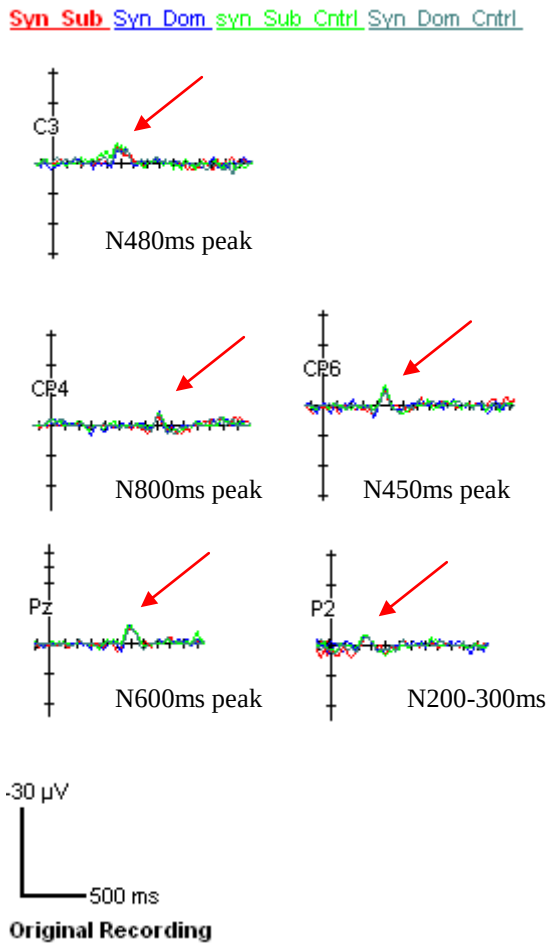


Figure 32: Late Bilingual Negativities for the Priming Conditions

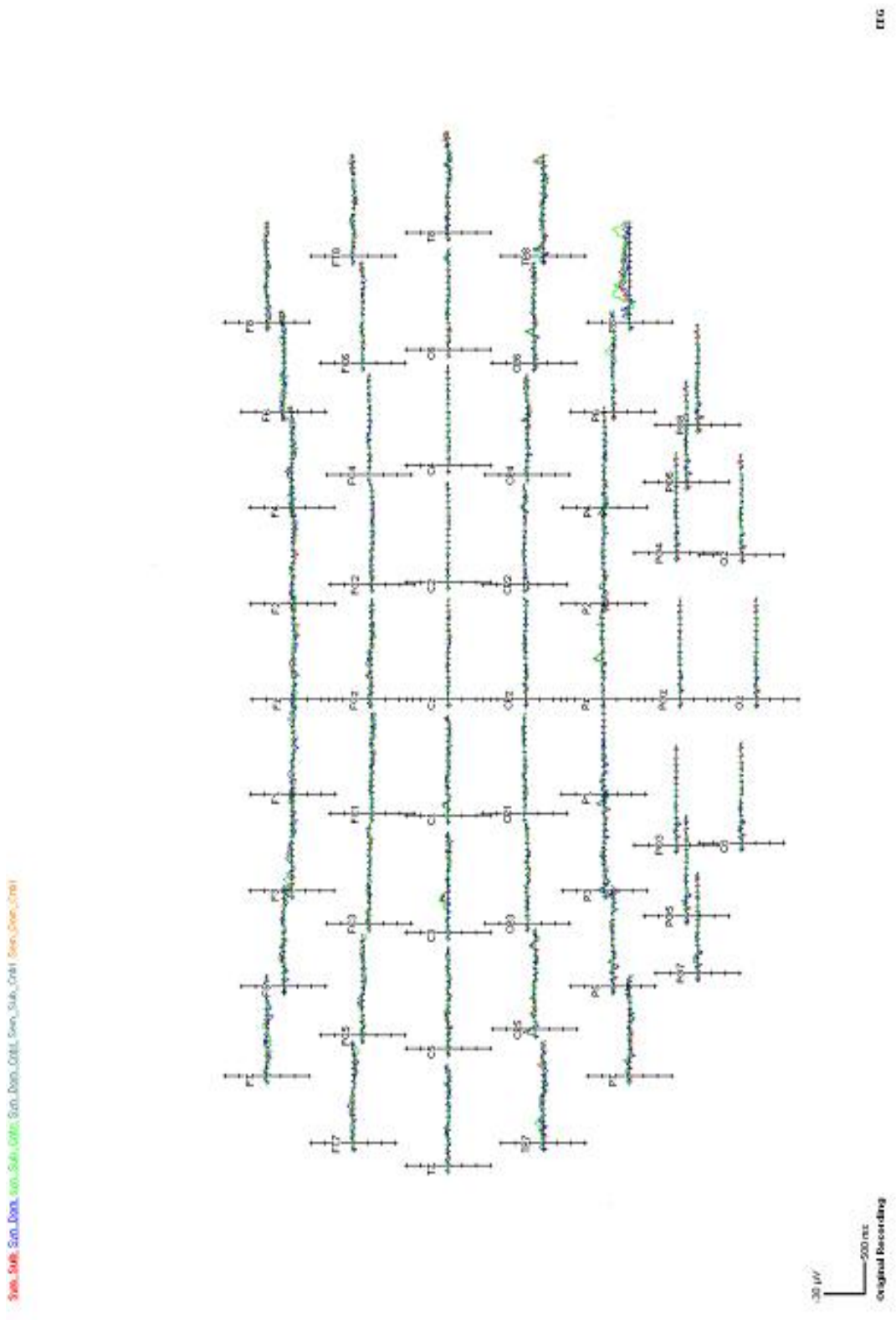


Figure 33: Late Bilingual Responses in the Syntactic Priming Conditions

Statistical Analysis

A 4-way repeated measures analysis testing condition (4 levels: synsub, synsub control, syndom, syndom control), laterality (7 levels), anteriority (6 levels), and LG (four levels) was performed for twelve 50ms time windows between 400ms to 1000ms. Figure 34 below illustrates the approximate location of electrodes used in the experiment and light grey circles indicate electrodes chosen to examine the distribution of effects.

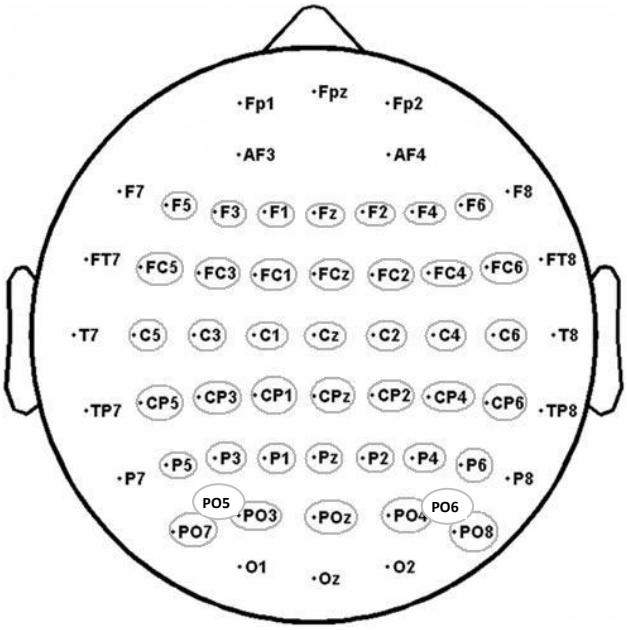


Figure 34: Electrodes Included for Statistical Analysis

For the complete results information, please see Appendix 11: Results of 4-way ANOVA in the ERP Statistical Analysis of the Priming Condition by Time Window. The simplified results of these analyses are presented next in Table 10: Simplified Results of 4-way ANOVA of Priming by Time Window. In this table, "?" indicates a trend toward a significant finding, "*" indicates a significant value of $p<.05$, "**"indicates a significant value of $p<.01$, and "***" indicates a significant value of $p<.001$.

Table 10 shows there were no main effects or interactions found for the time windows 500-600ms, which may indicate that effects were only found during the time windows where typical N400 and P600 ERP components may be found for these conditions. Otherwise, there was an interaction between anteriority and language group for all other time windows, indicating that priming effects were found differing by the anteriority (but not laterality) of scalp activation and language group. This interaction was further supported in the later time windows post-850ms, where a 3-way interaction between condition, anteriority, and language group was found. This suggests that for some language groups, processing of the priming conditions elicited scalp activity in more frontal regions compared to others.

Table 10: Simplified Results of 4-way ANOVA of Priming by Time Window

FACTOR / TIME	anteriority x LG	anteriority x laterality x LG	condition x anteriority x LG	condition x anteriority x laterality	LG	multiple comparisons
400-450ms	***					
450-500ms	**			?		
500-550ms						
550-600ms						
600-650ms	?					
650-700ms	**				*	LG2 vs. LG3 ?
700-750ms	*				?	
750-800ms	*	?				
800-850ms	**				?	
850-900ms			*			
900-950ms	*		***			
950-1000ms	**		**			

"?" indicates a trend toward a significant finding
"*" indicates a significant value of $p<.05$
"**"indicates a significant value of $p<.01$
"***" indicates a significant value of $p<.001$

SYNSUB – SYNSUBCONTROL

A 4-way repeated measures ANOVA was performed on the appropriately-related and subordinate reading in the priming syntactic conditions (synsub) compared to the non-priming control condition (synsubcontrol) in order to investigate the priming effects found by RT in the behavioural experiment which are presented and discussed above in Study 1. The RT results from Study 1 found a main effect of priming (p=.029) and an interaction between priming and language group (p=.014), which was reflecting the monolinguals being slowed down by the target word that is appropriately-related to the subordinate reading of the syntactically-constrained priming homonym compared to the non-priming control condition. The bilinguals on the other hand, revealed priming effects for the priming condition compared to the non-priming control condition.

The current 4-way repeated measures ANOVA testing condition (2 levels: synsub, synsub control), laterality (7 levels), anteriority (6 levels), and LG (4 levels: monolinguals, simultaneous bilinguals, early bilinguals, and late bilinguals) was performed to test the effects of the appropriate syntactic priming conditions alone – that of synsub and synsub control. This analysis was performed for the same 50ms time windows as presented above, resulting in 12 time windows ranging from 400ms to 1000ms post-stimulus onset. For the complete information of these results, please see Appendix 12: Results of Synsub Priming and Non-priming Condition by Time Window. The simplified results of these analyses are presented next in Table 11: Simplified Results of Synsub Priming and Non-priming Condition by Time Window. In this table, "?" indicates a trend toward a significant finding, "*" indicates a significant value of p<.05, "**"indicates a significant value of p<.01, and "***" indicates a significant value of p<.001.

Table 11 next shows a consistent interaction between laterality and language group for all time windows, suggesting that all language groups differed in the location of recorded scalp activity and this variance was further modulated by laterality. This is found to be different from the previous 4-way analysis involving all conditions, which found the language groups to differ by anteriority rather than laterality. This suggests that there is a difference in scalp distribution according to the condition, which is supported by the later time windows in both analyses. In Table 11 below, it appears that interactions between anteriority, laterality, language group, and also condition are found at the later time windows, those after 850ms. These findings support the suggestion that a reanalysis of primed homonyms occur at these later stages of processing. Further, main effects of language group are found within the time windows 600-750ms, which multiple comparisons found the early bilinguals to be differing from the other bilingual groups. This suggests that the early bilinguals may be revealing a stronger sensitivity to the priming condition compared to the other bilingual groups, which may indeed reflect a process of reanalysis expected to occur at this time due to the priming constraints of this condition.

Table 11: Simplified Results of Synsub Priming and Non-priming Condition by Time Window

FACTOR / TIME	laterality x LG	anteriority x LG	condition x anteriority	anteriority x laterality x LG	condition x laterality x anteriority x LG	LG	multiple comparisons
400-450ms	***		*		?		
450-500ms	***						
500-550ms	**						
550-600ms	**						
600-650ms	**		?			*	*
650-700ms	***					**	LG3 vs. LG2 ** LG3 vs. LG4 ?
700-750ms	**					*	LG3 vs. LG2 * LG3 vs. LG4 ?
750-800ms	**			*			
800-850ms	**						
850-900ms	***			?			
900-950ms	?	***			*		
950-1000ms	***			*	*		

5.4.3.2 Discussion of negativities for the priming conditions

The priming analysis of the two homonym priming conditions compared to the non-priming control conditions revealed many main effects of condition, laterality, anteriority, language group, and interactions thereof. These effects were also found for each language group independently, and differences between language groups were only found to occur within the time windows of 650ms to 850ms post-stimulus onset. One brief 50ms time window, that of 650-7-00ms post-stimulus onset, also revealed the simultaneous bilinguals and the early bilinguals differing significantly from each other. These findings suggest that each language group processed the priming conditions differently, and that the only window of differences between the language groups themselves can be found within the smaller window between 650ms and 850ms post-stimulus onset. The differences found between the early bilinguals and the simultaneous bilinguals suggest that the one of the bilingual groups

was more sensitive to the priming conditions compared to the other group. Indeed, the early bilinguals were also found to differ from the late bilinguals within the subset analysis involving the synsub and synsubcontrol conditions only, which suggests that the early bilinguals may indeed have been more sensitive to the priming effects of this condition. Indeed, in the second analysis involving the synsub and synsubcontrol conditions, the main interactions involving language groups were found to occur between 600ms and 1000ms post-stimulus onset, with the main differences found between language groups occurring only between 600ms and 750ms post-stimulus onset. This suggests that the processing of the syntactically-constraining information may have been occurring at the later stages of processing, which are suggested to occur around 600ms post-stimulus onset. Further, it is indeed at this later stage of processing that the bilingual groups appear to diverge from each other.

5.4.4 Discussion of negativities found overall

This exploratory analysis examined certain time windows for N400-like effects anticipated for the conditions of relatedness and frequency and for the conditions of priming. These conditions and time windows were analysed by language group as the language background of the participants was anticipated to be one of the greatest factors influencing the results.

I hypothesized that the monolinguals would show reduced negativities in the subordinate reading of the syntactic condition as the priming condition raised the appropriate and subordinate reading of the homonym to the same level of facilitation for access as the dominant reading. This hypothesis was supported by the visual observation of waveforms in both the relatedness and frequency condition as well as the priming condition as the

monolingual group appears to show equal negativity for both homonym conditions, regardless of appropriateness, lexical frequency, and priming constraints. The planned comparisons also did not reveal any difference between the two subordinate conditions, suggesting that the monolinguals processed the constrained subordinate condition in the same manner as the unconstrained and ambiguous subordinate condition. I also anticipated this group to show a greater negativity for low frequency words, which the results of the 1-way ANOVA showed to be significant in the later time windows between 750-950ms at parietal electrodes at scalp level. However, these differences are not evident from the visual observation analysis. These findings suggest that this group was not sensitive to surface cues such as priming as they processed the homonym conditions equally, in particular the two constrained and unconstrained subordinate conditions. This group does however show evidence of lexical frequency effects which appears to occur at later stages of processing.

I hypothesized that the bilinguals would show sensitivity to surface cues such as priming due to acquiring the L2 through the L1. Specifically, I anticipated the bilingual groups to show greater negativities for the syntactically-constrained inappropriately-related and dominant condition as this would reflect a processing strategy due to a heightened sensitivity to surface cues due to having learned the L2 through the L1, thereby resulting in an increased metalinguistic awareness in the L1. This hypothesis was upheld as the bilingual groups did vary from the monolinguals.

Although the simultaneous bilingual group also appeared to process both homonym conditions (syntactic and semantic) and the subordinate and dominant conditions similarly, these were shown to have reduced negativities compared to the monolingual group, with the planned comparison revealing significant differences in only three electrodes, whereas the

monolinguals showed effects in four. In the relatedness and frequency analyses, N400-like effects were found with scalp distribution and latencies which differed from the monolingual group's scalp distribution and latencies. Specifically, these were found in the left central electrode region, the mid parietal region, and the right centro-parietal region. The latency of the negativities varied, with P2 peaking at 222ms, CP6 peaking at 445ms, C3 peaking at 507ms, and Pz peaking at 576ms. These differences were supported in a planned comparison as the simultaneous bilinguals show longer and more widespread differences between the subordinate and dominant conditions, suggesting that this group processed these two conditions differently. C3 was also found to show differences for the subordinate conditions only during the early time windows between 350-700ms, suggesting that lexical frequency processing might be occurring at the earlier stages of homonym processing with a more anterior distribution. This early anterior activity appears to be in complimentary distribution with later posterior activity for the same conditions - that of the subordinate conditions between the time windows of 550-1000 at the electrode site Pz. This suggests that these conditions required more processing which was subsequently reflected in a more widespread distribution and longer times of elicitation of an N400-like effect. This in turn suggests that the simultaneous bilinguals appear to be sensitive to lexical frequency and appropriateness as they show longer processing times between the syntactic and semantic conditions. Thus, the simultaneous bilinguals appear to differ from the monolinguals, this may be due to having acquired a L2 which is influencing their strategies for homonym processing.

The early bilingual group appeared to vary the most from all other groups. This group revealed smaller negativities relative to the monolinguals in the relatedness and frequency analysis with differing distribution and earlier latencies of activation. Further, the early

bilinguals differentially processed the relatedness of the syntactic conditions and the semantic conditions, with additional distribution found for the semantic conditions, specifically at the later time windows between 600-950ms. The earlier latencies (18ms earlier in the syntactic condition and 30ms earlier in the semantic condition at CP6, 37ms earlier for the semantic condition at P2, and 18ms earlier for the semantic condition and 25ms earlier for the syntactic condition at Pz) suggest that the early bilinguals were faster to process the prime and target word relationships compared to the monolingual group. However, it is not clear whether this group processed the syntactic conditions faster than the semantic conditions due to the specific locations of activation varying in timing differences. For example, the negativity found at C3 occurred equally as a window at 450-600ms for both the syntactic and semantic conditions, the negativity found at CP6 occurred at 438ms for the semantic condition, but at 450ms for the syntactic condition. The negativity found at P5 occurred at 336ms for the syntactic condition, but at 352ms for the semantic condition. The negativity found at Pz occurred at 573ms for the syntactic condition, but at 590ms for the semantic condition. The earliest negative activity was found occurring at P2 at 227ms for the semantic condition only. These greater activations and latencies for the semantic condition suggest that the unconstrained and ambiguous condition was harder to process. This may have been exacerbated by the additional factor of low frequency, as C3 again revealed differences within the early time windows between 350-600ms for the subordinate reading in the semantic condition. Further, in the syntactic priming analysis, the early bilingual group differed significantly from the other bilingual groups within the time windows of 600ms to 800ms post-stimulus onset. These findings suggest that this group processed the syntactically-constrained conditions differently compared to both the unconstrained semantic conditions, as well as the non-priming control conditions which suggest that this group was

sensitive to both priming and lexical frequency information aiding them for homonym processing.

The late bilinguals also revealed smaller negativities compared to the monolinguals, with fewer scalp distributions compared to both the monolingual and early bilingual groups. The latencies of these distributions also varied from the other groups, as well as by condition. Compared to the monolingual group, the late bilinguals showed a negativity occurring 12ms earlier for the syntactic condition and 15ms earlier for the semantic condition at CP6, and 8ms earlier for the semantic condition and 18ms earlier for the syntactic condition at Pz. These latencies were found to be occurring slightly later compared to the early bilingual group. Specifically, although the negativity occurring at C3 was a similar window of negativity at 450ms – 600ms, the late bilinguals showed a negativity occurring 6ms later for the syntactic condition and 15ms later for the semantic condition at CP6, and 17ms later for the syntactic condition and 10ms later for the semantic condition at Pz, compared to the early bilinguals. Within the late bilingual group, it is again hard to say if the syntactic condition was processed earlier than the semantic condition due to timing differences. The window of negativity found at C3 occurred at 450-600ms for the syntactic condition, but 450-590ms for the semantic condition, whereas the planned comparison found differences within the early time window between 350-650ms, specifically for the subordinate reading in the unconstrained and ambiguous condition. This suggests that lexical frequency processing may have been occurring within this early time window. The negativity found at CP6 occurred at 453ms for the semantic condition, but at 456ms for the syntactic condition. Lastly, the negativity found at Pz occurred at 590ms for the syntactic condition, but at 600ms for the semantic condition. Similar to the early bilinguals, the greater activity found for the semantic

condition suggests that the unconstrained and ambiguous condition resulted in greater processing. These findings also suggest that the late bilingual group, similar to the early bilingual group, processed the syntactically-constrained conditions differently compared to the unconstrained semantic conditions, which similarly suggests that this group was sensitive to the priming and lexical frequency information aiding homonym processing. However, as the planned comparison did not find any differences between these two conditions, it may be that any process of reanalysis occurring for either of these conditions may not be found at electrode sites C3, Pz, and P2, nor might it be found within the time windows analysed here.

These results suggest that the bilingual groups, but not the monolingual group, might be sensitive enough to the priming condition to reveal a P600 effect. More specifically, the bilinguals are anticipated to show a positive effect reflecting a garden path effect when presented with a target word that is inappropriately-related to the priming homonym. This is investigated next.

5.4.5 Positivities

5.4.5.1 Observations

A visual inspection of the grand averages of the inappropriately-related and dominant priming condition compared to the non-priming control condition (syndom vs. syndom control) for each language group revealed only slight differences in amplitudes, scalp distribution, and timing of positive-going deflections. These can be seen in Figures 35 through 42 which show a subset of frontal electrodes and the grand averaged wave forms for all electrodes for the inappropriately-related and dominant reading of the target word in the syntactic priming condition (syndom) and the non-priming control condition (syndom control) for each language group. These are described separately by language group.

As can be seen in Figure 35 and Figure 36, for the monolingual group, as expected, there is no obvious evidence of positivities for the inappropriately-related and dominant reading of the target word in the priming condition (syndom) in comparison to the non-priming control condition, suggesting that this group did not undergo a garden path effect when presented with a target word that is inappropriately-related to the priming homonym.

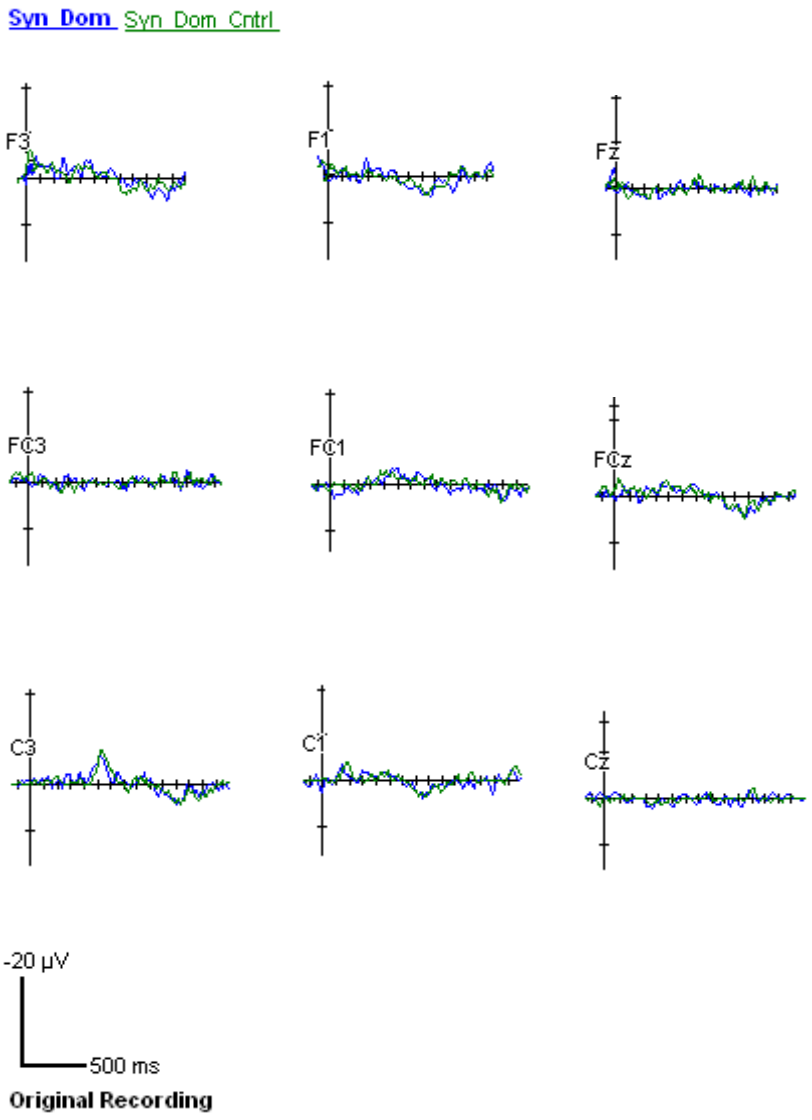


Figure 35: Subset of Electrodes for Monolingual Responses in the Inappropriately-related Priming Condition

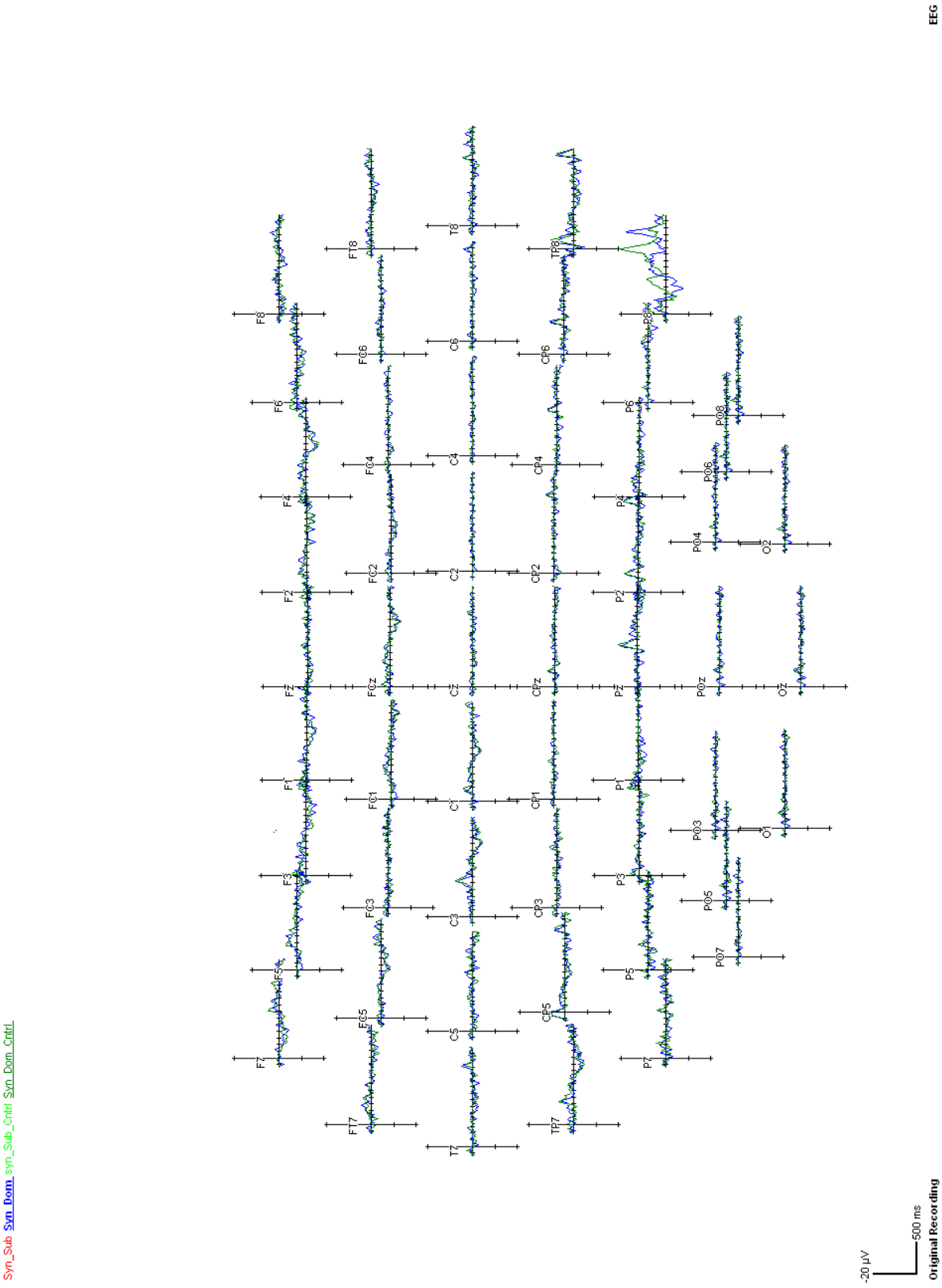


Figure 36: Monolingual Responses in the Inappropriately-related Priming Condition vs. Control Condition

As can be seen in Figure 37 and 38 next, the simultaneous bilingual group appears to show evidence of positivities (indicated with arrows and peak latencies) to the inappropriately-related priming condition compared to the control condition. These are found in the left frontal region, with the latency as follows, F1 showed a reduced peak at P648ms, F3 and FC3 both show peaks at P964ms, with F3 showing larger amplitudes compared to the other positivities.

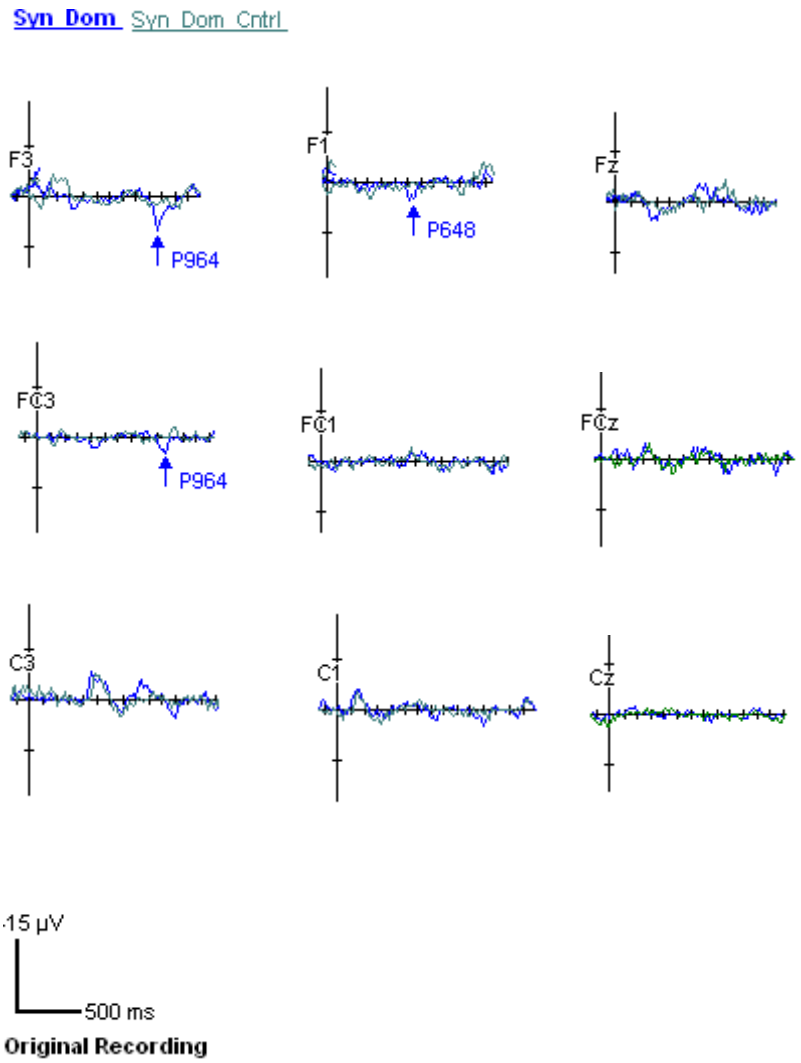


Figure 37: Subset of Electrodes for Simultaneous Bilingual Responses in the Inappropriately-related Priming Condition

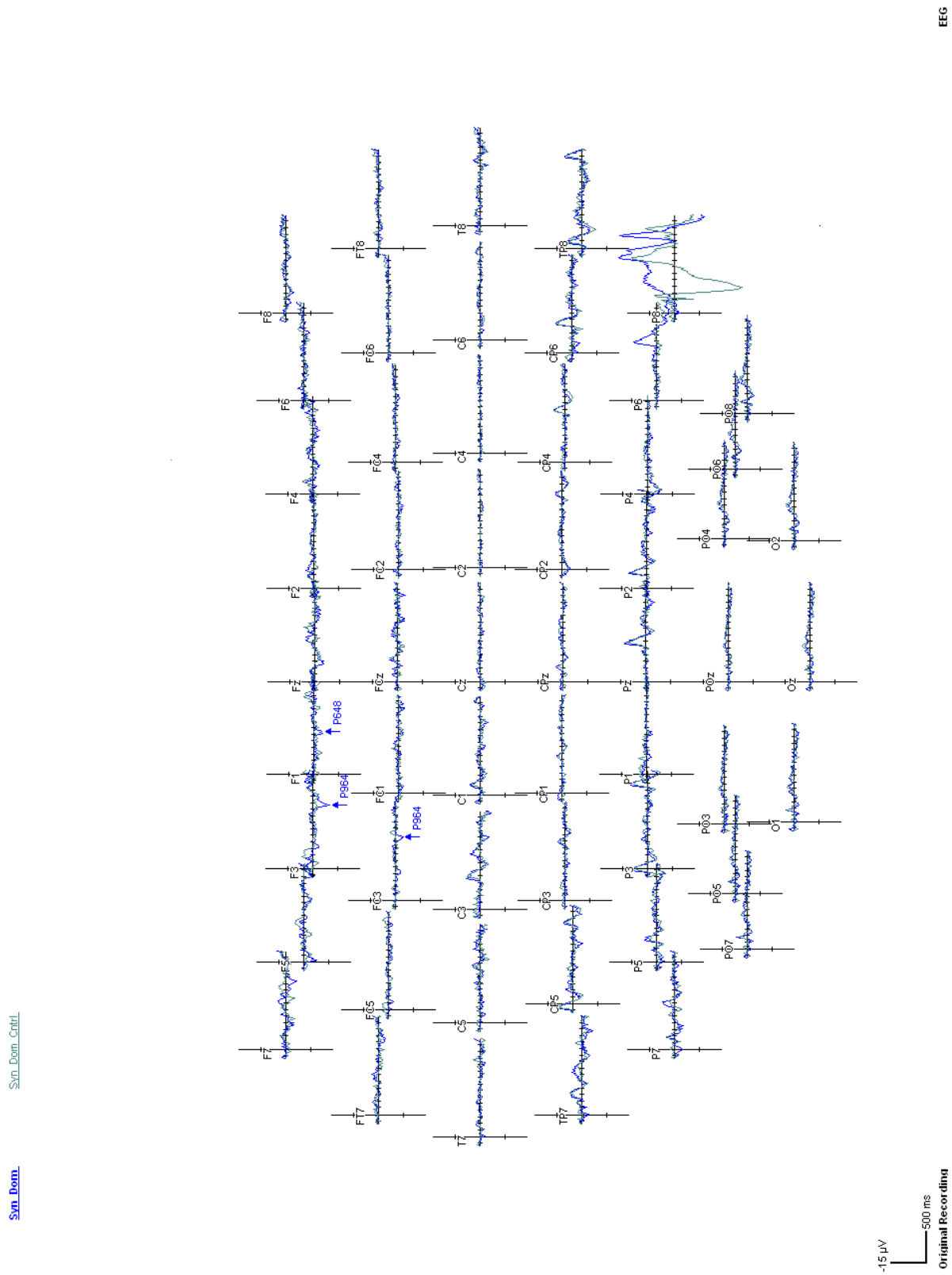


Figure 38: Simultaneous Bilingual Positivities in the Inappropriately-related Priming Condition vs. Control Condition

As can be seen in Figure 39 and 40, the early bilinguals show evidence of positivities for the inappropriately-related priming condition compared to the control condition. These are found in the fronto-central region, indicated with arrows and similar latencies. There is a small positive-going deflection at Fz occurring at 590ms post-stimulus onset, at FC1 at 615ms, and at F1 occurring at 637ms. These positive-going deflections appear to be reduced compared to the positive-going deflections of the simultaneous bilinguals.

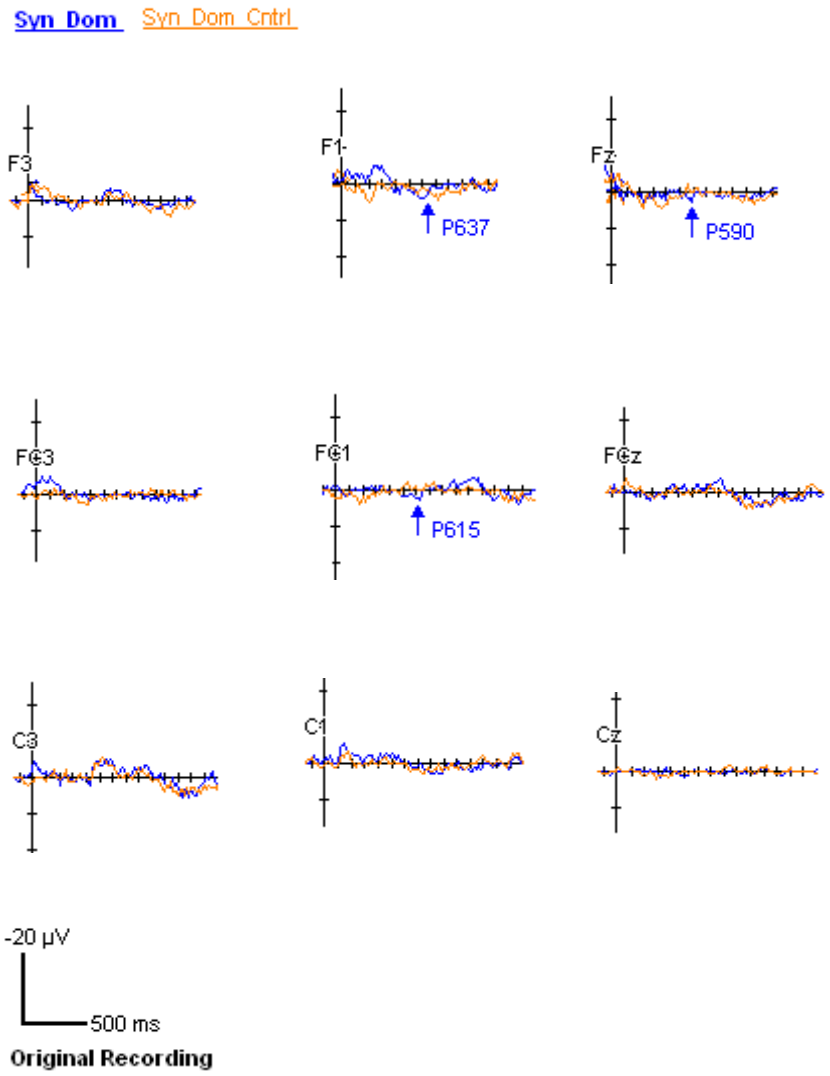


Figure 39: Subset of Electrodes for Early Bilingual Responses in the Inappropriately-related Priming Condition

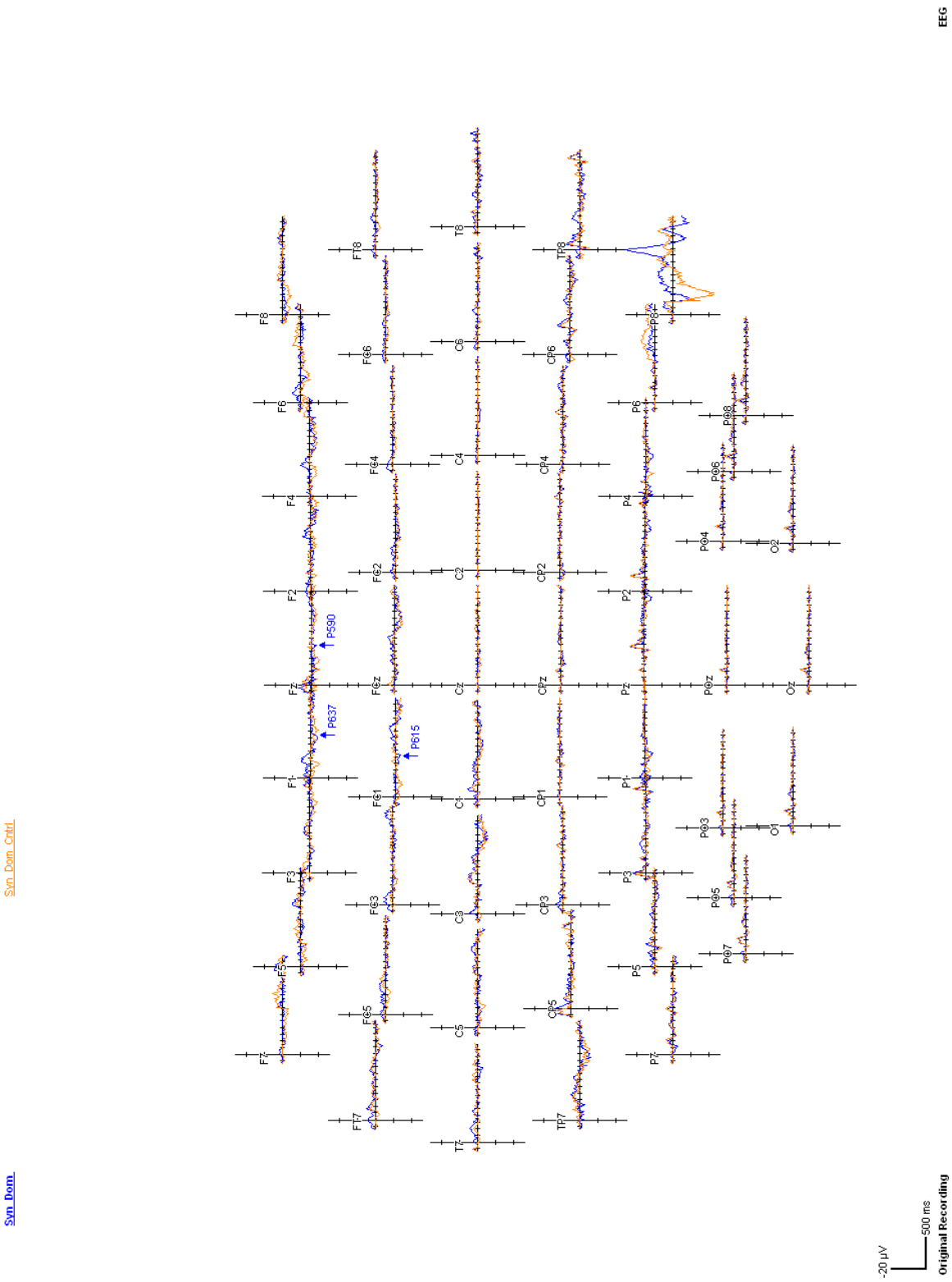


Figure 40: Early Bilingual Positivities in the Inappropriately-related Priming Condition vs. Control Condition

As can be seen in Figure 41 and 42, the late bilingual group also appears to show evidence of positivities for the inappropriately-related priming condition compared to the control condition. These are likewise found in the fronto-central region, indicated with arrows and latency peaks. There is a positive-going deflection at F1 occurring at 689ms post-stimulus onset, Fz occurring at 702ms, at FC1 at 816ms, and at F3 at 1040ms. The positive-going deflections for this group appear to have a more wide-spread distribution compared to the other language groups and they appear to be reduced compared to the positive-going deflections of the simultaneous bilinguals.

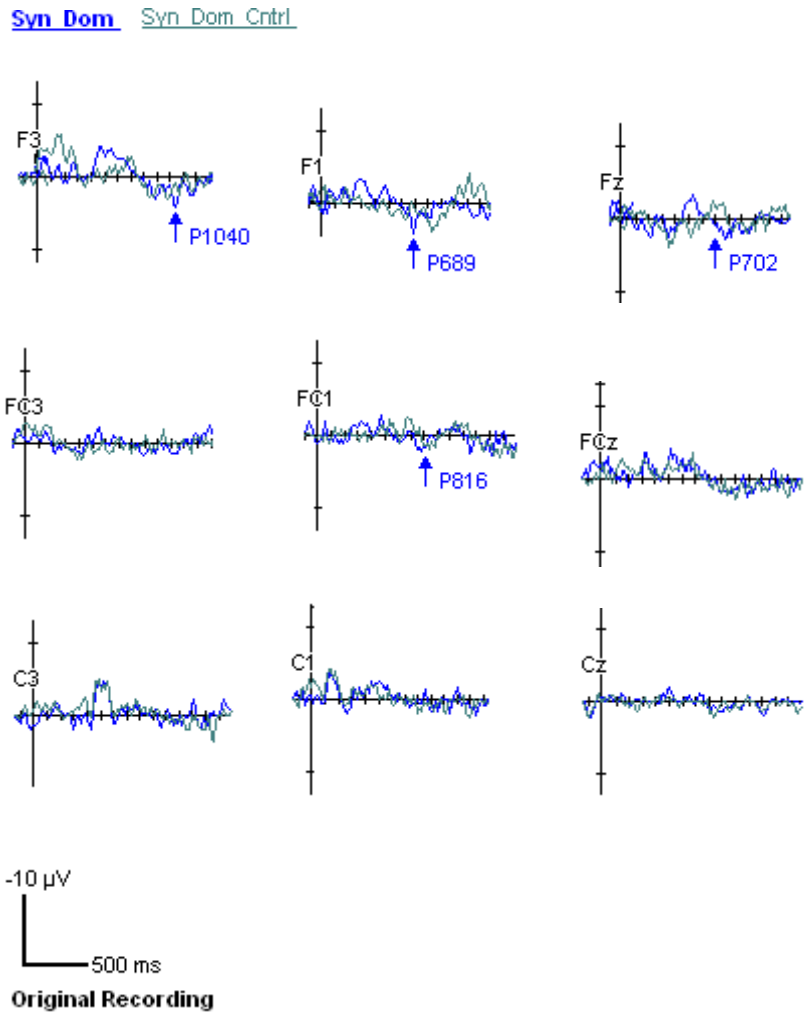


Figure 41: Subset of Electrodes for the Late Bilingual Responses in the Inappropriately-related Priming Condition

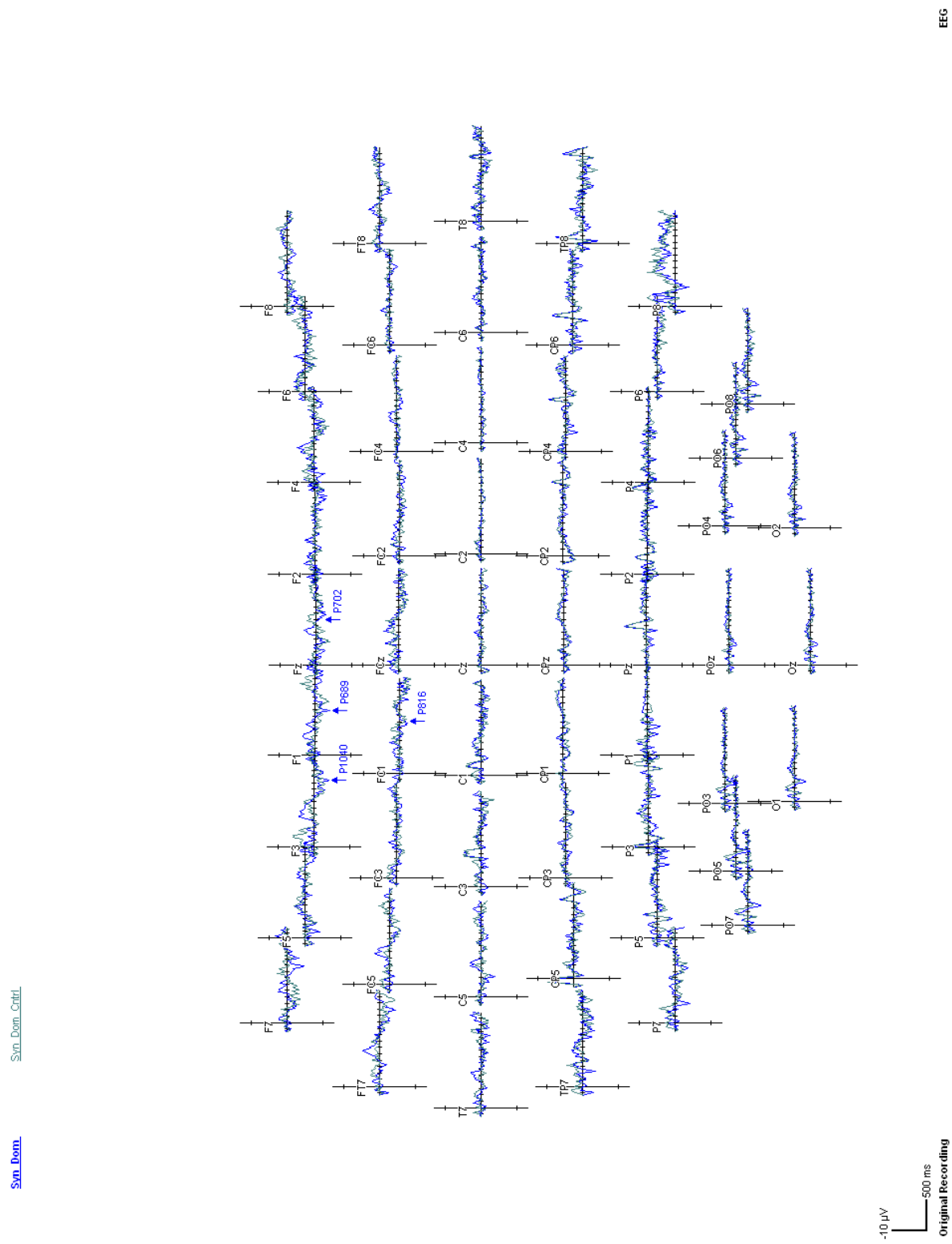


Figure 42: Late Bilingual Positivities in the Inappropriately-related Priming Condition vs. Control Condition

Statistical Analysis

To investigate the observed variations in amplitudes of P600-like effects for the conditions syndom vs. syndom control, a 4-way repeated measures analysis testing condition (2 levels: syndom and syndom control), laterality (7 levels), anteriority (6 levels), and LG (4 levels) was performed for each of nine 50ms time windows between 550-1000ms. Figure 43 below illustrates the approximate location of electrodes used in the experiment and light grey circles indicate electrodes chosen to examine the distribution of effects.

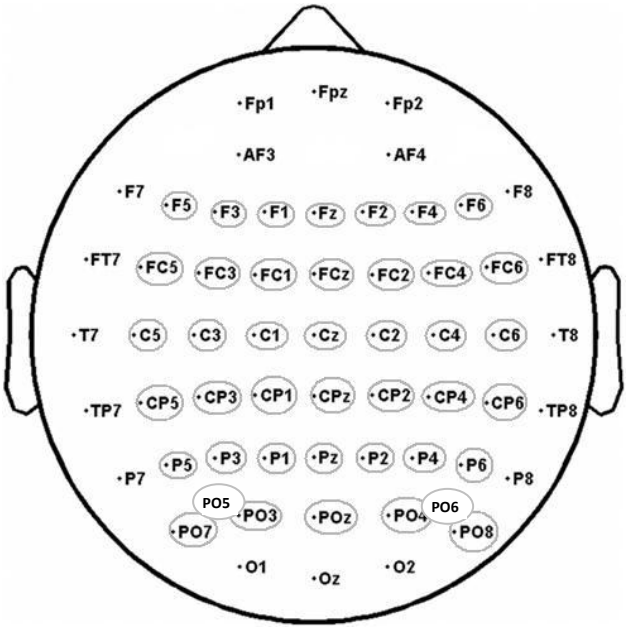


Figure 43: Electrodes Included for Statistical Analysis 1 and the Circled Subset of Electrodes for Statistical Analysis 2

Only two time windows revealed significant interactions. There was a trend towards a significant interaction between condition, anteriority, and LG ($F(18,240)=1.526$, $p=.082$) at time window 650-700ms. There was also a significant interaction between condition, anteriority, and LG ($F(18,240)=1.773$, $p=.029$) at time window 750-800ms. There were no other statistically-significant main effects nor interactions found in this analysis.

A planned pair-wise comparison of the interactions found above was carried out testing the time windows 650-700ms and 750-800ms for the electrode sites observed to reveal P600-like effects for each language group separately. Time window 650-700ms revealed the most significant effects in the fronto-central regions. Unexpectedly, the late bilinguals were not found to reveal any significant effects in this exploratory analysis. Table 12 below shows the effects found in this short exploratory analysis.

Table 12: Results of Positive Effects for syndom - syndom control

Language Group	Time window	F3	FC1	FC3
LG1	650-700ms	(p=.012)	(p=.057)	(p=.005)
LG2	650-700ms			(p=.089)
LG3	650-700ms			(p=.055)
LG3	750-800ms		(p=.086)	(p=.030)
LG3	800-850ms		(p=.077)	(p=.043)

5.4.5.2 Discussion of positivities found

I hypothesized that the bilingual groups would show a P600-like effect as they reassessed what they had just heard when presented with a target word that is inappropriately-related to the priming homonym. This hypothesis appears to have been upheld in the observable results of the responses of the bilingual groups, as well as the interactions found between condition, anteriority, and LG. As expected, the monolingual group did not reveal any evidence of positivities for the inappropriately-related condition in the visual observation. However, the planned comparison analysis revealed differences for this group at the electrode sites anticipated to show P600-like effects. These differences were found at the earlier time window and not at any subsequent time windows. The observed

results support the suggestion that this group is less sensitive to surface cues constraining processing toward only one appropriate reading of the priming homonym, and instead that all readings were equally facilitated for processing regardless of the constraining sentential frame, while the planned comparison suggests that the monolinguals were processing these two conditions differently at an earlier time window.

The bilingual groups did reveal a late positive effect in the left frontal and fronto-central regions involving F1, F3, FC3, FC1, and Fz for the inappropriately-related priming condition relative to the non-priming control condition. These observable positive-going deflections are supported by the findings of an interaction between the factors of condition, anteriority, and language group at the time windows of 650-700 and at 750-800ms post-stimulus onset. These findings support the suggestion that these groups processed the target word that was inappropriately-related to the priming homonym according to the syntactically-constraining sentential cues. This suggests that the bilinguals may have reassessed what they had just heard, which supports the claim that such a reassessment occurs at later stages of homonym processing (Elston-Guettler & Friederici, 2005). The planned comparison further supported the observed findings for the simultaneous bilinguals and the early bilinguals, but not the late bilinguals.

The early bilinguals revealed the greatest effects within three time windows, between 650-850ms and at two electrode sites. This suggests that the early bilinguals processed these two conditions differently and to do so, brain activity was recruited over a more widespread distribution and for a longer time period compared to the simultaneous bilinguals. The late bilinguals, on the other hand, did not show any such effects of priming in these time windows at the electrode sites analysed. It may be that there is an unknown factor affecting

the results of this analysis to not support the observable results of priming for this group. This issue will be investigated more thoroughly, but for the purpose of the dissertation, I will report on the observable results for the late bilinguals and all other results for the other language groups.

The hypothesis that all bilingual groups would reveal a positive effect for the inappropriately-related target words was upheld, as they did reveal evidence of greater amplitude P600-like effects for the inappropriately-related priming condition relative to the non-priming control condition. This suggests that the three bilingual groups were sensitive to the surface cues of the syntactic information preceding the priming homonym. This suggests that acquiring two L1s does not necessarily result in monolingual-like homonym processing, since the monolingual native speakers do not show such positive-going deflections for the inappropriately-related condition compared to the control condition as noticeably or at the same later time windows as the simultaneous bilinguals and early bilinguals do. This also suggests that the bilinguals are not unique from each other in their results as they each appear to have an increased sensitivity to surface cues due to a heightened metalinguistic awareness in the L1. Since the simultaneous bilingual group did not learn the L2 through the L1 as did the early and late bilingual groups, the method of L2 acquisition cannot be a factor to account for this positive effect. Rather, the one factor that the bilinguals have in common with each other (but not with the monolingual group) is the fact that they all have acquired French as an extra language at some stage of language development. This may indeed be the factor influencing their sensitivity to the surface cues such as has been found in this study. Thus, the L2 must be an influential factor on L1 homonym processing for the bilingual groups, as they show evidence of a garden path effect for the inappropriately-related priming

condition relative to the control condition at the later stages of processing at left anterior locations as suggested by Lee and Federmeier (2011). These positivities as well as the negativities found in this analysis are discussed more at length next in the general discussion section.

5.5 General Discussion for Study 2[8]

The results of Study 2 supported the results found in Study 1 by providing corresponding neurophysiological evidence of the online processing required to process homonyms embedded within sentential frames. Specifically, ERP evidence was found which suggests that processing varies according to surface information such as syntactic context constraining a homonym's meaning to only one appropriate reading, or lexical frequency. The results also revealed timing and amplitude differences of such online homonym processing between language groups.

The monolingual language group was expected to reveal a reduced N400-like effect for the subordinate reading compared to the dominant reading in the syntactic condition, suggesting a possible effect of priming and frequency interacting, as posited by the Reordered Access Model (Duffy et al., 1988). This hypothesis was supported, as this group revealed equal negativities for both homonym conditions, regardless of syntactic information constraining the homonym's meaning to only one appropriate reading. However, these equal negativities for both syntactic and semantic conditions also countered the hypothesis that the monolinguals would reveal larger negativities for low frequency items. This suggests that the monolinguals in this study accessed and processed all readings of the priming homonyms

[8] Although not important for the interpretation of the current study, an evaluation of the grand averaged waveforms for the pseudowords relative to real words was carried out. The grand averaged waveforms for these pseudowords vs. real words are presented in a series of figures in Appendix 13.

regardless of constraining syntactic information and lexical dominance within the unconstrained and ambiguous semantic condition. These results were correctly anticipated to counter Folk and Morris (2003) who suggested that syntactic information is processed before and independently from semantic information as well as the suggestion of Swinney (1979) that preceding syntactic cues inhibit inappropriate meanings.

The results of the simultaneous bilinguals were anticipated to support the suggestion that the earlier one acquires the L2, the more closely one resembles monolingual native speakers since they have, in fact, acquired 2L1s. Consequently, the results of this group were anticipated to be synonymous with the monolingual group in revealing N400-like effects for lexical frequency effects, but no P600-like effects for syntactic priming. This hypothesis was not upheld as the simultaneous bilinguals differed from the monolinguals in processing of the syntactically-constrained conditions. The simultaneous bilinguals appeared to differentiate between the two conditions and be influenced by both lexical frequency effects and syntactic priming. In this way, the simultaneous bilinguals appear to be more similar to the early and late bilinguals compared to the monolinguals, which suggests that the L2 of this group was influencing homonym processing in the L1.

The results of the late bilingual group were anticipated to diverge the most from the results of the monolingual group. Specifically, the ERP results for this group were anticipated to support the findings of the L2 influencing homonym processing in the L1 as reported in Study 1. As expected, this group revealed a differentiation between homonym conditions, as found in differing times of electrical activity at differing locations on the scalp correlating to the different conditions. [Also, negativities appear to be slightly greater for the unconstrained appropriately-related and dominant condition at CP6 and Pz compared to the syntactically-constrained inappropriately-related and dominant condition, suggesting a slight

effect of lexical frequency. Also as expected, the late bilingual group revealed a P600-like effect in the syntactic condition as evidence of a neurological sensitivity towards syntactic priming, triggered by the recently acquired processing strategy of relying on surface cues (such as syntactic information) for lexical parsing in the L2. This evidence supports the suggestion that the later an L2 is acquired, the more dissimilar the speaker will resemble monolingual native L1 speakers (Cook, 2003; Dussias, 2007) as this population is postulated as having separate mental lexicons and variations in online processing strategies (Fabbro, 2001; Meisel, 2009) due to the recently-acquired L2 influencing L1 processing (Cook, 2003; Dussias & Sagarra, 2007).

Following the results of Study 1, the early bilingual group was anticipated to differ from the monolingual, simultaneous bilingual and late bilingual groups. The processing strategies (sensitivity to surface cues) of this group were expected to reveal separate but interacting mental lexicons for each language, although these processing strategies were not expected to be identical to the processing strategies of the late bilingual group due to this group's earlier AoL2A. Although the early bilingual group was anticipated to reveal a P600 effect for the syntactic priming condition, that is syntactically-constrained inappropriately-related and dominant, this was not found. However, as expected, the early bilingual group did reveal ERP evidence of a heightened sensitivity to surface cues as they appear to be processing the two homonym conditions differently. Also, negativities appear to be slightly greater for the unconstrained appropriately-related and dominant condition at CP6 and Pz compared to the syntactically-constrained inappropriately-related and dominant condition, suggesting a slight effect of lexical frequency. Further, the early bilinguals show negative effects which are unique from the other language groups in scalp distribution and earlier latencies. The more widespread distribution of negativities in the semantic condition

suggests that this group is recruiting a greater underlying processing mechanism to resolve the ambiguity of the sentences as well as possibly resolving the competition of lexical frequencies. The earlier latencies found for both conditions compared to the other language groups coupled with the evidence of a greater sensitivity to surface cues suggest that the two languages in this group are closely integrated, as the acquisition of the L2 appears to help them to be more sensitive to surface cues, yet does not result in a delay of these effects.

Obviously, the ERP evidence discussed here is only half of the picture. The behavioural results of Study 1 also need to be examined in light of the results of Study 2 and vice versa so that we can better understand the underlying processing mechanisms involved in lexical ambiguity resolution and what these may indicate for the mental lexicons of monolinguals and bilinguals, and how these may be differing according to the age at which the L2 was acquired. These issues are taken into account and discussed more at length in the next chapter, Chapter Six: General Discussion and Conclusions.

Secondly, the exploratory analysis used to examine the conditions of this study also helped to evaluate the outcome of combining a cross-modal lexical decision task involving sentences with ERPs.

Overall, the effects that were found do not look like the typical findings for ERP priming effects. Typically, ERP effects are found spread over a number of electrode sites which are commonly analysed as regions of interest. This study however, did not reveal observable ERP effects spread over more than one or two electrode sites in any one region for the relatedness and frequency analysis. This was unexpected due to the findings of previous lexical priming studies (e.g.: Klepousniotou et al., 2012). However, as this study is the first of its kind to adapt the cross-modal lexical decision task involving auditorily-presented priming homonyms with visually-presented target words to the ERP methodology, these

findings are the first of their kind as well. Thus, the consistent findings of N400-like or P600-like effects being found for all four language groups for the same conditions with only small differences found in the latency and amplitude of these effects indicates that the ERP technique did indeed capture evidence of the online processes involved in homonym processing. I further believe that with more items and a larger number of participants in each group, the results would show more reliable and robust results.

Indeed, it appears that in combining these two techniques, the time windows and anteriority involved in lexical processing compared to lexical integration may be identified. Most notably for the bilingual groups, lexical frequency effects appear to be evidenced within the early time windows of 350-600ms at an anterior location (as found at electrode site C3), whereas lexical integration appears to be evidenced within the later time windows of 550-1000ms at a posterior location (as found at electrode sites Pz and P2). These findings may be evidence of the latency and anteriority involved in the earlier and later stages of homonym processing, particularly in the case of auditorily-presented sentential priming frames coupled with visual lexical targets Indeed, further research needs to replicate or counter these findings presented here. As such, as a pilot study utilising this particular combination of techniques, the findings of the current study are to be considered a good starting part for future analyses.

CHAPTER SIX: GENERAL DISCUSSION AND CONCLUSIONS

6.1 Summary

6.1.1 Behavioural Experiment: Accuracy, RT, Syntactic Priming, and Lexical Frequency

Study 1 set out to analyze accuracy rates and RTs of a cross-modal lexical decision task to determine whether differences could be found between participant groups according to language background and the age at which the bilingual participants had acquired French as the L2. The goal of this study was to ascertain whether both meanings of ambiguous homonyms are accessed even when presented in a biasing syntactic context, such as reported by Tanenhaus and Donnenwerth-Nolan (1984). Variations in processing were anticipated to correlate with the language background of the participants. Based on previous research, I speculated that the initial stage of access and processing for all words, ambiguous or not, would occur in a bottom-up manner for monolingual and L2 learners alike. However, it was at the later stages of processing, postulated to occur after 500ms of offset of a stimulus (Elston-Guettler & Friederici, 2007; Friederici, 1995), where differences were expected to lie in each language group's processing of constrained (syntactic) and unconstrained (semantic) homonyms.

The results of Study 1 found that the acquisition of an L2 does indeed result in differences in homonym processing in regards to overall accuracy and RTs in regards to the relationship between prime and target, and sensitivity to priming and lexical frequency. The study did not find that the acquisition of an L2 increased RTs overall, but rather only in specific conditions. There were indications that the later the L2 is acquired, the more the L2 is found to influence the L1, as evidenced by signs of serial processing rather than parallel. These findings support claims by Cook (2003) that bilinguals naturally focus their attentional

skills on linguistic structure, resulting in an increased sensitivity to surface cues and possible interactions between the two languages, and by van Hell and Dijkstra (2002) who found that foreign language knowledge affects L1 target word processing even in an exclusively native language context. Specifically, the results of the early and late bilingual groups counter the Subordinate Access Effect suggested by Duffy, Morris, and Rayner (1988) as these groups showed a greater sensitivity to surface cues as they were influenced by syntactic priming in conditions where the monolinguals and simultaneous bilinguals were not. This may be that as these bilinguals acquired the L2 through the L1 and relied on surface cues as a strategy for processing in the L2, they may unconsciously have become more aware of and aided by surface cues existing in the L1. This suggests that any speaker who has recently acquired an L2 may process their L1 differently, due to a more heightened metalinguistic awareness to language overall, albeit unconscious. One of these ways may be that lexical access is not as automatically exhaustive, but rather the order in which meanings of words are accessed is determined either by preceding contextual information or by meaning dominance, but not by both (as was found with the monolingual speakers). The specific results for accuracy, RT, priming, and lexical frequency are summarized here.

The results of the RT analysis suggest that acquiring 2L1s provided the simultaneous bilinguals with a heightened sensitivity to lexical frequency as their RTs were faster in the dominant (and inappropriate) conditions than for the subordinate (but appropriate) conditions. As such, they did not reveal any evidence of a delay which might be due to having to search through a larger store of words, or of having to inhibit the unintended meaning. Just the opposite, the simultaneous bilinguals were aided by lexical frequency as a strategy for processing homonyms more quickly, and even more efficiently, as shown by their better accuracy rates in the homonym conditions compared to the other language

groups. Comparatively, the early bilingual group showed the longest RT overall in the unconstrained semantic conditions, which supports previous postulations that early bilinguals may be searching through a larger store of words (Fabbro, 2001; Murray & Forster, 2004; Paradis, 1998, 2001), as well as having to inhibit the inappropriate word due to a competition of lexical activation (Van Assche et al., 2009). The late bilinguals revealed longer RTs in the syntactically-constrained inappropriately-related and dominant and unconstrained appropriately-related and subordinate conditions, supporting our hypothesis of the recent acquisition of the L2 affecting this group's RTs in these particular conditions which are expected to enable speakers to use surface cues for easier homonym processing. Evidence of this group thus being influenced by priming in the syntactic condition and lexical frequency in the semantic condition appears to indicate a processing of surface cues in the L1 due to the influence of a heightened sensitivity to surface cues used as a strategy for acquisition of the L2.

The goal of the priming analysis was to investigate whether or not both meanings of a priming homonym were facilitated for access regardless of sentential bias. It was hypothesised that the presentation of syntactically-constrained homonyms followed by appropriately-related and subordinate target words would reveal a greater effect of syntactic priming compared to the inappropriately-related and dominant target word. The results suggest that the three bilingual groups were more sensitive to syntactic priming as they revealed shorter RTs for target words appropriately-related to the priming homonym relative to the monolingual group. The longer RT results of the monolingual group in the syntactic condition support the Reordered Access Model (Duffy et al., 1988) and the Subordinate Bias Effect (Rayner, et al., 1994) as both syntactic priming and lexical frequency appear to be competing. This also supports the suggestion of Tanenhaus and Donnenwerth-Nolan (1984)

that listeners access all readings of an ambiguous word even when one of the readings is inappropriate given the preceding syntactic context.

The analysis of lexical frequency was expected to show all groups with shorter RTs for dominant frequency items in the semantic condition since these items were not constrained by cues to one reading over the other, and would therefore conceivably be free of competition. This was found in the results of the monolingual, simultaneous bilingual, and late bilingual groups. This supports the findings of Bilenko et al., (2008) who found longer RTs and an increase in neural recruitment for the subordinate meaning of an ambiguous word. The early bilinguals did not show any effect of lexical frequency in the semantic condition. Although unexpected, this supports the weaker links hypothesis (Gollan & Silverberg, 2001) which suggests that bilinguals use their languages half the time compared to monolinguals, consequently resulting in weaker links between items. Frequency effects within the syntactic condition confirmed my hypothesis that syntactic and semantic processing occurs in a parallel manner at this higher level of processing, as syntactic priming and lexical frequency were found competing for the monolinguals and the simultaneous bilinguals. A main effect of Frequency showed faster RTs for the more dominant reading even when inappropriately-related to the priming homonym. This suggests that both meanings of the homonyms were accessed; supporting the Reordered Access Model (Duffy et al., 1988). The early and late bilinguals revealed longer RTs for the dominant reading (12.63ms longer for the early bilinguals and 17.84ms longer for the late bilinguals) than the subordinate reading, suggesting that lexical frequency is not in competition with syntactic priming, but rather syntactic priming appears more influential as appropriate meanings resulted in shorter RTs.

These results were further investigated in Study 2, the ERP Experiment, the results of which are summarized next. A combination of the results of both studies follows the summary of the results of Study 2.

6.1.2 Event-Related Potential Experiment: Negativities and Positivities

Study 2 set out to analyze possible N400- and P600-like effects found in a neurophysiological method investigating lexical ambiguity resolution in real-time at the level of neurological processing. The results of Study 2 were anticipated to reveal evidence of L2 effects on L1 homonym processing in the timing, generalised scalp distribution, and amplitude of wave forms representative of electrical activity of the brain which occurs with language processing. These results were anticipated to reflect the results found in Study 1 which suggested that the two languages interact due to the acquired strategy of relying on surface cues for lexical ambiguity resolution, with the integration of the two languages affecting L1 processing to a greater extent for the early and late bilinguals and to a lesser extent for the simultaneous bilingual group.

In the analysis of the negative effects, the monolinguals were anticipated to show small negativities in the syntactic conditions due to the appropriate and subordinate reading of the homonym being facilitated for access similarly to the dominant reading. I also anticipated this group to show a greater negativity for low frequency words. These hypotheses were not found as the monolingual group revealed equal negativity for both homonym conditions, regardless of appropriateness and lexical frequency. These findings suggest that this group was not sensitive to surface cues as they processed all prime and target word relationships equally. The bilinguals were anticipated to show greater negativities for the syntactically-constrained inappropriately-related and dominant condition

as this would reflect a processing strategy due to a heightened sensitivity to surface cues due to having learned the L2 through the L1, thereby resulting in an increased metalinguistic awareness in the L1. This hypothesis was upheld. The early bilingual group revealed negativities differing in scalp distribution and earlier latencies of activation by condition and relative to the monolinguals. The late bilinguals revealed negativities with fewer scalp distributions and different latencies by condition and relative to the other groups. These findings suggest that the bilingual groups processed the syntactically-constrained and unconstrained semantic conditions differently, which consequently suggests that the bilinguals were sensitive to the priming and lexical frequency information aiding homonym processing.

In the analysis of the positive effects, the bilingual groups were anticipated to show a P600-like effect when presented with a target word that is inappropriately-related to the priming homonym. This hypothesis was upheld. As expected, the monolingual group did not reveal any evidence of positivities for any condition. All three bilingual groups revealed late frontal and fronto-central positive effects for the inappropriately-related target word in the syntactic condition but not the appropriately-related target word. As the simultaneous bilinguals also revealed evidence of P600-like effects, this suggests that having acquired 2L1s increased their sensitivity to sentential bias, leading them to reanalyse the presentation of an inappropriately-related target word. Further, the P600-like effects were found late, which is supported by the second and third phases of homonym processing proposed to occur at this time as the later stages of homonym disambiguation due to contextual integration (Elston-Guettler & Friederici, 2005).

6.1.3 Validity of the Combination of the Cross-modal Lexical Decision Task with ERPs

As discussed above in section 5.5, the exploratory analyses of the ERP results found in Study 2 were not restricted to the investigation of the behavioural results of Study 1. These ERP analyses were also performed in order to test the ability of ERPs to identify modulations of the amplitudes of waveforms found for both lexical and sentence processing in the presence of a multi-faceted task such as this cross-modal lexical decision task involving auditorily-presented complete sentences with the priming homonym found at a mid-point of the priming sentence. Although it was unknown as to the effect of the task on the reliability of the ERP technique to capture evidence of the underlying mechanisms involved for homonym processing, the results of the analyses appear promising as a useful measure. Although the exploratory results show observable and statistically significant amplitude modulations which differ in latency and anteriority according to the language background of the groups tested, more trials are needed to substantiate or refute the findings presented here.

Indeed, I concede that not all factors have been taken into consideration which may have influenced the results of the bilingual groups in particular. Factors such as the relationship to words in the L2, for example neighbourhood density, might have had an effect on processing in the L1. A limitation of this study is that each participant saw only five items per condition, which is a small number considering the small number of participants this study currently involves. As such, these factors still need to be investigated in order to substantiate or refute the findings presented in this study.

6.2 Behavioural vs. Neurophysiological Effects

The results of the neurophysiological study support the RT and accuracy results of the behavioural study. Overall, the results of both experiments appear to correlate and do

indeed suggest that the initial stage of homonym processing appears to occur in a bottom-up manner for all participants. This is found in evidence of better accuracy to the homonym conditions compared to the pseudoword conditions, longer RTs to the syntactically-constrained conditions compared to the unconstrained conditions, and evidence of negative components (albeit sporadic) for the target words related to the priming homonym conditions compared to the unrelated target words. This evidence counters previous findings of an RT-ERP dissociation whereby RT lexical priming effects are obtained in the absence of N400 lexical priming effects (Brown & Hagoort, 1993) and vice versa (Chwilla et al., 2000), which could be due to the task used. The previous studies reporting RT-ERP dissociations employed single word lexical decision tasks not involving homonym items whereas the current study involved complete auditorily-presented sentences involving homonymous items. Indeed, as was found in a follow-up experiment of the same study by Chwilla, Kolk, and Mulder (2000), they found priming effects occurred for both the N400 and RT when a lexical decision to the prime as well as the target was required. This may explain the lack of an RT-ERP dissociation found in the current study. The processing difficulty found with homonyms themselves may require attention to be drawn to them for processing as well as the processing required for the lexical decision to the target word, thereby eliciting the same RT-ERP association found in the follow-up study of Chwilla and colleagues (2000).

Indeed, the results of Study 2 support the results of Study 1 at the later stage of processing where the greatest differences were found for the early and late bilinguals as they appear to differ in RTs, ERP negativities, and ERP positivities relative to the monolinguals. The combined results of the behavioural and ERP studies for each group are discussed next.

6.3 Monolinguals vs. Bilinguals

The monolinguals and the bilinguals differed in regards to their level of sensitivity to the surface cues aiding lexical ambiguity resolution in the current study. The longer RTs and ERP evidence of equal negativities shown by the monolinguals suggest that syntactic priming context and lexical frequency were competing for processing in the syntactically-constrained appropriately-related and subordinate condition, that of the appropriately-related and subordinate reading of the priming homonym. This supports the Reordered Access Model (Duffy, et al., 1988) as it appears that the subordinate reading is facilitated for access simultaneously and to a similar level with the dominant frequency reading, thus resulting is a slowdown due to competition. Although the ERP results showed equal negativities for all the homonym conditions, regardless of appropriateness and lexical frequency, these were found occurring at a slightly later time compared to the bilingual groups. This delay in ERP latency does not appear to correlate with the monolingual group's RT results for each condition which were captured simultaneously. The RT results showed variation across conditions, whereas the latencies of the N400-like effects did not. For example, given the monolinguals' faster RTs to the dominant reading of the priming homonym in the semantic condition, it was unexpected to find ERP negativities which were equal in amplitude, scalp distribution, and latencies for both the dominant and subordinate reading in the same condition. In this case, there is a RT-ERP dissociation for these particular conditions, which suggest that the lack of difference in N400-like amplitudes reflect the subordinate reading being activated to an equal level of access as the dominant reading due to the biasing sentential context. Coupled with the evidence of a longer RT for this condition, such findings support the Subordinate Bias Effect which postulates the lower frequency item being facilitated for access to an equal level of facilitation as a higher frequency item thanks to sentential context (Rayner et al.,

1994). Indeed, these negativities which were equal across conditions coupled with a lack of observable P600-like effects in the inappropriately-related condition suggest that the monolinguals were not as sensitive to surface cues compared to the late bilinguals. This consequently suggests that lexical access is exhaustive for the monolinguals and that the underlying processing mechanism for this group functions in a parallel manner, which supports the Subordinate Access Effect (Rayner et al., 1994). As expected, there is no strong evidence of reanalysis due to a garden path effect for the inappropriately-related target words at a later stage of processing, suggesting that the monolingual group was not sensitive to the priming sentence frame biasing the reading of the homonym towards only one appropriate meaning.

The results of the bilingual groups in the behavioural and neurophysiological experiments on the other hand, do not support the Reordered Access Model (Duffy et al., 1988) and do not suggest that both meanings of a priming homonym are activated simultaneously and equally for processing. Rather, the findings appear to indicate selective access and that the underlying processing mechanisms function in a serial manner for these groups. The results of the behavioural and neurophysiological analyses for the early and late bilinguals are discussed more in depth in the next section.

6.4 The Bilinguals

Compared to the monolingual group, the early bilingual and late bilingual groups revealed heightened sensitivities to the surface cues aiding lexical ambiguity resolution in the current study. This evidence was found in both the behavioural experiment results and the neurophysiological experiment results.

The early bilingual group shows priming in the syntactically-constrained appropriately-related and subordinate condition (synsub) compared to the syntactically-constrained inappropriately-related and dominant condition (syndom), suggesting that syntactic priming and lexical frequency were not competing for this particular condition as was found for the monolingual group. Compared to the other language groups, the early bilinguals show the greatest effect of priming in the syntactically-constrained appropriately-related and subordinate condition (synsub) and further priming in the unconstrained appropriately-related and subordinate condition (semsub) compared to the non-priming control conditions. However, the early bilingual group does not show evidence of lexical frequency effects in the semantic condition. The results of the ERP analyses support these behavioural findings as the ERP negativities differ in scalp distribution and latencies across conditions. The latencies of the N400-like effects found for the semantic conditions have an elongated period of activation with an earlier onset compared to the syntactic condition, which was found in both the visual evaluation and the statistical analysis. Additionally, the distribution of the N400-like effects for the semantic condition involved a more widespread distribution than those found in the syntactic condition. These findings coincide with the lack of frequency effects found in the behavioural experiment and support the postulations of this group having to search through a larger store of words in order to process the unconstrained and ambiguous primes. It appears that the ambiguity of the unconstrained homonyms were harder to process and consequently resulted in greater processing effects reflected in modulations of the latency, distribution, and amplitudes of the N400-like effects. The latencies to the syntactically-constrained target words appear to occur at an earlier time compared to the monolingual group, which supports the large priming effect found in the RT analysis for this group and is believed to reflect the ease with which they process the

constrained (and therefore disambiguated) homonyms compared to the ambiguous homonyms in the semantic condition. These differences are unique to this group and therefore may be correlated to the age at which the L2 was acquired.

The late bilingual group revealed the greatest effects of syntactic priming and lexical frequency in both the behavioural and ERP results. The faster RTs found for the appropriately-related target word in the syntactic condition and for the ambiguous but dominant reading target word in the semantic condition were supported by ERP evidence of N400-like effects. Contrary to the negativities found for the monolingual group, the late bilinguals reveal variation in the latencies of negative effects according to condition. However, the negativities of the late bilingual group do not show as wide scalp distribution as the other bilingual groups. This particularly contradicts the distribution found for the early bilingual group and suggests that these two groups differ from each other in homonym processing. The late positivities found for the late bilingual group appear to be correlated to the longer RTs which were captured simultaneously as they were processing the inappropriately-related target words in the syntactic condition (syndom). It is believed that these complimentary effects reveal a process of reassessment due to a garden path effect as this group was presented with inappropriately-related target words. These findings support the suggestion of Elston-Guettler and Friederici (2005) which states that a re-evaluation of what was just heard occurs at this later stage of homonym processing. These behavioural and neurophysiological results suggest that the late bilingual group appeared to be most sensitive to the surface cues in this task. These surface cues were both that of syntactic priming and lexical frequency. Thus, it appears that the more recent acquisition of French as L2 has

influenced this group's processing of homonyms even though the task was carried out in the L1.

The RT and ERP results of the simultaneous bilinguals reveal this group being aided by having 2L1s. This group was not slowed down by the interaction of priming and frequency as the monolinguals were, which contradicts previous studies which found a "context-by-frequency-interaction" resulting in longer RTs and larger N400 effects due to greater processing demands (Duffy et al., 1988; Lee & Federmeier, 2011; Sereno et al., 1998; Stanovich & West, 1981). Nor did this group reveal a delay in processing postulated to occur due to the links between lexical items being weaker because of lower frequency usage of each language (Gollan & Silverberg, 2001). In fact, this group revealed faster RTs and longer latencies and more widespread distribution for N400-like effects in the dominant conditions, which suggests that they were sensitive to frequency effects for homonym processing. The simultaneous bilinguals also revealed priming effects in modulations to the amplitude, latency, and distribution of ERP components in the syntactically-constrained conditions compared to the unconstrained and ambiguous semantic conditions. This suggests that this group was more sensitive to both priming and frequency for homonym processing, which is also reflected in this group's better accuracy and faster RTs to the homonym conditions compared to the pseudowords. This suggests that this group's parsing decisions were easier to make when in the presence of priming or lexical frequency, which may reflect a reliance on lexico-semantic information and other surface cues to aid in lexical ambiguity resolution. Such a strategy has been suggested as being due to the L2 influencing processing in the L1 (Dussias & Sagarra, 2007). In this case, the influence of the L2 on the L1 has resulted in a lack of context-by-frequency-interaction slowing them down, and consequently less

processing demands for these conditions. This subsequently supports the suggestion of a shared storage memory system for both languages in which the two language do not compete, but rather facilitate access for like representations regardless of language (Sabourin, Brien, & Burkholder, in press) and where information sources which normally guide one language aid parsing decisions in the other (Dussias & Sagarra, 2007), resulting in better competence in both languages (Bylund, 2009), which has been referred to as a bilingual advantage (Bialystok, 1987, 1999; Wu &Thierry, 2011) due to better overall cognitive control (Costa et al., 2009).

In conclusion, the differences found both behaviourally and neurophysiologically between the monolingual group and the bilingual groups suggest that the acquisition of a L2 has an influence on homonym processing in the L1. Further, the differences found between the bilingual groups themselves appear to correlate with the age at which the L2 is acquired, with the late bilingual group revealing an exponentially marked divergence from the monolingual group. In particular, the distribution and latency of ERP effects, RTs, and accuracy varied by language group according to priming and relatedness, which suggests that AoL2A specifically influences the sensitivity of lexical relationships in homonym processing.

6.5. Implications for the Field of L2 Acquisition

6.5.1 Implications for the Field of L2 Research

The sensitivity of the negative and positive components of ERPs to semantic congruity and grammatical processing has enabled this study to determine whether processing differences found between language groups are mainly due to the fact that

different neural procedures occur due to influences of L2 processing on the L1. Although L2 factors such as language dominance, level of proficiency attained, and AoA have all been suggested as influential properties, this study makes no claims as to the influence of language dominance or proficiency. Although care was taken to exclude L2 dominant participants, I do concede that the mental representations in the minds of bilinguals may not be the same mental representations as those of the monolinguals. The only way to truly investigate the possibility that languae dominance may have had an effect on the results reported here, is by re-examining the results in light of dominance measures, an analysis which will be carried out in future. Further, although proficiency may have also had an effect on the results reported here, an initial analysis of the results taking into consideration the French cloze task scores available at the time of testing does not indicate that proficiency was a factor in the results. The results of the participants in Study 2 were grouped according to Cloze Task scores (Tremblay, 2010), resulting in four groups. Group 1 consisted of participants with a score of 1-10 (8 participants); Group 2's participants had a score of 11-20 (11 participants); Group 3 had a score of 21-30 (7 participants); and Group 4 had a score of 31 and above (15 participants). A general linear model analysis found an effect of relatedness ($p=.034$), but there was no interaction between relatedness and proficiency group ($p=.687$). A planned multiple comparison of group was also not found to be significant ($p=1.000$). Consequently, at least initially, it does not appear that appear that proficiency is influencing the results reported in this study. Language dominance and L2 proficiency are factors which will be investigated further in a follow-up study. On the other hand, I have determined that processing differences found between language groups correspond to the age at which the L2 was acquired. The results of these two studies combined do not strongly support recent suggestions that the earlier a speaker acquires an L2, the more closely he or she will

resemble monolingual native speakers, at least not in the case of two languages being acquired simultaneously from birth. Rather, in the case of 2L1s, it appears that the acquisition of 2L1s aids cognitive processing such that strategies for lexical ambiguity resolution do not compete. Indeed, it is the manner of processing which appears to be sensitive to the influences of L2 acquisition. Whereas the monolingual speakers appear to process the sententially-constrained homonyms in a parallel manner, the bilinguals appear to process them serially. The monolinguals showed evidence of lexical frequency and syntactic priming interacting and competing, which suggests that there was no clear chronology of the theoretical modules generally perceived to be involved in language processing. This supports neither the bottom-up nor the top-down view of language processing, but rather a hybrid view of both. The bilinguals, on the other hand, did not show such an interaction/competition effect between frequency effects and priming. This espouses a serial manner of processing which supports both the bottom-up and top-down view of language processing. This has been evidenced in such findings of Elston-Guettler & Friederici (2005), among others, who have suggested that the initial stages of homonym processing may involve a bottom--up manner of processing, while the later stages of processing involve a top-down manner of processing. The sensitivity of the bilinguals to syntactic priming supports the suggestion that evidence of speaker prediction can be found in these later stages of processing due to the higher levels influencing the lower levels. Thus, the bilinguals were able to rely on contextual integration for disambiguation over lexical frequency.

The results of this study also revealed that acquiring the syntax of an L2 after the age of 6 has two main implications on L1 syntactic processing. First, later L2 acquisition results in a heightened sensitivity to those syntactic processing strategies required for parsing in the L2 similarly influencing syntactic processing in the L1. This consequently suggests that later

L2 acquisition entails integrated mental lexicons as the L2 is found to influence processing in the L1. This indicates that any speaker acquiring an L2 after the age of 6 cannot be assumed to process his or her L1 with the same syntactic processing strategies as a native monolingual. Although this evidence appears to support Pavlenko's (2000) suggestion that "the L1 grammar is simplified or restructured when the L2 has a simpler, more widely-distributed rule", I argue that this is a case of improved efficiency rather than a case of parameter resetting. The results of this study reveal improved efficiency in recognizing cues for lexical ambiguity resolution due to a familiarization of recognizing similar cues in the L2 for L2 acquisition. This can be compared to fine-tuning one's attention span rather than language-specific parameters in the L1 being "reset" by adopting L2 parameters as is suggested by Pavlenko (2000). Secondly, L2 acquirers should not be reported as native monolingual speakers in online behavioural or neurophysiological tasks involving syntactic processes.

6.6 Future Directions

Although this dissertation is a completed project, there are a few issues which have come to my attention only recently, which I intend to resolve. First and foremost, I intend to increase the number of participants and condition items presented in order to test the results discussed here. Secondly, I intend to compare a group of early bilinguals and a group of late bilinguals who have the same proficiency scores in order to confirm that the effect I am reporting is indeed an effect of AoA and not an effect of proficiency. Thirdly, I intend to investigate the possible effect that language dominance may have had on the results of the bilinguals by re-evaluating the results according to participant scores on language dominance measures. Lastly, I intend to investigate cross-linguistic influences in a two-fold manner: (i)

by comparing and contrasting the 28 true cognates found within the existing experimental items, 8 false cognate items, 15 borrowings, and 399 non-cognate items; and (ii) by replicating this study in French testing monolingual French speakers andL1 French bilinguals who vary in the age at which they acquired L2 English.

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Appendix 1: List of Stimuli - Syntactic Condition Primes with Target Words and Frequencies

noun/verb Homonym Primes	Target Words							
	appropriate subordinate reading	freq.	inappropriate dominant reading	freq.	unrelated	freq.	Control Primes	freq.
PINCH	noun	1.58	verb	1.65	SHOE	2.48	PLUM	1.10
	SALT	3.52	SQUEEZE	1.92				
WATCH	noun	3.23	verb	4.28	LAKE	3.19	HOUSE	6.08
	WRIST	2.19	VIEW	2.59				
HUNCH	noun	0.68	verb	0.98	MITTEN	0.54	HEADACHE	2.07
	IDEA	5.31	BACK	5.38				
CHANGE	noun	5.04	verb	5.70	SNOW	3.52	BOOKS	4.78
	COIN	1.94	SWITCH	2.72				
BOX	verb	1.67	noun	4.53	HOTEL	4.51	STUDY	3.21
	FIGHT	4.03	CRATE	0.50				
RING	verb	2.89	noun	3.83	FLOOR	4.50	START	5.03
	BELL	2.71	JEWELLERY	2.48				
REAR	noun	1.95	verb	2.25	WALL	4.59	OFFICE	5.52
	BEHIND	0.75	CHILD	5.46				
SHED	noun	2.02	verb	2.34	KNOB	0.80	TREE	4.03
	BARN	2.16	SKIN	4.40				
SPELL	verb	1.93	noun	2.70	BREAK	4.19	COOK	2.92
	WRITE	4.81	CAST	1.90				
CROSS	verb	3.00	noun	4.40	CALCULATE	1.76	PAINT	3.01
	TRAVERSE	1.50	CRUCIFY	0.78				
STICK	noun	2.99	verb	3.25	KITE	0.53	DOG	4.18
	TWIG	0.26	GLUE	1.43				
TAP	noun	2.40	verb	2.80	DESK	3.78	BAG	3.78
	SINK	2.02	TOUCH	3.03				
PUNCH	verb	0.96	noun	2.39	ROOM	5.56	KISS	2.03
	FIST	2.04	FRUIT	4.00				
MUG	verb	1.25	noun	1.46	SHAKE	2.63	VISIT	3.88
	ROB	1.15	DRINK	3.81				
FALL	noun	4.09	verb	4.17	COFFEE	4.06	HILLS	3.13
	SEASON	5.36	GROUND	5.07				
SPOT	verb	2.28	noun	3.88	CLOUD	2.82	NEED	5.68
	NOTICE	3.24	STAIN	1.12				
PRESS	verb	2.96	noun	4.74	CRAWL	1.14	FIND	5.96
	PUSH	3.53	PUBLISH	2.59				
BLOCK	verb	2.61	noun	3.73	JACKET	3.14	ASSIST	2.59
	OBSTACLE	2.15	CUBE	1.25				
STALL	verb	0.24	noun	1.65	SUBMIT	2.13	GUIDE	3.91
	HINDER	0.70	ENCLOSE	0.83				
GROOM	noun	1.30	verb	1.68	APPLE	3.11	CHILD	5.46
	BRIDE	2.42	COMB	0.57				
DRAFT	noun	2.57	verb	3.22	FOLLOW	4.50	HELP	5.68
	RECRUIT	1.03	SKETCH	1.20				

TRAIN	verb	2.61	noun	4.11	CARESS	0.94	JOIN	4.42
	INSTRUCT	0.78	TRAVEL	3.56				
LOBBY	verb	0.97	noun	2.70	BISHOP	2.47	TALK	5.02
	STRIKE	2.97	ENTRANCE	3.16				
PRUNE	noun	0.52	verb	1.32	BATH	3.25	SHOVEL	0.49
	JUICE	3.08	CUT	4.33				
TIE	verb	2.17	noun	3.32	BIKE	3.06	TOUCH	3.03
	KNOT	1.71	NECK	3.73				
SHOW	noun	5.13	verb	6.16	FLAKE	0.11	PARK	4.00
	THEATRE	4.11	EXHIBIT	1.18				
PUZZLE	verb	2.28	noun	2.48	SPRINKLE	1.14	HURT	3.06
	MYSTIFY	0.85	ASSEMBLE	1.47				
DICE	verb	0.96	noun	1.13	SING	3.09	TASTE	2.07
	CHOP	1.50	GAME	5.48				
STEEL	noun	3.65	verb	4.04	MOUTH	4.01	BOWL	3.26
	METAL	3.69	THIEF	1.91				
HEEL	noun	1.97	verb	2.13	RAIN	3.95	SLEEVE	2.00
	FOOT	4.29	CURE	1.94				

Appendix 2: List of Stimuli - Semantic Condition Primes with Target Words and Frequencies

noun/noun HOMONYM PRIMES	TARGET WORDS							
	appropriate subordinate reading	**freq.**	**appropriate dominant reading**	**freq.**	**unrelated**	**freq.**	**Control Primes**	**freq.**
straw 0.20 / 2.38	hay	1.86	juice	3.08	card	4.32	sparkle	0.93
yard 1.62 / 3.35	amount	4.61	garden	4.55	helmet	1.94	value	4.86
pipe 2.23 / 2.54	water	5.70	smoke	3.42	star	4.74	tires	0.63
diamond 2.37 / 3.22	shape	3.89	jewel	1.82	sparrow	0.02	blanket	2.31
nail 1.13 / 2.07	hammer	2.18	finger	3.29	marker	1.40	plate	3.24
speakers 2.64 / 4.38	music	5.42	orator	1.41	brush	2.56	skaters	0.08
crane 1.06 / 1.14	bird	3.51	machine	4.31	essay	2.94	rainbow	2.36
club 3.74 / 5.32	stick	2.99	disco	2.17	truck	3.21	coat	3.02
fan 0.72 / 3.20	breeze	2.10	admirer	1.06	binder	0.84	mall	1.90
cellar 1.69 / 2.15	vendor	0.82	storage	2.79	napkin	0.54	kennel	0.26
flour 0.65 / 2.61	cookie	0.89	blossom	1.05	picture	4.74	help	4.63
flare 0.96 / 1.81	style	4.93	flame	2.19	couch	1.93	group	5.95
pole 3.12/ 3.74	survey	4.16	rod	2.09	lens	2.59	present	2.42
piece 4.52 / 5.15	quiet	3.98	puzzle	2.19	phone	4.62	talent	3.62
steak 1.85 / 3.77	meat	3.81	post	4.85	clip	1.76	patio	1.32
port 1.39 / 3.32	harbour	2.23	alcohol	3.68	lantern	0.75	movie	4.27
bun 0.65 / 0.78	bread	3.62	hair	4.72	purse	2.02	company	6.13
spring 1.33 / 4.12	bounce	1.42	winter	4.32	pillow	1.73	soup	2.69
boos 0.89 / 1.39	taunting	0.05	whiskey	1.03	summer	5.02	homework	2.05
male 4.24 / 2.37	chap	2.40	stamp	2.51	pork	2.26	car	5.66
pitcher 0.82 / 3.39	container	2.12	baseball	3.11	freezer	1.59	goat	1.61

cap 0.75 / 3.13	lid	2.21	hat	3.56	cat	3.41	camera	3.68
letter 2.27 / 5.07	document	3.45	alphabet	1.07	cracker	1.14	towel	2.02
fir 0.46 / 2.15	tree	4.03	coat	3.02	desk	3.78	house	6.08
sun 4.83 / 4.92	moon	3.38	boy	4.77	pen	2.80	food	5.39
moles 0.11 / 0.66	animal	4.06	warts	0.61	army	5.05	hands	5.04
bank 1.15 / 5.36	river	4.18	money	6.08	chair	3.90	hotel	4.51
mouse 0.82 / 2.27	cheese	3.26	computer	4.81	perfume	1.93	coffee	4.06
ant 0.69 / 2.24	insect	1.78	family	6.00	leaf	2.61	tea	4.04
tail 2.92 / 3.30	spine	2.14	story	5.29	pencil	2.12	gift	3.54

Appendix 3: Stimuli by Conditions

Condition	Auditory Prime	Visual Target	Relationship
synsub	*Albert bought a fine new watch on the weekend.*	WRIST	appropriate subordinate reading
syndom	*Albert bought a fine new watch on the weekend.*	VIEW	inappropriate dominant reading
synunr	*Albert bought a fine new watch on the weekend.*	LAKE	unrelated
synsub control	*Albert bought a fine new house on the weekend.*	WRIST	control
syndom control	*Albert bought a fine new house on the weekend.*	VIEW	control
synunr control	*Albert bought a fine new house on the weekend.*	LAKE	control
semsub	*Peter and Joe knew of a cellar that later proved to be extremely valuable.*	STORAGE	appropriate subordinate reading
semdom	*Peter and Joe knew of a cellar that later proved to be extremely valuable.*	VENDOR	appropriate dominant reading
semunr	*Peter and Joe knew of a cellar that later proved to be extremely valuable.*	NAPKIN	unrelated
semsub control	*Peter and Joe knew of a kennel that later proved to be extremely valuable.*	STORAGE	control
semdom control	*Peter and Joe knew of a kennel that later proved to be extremely valuable.*	VENDOR	control
semunr control	*Peter and Joe knew of a kennel that later proved to be extremely valuable.*	NAPKIN	control
filler	*Zoe really likes her new stuffed panda bear.*	STROMBLE	pseudoword

Appendix 4: List of Stimuli - Filler Sentences with Pseudowords

	FILLER SENTENCE	PSEUDOWORD
1	Isaac will never borrow Mary's vehicle ever again.	BLINT
2	Kevin will retire from his horrible job within the next couple of years.	DRACK
3	Zoe really likes her new stuffed panda bear.	HOOPLES
4	The weather man is predicting a cold winter storm to hit tomorrow.	SLOWPLY
5	Francis owns a large farm at the end of this lane.	COMEL
6	Elaine lives next door to the retired fire chief.	ARKLED
7	Terence will never lend Peter any money ever again.	DEDITUS
8	Candace will guard the front door of the building for us.	KECHIN
9	Nina really should study more for a better grade in her courses.	WETCH
10	Mr. Gyles does not enjoy waiting for any kind of transportation.	VONGY
11	The director will shift the schedules at the beginning of next month.	LOGITUDE
12	Those flowers never bloom in the shade of the garden trees.	BULIPS
13	Douglas is looking forward to spending time on the beach.	CRABBLE
14	Jessica tasted the chicken without any spices first.	EGMAR
15	Harold never experiments with new recipes on his dinner guests.	GROJET
16	Emily has just decided to cut her hair very short.	KARPLE
17	Mark and Yvonne should make a decision about their trip soon.	PLINGT
18	Shelley does not like horribly scary movies.	MOGININ
19	Lucy cannot tolerate people calling during dinner time.	OFFEN
20	Joseph must never alter his grandmother's medication.	QUELTER
21	The two youngest girls will dance at the front of the group first.	DRIVOR
22	This policeman will escort you the rest of the way on foot.	UPPENOR
23	Gwyneth would never agree to such a crazy idea.	RAIPEN
24	Theresa should find the milk at the back of the fridge.	JAYL
25	Norman has never been so angry with his girlfriend.	LEPSET
26	Marianne will quit her secretarial job next week.	CHARTLE
27	I would not ask Tammy about her day if I were you.	BOUFER
28	Stephen will request an extension of his leave of absence.	APINGO
29	Linda must not miss any more classes this semester.	JOURCH
30	Richard will never schedule a meeting for Friday afternoon.	STOODLE
31	Babies usually become hungry every two hours or so.	KREEPEE
32	Daniel hopes to never break another bone in his body.	SKULE
33	Benjamin should not purchase his groceries over the internet.	FUDE
34	Margaret really must visit her neighbours before they leave next month.	BANJOW
35	Fernando was very happy to receive the news from his mother.	MINSE
36	Lucas is looking forward to going to the cottage this weekend.	BELTY
37	The library will close in a few hours.	BANCH
38	Jillian hates having to wear her sister's old clothes.	FLIANGE
39	The neighbours always complain about the noise level.	ZUPLING
40	Martha usually makes a scrumptious dinner with simple food.	YALLO
41	Mr. Smith's flight arrived a lot later than expected.	PLAMPLE
42	Philip always has expensive new shoes from Italy.	GIENDER
43	Teddy may ask about the meeting later this afternoon.	FROMMIN
44	Thomas and Anne arrived at the party quite late yesterday.	STROMBLE
45	Samuel's alarm went off an hour early this morning.	NEXTING
46	George is worried about the future of his father's company.	RELAND

47	Brenda will meet Harry at the corner of Main street in an hour.	DURETS
48	The fire alarm went off as soon as the toast began burning.	ABLECK
49	This magazine is missing a few pages from the back of it.	GORMET
50	Raymond left his number by the door for you to remember.	BACKSET
51	Mathew really should pay more attention to the game.	RACHLER
52	Stephanie should remember her appointment with the dentist today.	BROIN
53	Michelle must include the recipe with her fabulous dish.	SCRAMP
54	Charles and Annie usually gossip after dinner on Sundays.	SPAKULA
55	The movie will start without us if we don't hurry.	HARETS
56	Jennifer was not happy with Stanley's reason for being absent.	WOBBEL
57	Oscar would like to talk with Linda after work today.	GLANGING
58	Leo never called to cancel his appointment for this afternoon.	CRICKAT
59	Jean-Marc will design and make these new jeans in France.	SPIGGLE
60	Heather has never seen an animal react in that way before.	MUNPY

Appendix 5: Consent Form

Information letter and consent/assent form

Research project: Investigating the effects of local syntactic constraints on grammatical processing in French/English bilinguals.
Student investigator: XXXXX **Supervisor:** XXXXXX

Invitation: You are invited to participate in a 45-minute research study conducted by XXXXXX and supervised by XXXXXXXX.

Purpose of the Study: We aim to investigate how bilingual people process spoken and written language.

Participation: You do not have to participate in this research and you may decline at any point.

There are two phases to the project. The first phase consists of a questionnaire designed to obtain some basic information about you and your relative amount of exposure to French and English. The information will help us select participants for the second phase of our research, which consists of a language processing experiment.

After you have completed the questionnaire, we may invite you to complete the second phase of the study. You are under no obligation to do so.

In the second phase of the study, while you listen to recorded sentences, you will be asked to indicate whether or not a string of letters that appears on a computer screen forms an actual word.

The experiment will take place in the Brain and Language Laboratory of Arts Hall (room 408). You may contact XXX or Dr. XXXXX if you wish to receive a certificate of your participation and you may list your participation as a volunteer activity on your CV. This study does not involve risk or deception.

Confidentiality: The information that you share will remain strictly confidential and will be used solely for the purposes of this research. The only people who will have copies of the research data are XXXXX and Dr. XXXXX. Results will be published in pooled (aggregate) format, which means that all answers will be discussed collectively and not released individually.

Anonymity: Your anonymity will be protected in the following manner: immediately upon completion of the experiment, each participant will be assigned a code that will replace the participant's name for all further purposes. Your name will not be disclosed to any third party under any conditions. You do not even have to give us your real name (use a nickname if you wish).

Conservation of data: The data will be collected in rich text format automatically by the software. Two copies will be stored separately on memory sticks kept locked in the offices of the student investigator and Dr. XXXXX for no longer than ten years. Only these two investigators will have access to the electronic data. The pooled data may be referred to afterwards for future related projects of the student investigator.

Voluntary Participation: You are under no obligation to participate in this research and if you do choose to participate, you may withdraw from the experiment at any time. If you choose to withdraw, all data gathered up to the time of withdrawal will be discarded. No negative consequences will result either from your refusal to participate in the study or from withdrawing from the study.

Remuneration: We are regretfully unable to compensate you for your participation in this experiment.

Information about the Study Results: The results of this study will be available to you if you are interested. If you need any additional information feel free to contact XXXXX (email address) or Dr. XXXXX (email address).

If you have any questions with regards to the ethical conduct of this study, you may contact the Protocol Officer for Ethics in Research, University of Ottawa.

Acceptance: Please sign below if you agree to participate in the above research study conducted by XXXXX (PhD candidate, Department of Linguistics, Faculty of Arts, University of Ottawa) under the supervision of Dr. XXXXX.
Thank you for your time and consideration. You are free to keep a copy of this document for your records.

Participant's signature: _____ Date: _____
Researcher's signature: _____ Date: _____

Appendix 6: Language Background Questionnaire

Participant's Code Name:	Date of participation:

Thank you for agreeing to fill out this questionnaire, which is part of a graduate research project being conducted by XXXXX under the supervision of Dr. XXXXX of the Linguistics Department at the University of Ottawa. There are two phases to the project. The first phase consists of a questionnaire designed to obtain some basic information about you and about your relative amount of exposure to French and English. The information you provide will help us select participants for the second phase of our research, which consists of a language processing experiment.

Your completion of this questionnaire is **voluntary.** You will not be compensated in any way for filling it out. All of the information you provide will be held in strict confidence and will not be shared with anyone else or used for any other purpose.

Background Questionnaire

Please fill in and/or check as much information as you can.

Date of Birth			
Gender	male ◻	female ◻	
Preferred language of communication	French ◻	English ◻	both ◻
I normally **write** with my...	right hand ◻	left hand ◻	both ◻
I have a known hearing impairment in my...	right ear ◻	left ear ◻	neither ◻

1. Which language(s) did your parents use to interact with you from birth?
   (1) _____ (2) _____
   - Do you still speak this/these language(s) natively? ◻ yes ◻ no
     If no, specify which language and your level of proficiency:
     Language: _____
     Level of oral proficiency: ☐ very low ☐ low ☐ intermediate ☐ near-native ☐ native
     Level of written proficiency: ☐ very low ☐ low ☐ intermediate ☐ near-native ☐ native
     Comments on proficiency:
     _____
2. When do you feel you became bilingual?
   _____
3. Has your language use changed over time? ◻ yes ◻ no
   - If yes, how so? When and why did it change?
     _____
4. Which language(s) did your parents favour for use in society and with friends?
   _____
   - Is this different from what they spoke with you? ◻ yes ◻ no
   - If yes, please specify.
     _____

Amount of **language**	PERCENTAGES

used.....		0	10	20	30	40	50	60	70	80	90	100	Notes
by maternal grandparents	French												
	English												
with you	Other												
by paternal grandparents	French												
	English												
with you	Other												
by mother	French												
	English												
with you	Other												
by father	French												
	English												
with you	Other												
generally in home	French												
	English												
from birth to pre-school	Other												
generally in home	French												
	English												
from pre-school to 14 years old	Other												
generally in home	French												
	English												
from 14 years old to departure	Other												
generally in home	French												
	English												
in last 5 years and currently	Other												
as language of communication	French												
with friends	English												
in pre-school	Other												
as language of communication	French												
with friends	English												
in primary school	Other												
as language of communication	French												
with friends	English												
in middle school	Other												
as language of communication	French												
with friends /community	English												
in childhood	Other												
in current workplace	French												
	English												
	Other												
in present daily use overall	French												
	English												
	Other												

Frequency of language use and exposure

In your childhood, **how often** did you interact with....	all day every day	every day	every couple of days	once a week	every couple of weeks	once a month	a few times a year	once a year	less than once a year
your maternal grandparents									
your paternal grandparents									
your mother									
your father									
your community									
friends in school									
friends outside of school									

Context of Language Acquisition

Please indicate which language(s) you have learned in the following context by writing the number of months, semesters or years you have been learning them in the appropriate squares. Also indicate the dates (e.g. 1990-2000) or age(s) involved. Please let the researcher know if you need additional columns.

Language / Context		English			
Home					
Nursery/ kindergarten	language of instruction				
	classes				
Elementary school	language of instruction				
	classes				
High school	language of instruction				
	classes				
College	language of instruction				
	classes				
University	language of instruction				
	classes				
Language school	language of instruction				
	classes				
Other: (specify)					

Thank you!

Merci!

Appendix 7: Participant Information – Study 1

Study 1: Behavioural Experiment – Participant Information

PARTICIPANT	DATE	SCRIPT	VERSION	GROUP	L1	NOTES	SEX	AGE
s03ST	15-Jul-08	List 1	English	SIMULTANEOUS	both		f	32
s14HT	28-Jul-08	List 5	English	SIMULTANEOUS	both		m	30
s15CC		List 6	English	SIMULTANEOUS	both		f	31
s16PD		List 1	English	SIMULTANEOUS	both		m	32
s28SD	02-Mar-09	List 2	English	SIMULTANEOUS	both		f	29
s38JE	08-Jul-09	List 6	English	SIMULTANEOUS	both		f	28
s42BG	22-Jul-09		English	SIMULTANEOUS	both		f	20
S44SM	27-Jul-09		English	SIMULTANEOUS	both		f	19
s46JJ	28-Jul-09		English	SIMULTANEOUS	both		m	31
s49ES	06-Aug-09		English	SIMULTANEOUS	both		f	26
s061LB	01-Oct-09	List 4	English	SIMULTANEOUS	both		f	19
s073JW	04-Nov-09	List 3	English	SIMULTANEOUS	both		m	23
s074KA	04-Nov-09	List 4	English	SIMULTANEOUS	English		f	22
s12EJ	24-Jul-09	List 3	English	EARLY	English		f	25
s13KF	28-Jul-08	List 4	English	EARLY	English		f	30
s43ET	23-Jul-09		English	EARLY	English		f	21
s47TH	28-Jul-09		English	EARLY	English		f	26
s48AP	31-Jul-09		English	EARLY	English		f	26
s50DL	15-Sep-09	List 6	English	EARLY	English		f	20
s053SS	23-Sep-09	List 3	English	EARLY	English		f	19
s056ML	29-Sep-09	List 6	English	EARLY	English		f	23
s062CC	06-Oct-09	List 5	English	EARLY	English		f	18
s067JC	14-Oct-09	List 1	English	EARLY	English	Late?	f	22
s076SB	18-Nov-09	List 3	English	EARLY	English		f	25
s079JS	27-Nov-09		English	EARLY	English	LG3	f	21
s080AB	30-Nov-09		English	EARLY	English	LG3	m	21
s072FL	22-Oct-09	List 2	English	Early	English		f	18
s19JJ	15-Oct-08	List 5	English	EARLY	English		f	21
S20aND	10-Oct-08	List 6	English	EARLY	English		f	29
s20bLM	17-Oct-08	List 2	English	EARLY	English		f	20
s27ES	17-Jun-09	List 6	English	EARLY	English		f	19
s29AJ	04-Mar-09	List 4	English	EARLY	English		f	21
s30MB	23-Jun-09	List 6	English	EARLY	English		f	27
s31ML	25-Jun-09	List 1	English	EARLY	English		f	24
s32AP	25-Jun-09	List 2	English	EARLY	English		f	23
s35AL	03-Jul-09	List 3	English	EARLY	English		f	27

s40JB	21-Jul-09	List 2	English	LATE	English		f	28
s45MR	27-Jul-09		English	LATE	English		m	30
s052CL	23-Sep-09	List 2	English	LATE	English		f	18
s059CD	30-Sep-09	List 3	English	LATE	English		m	18
s064KW	07-Oct-09	List 2	English	LATE	English	bilingual at 18	f	29
s082MC	07-Dec-09		English	LATE	English		f	23
s086EL	16-Aug-10		English	LATE	English		f	29
s17CC	06-Oct-08	List 3	English	LATE	English		f	23
s22PH	05-Nov-08	List 4	English	LATE	English		m	31
s24ML	12-Nov-08	List 5	English	LATE	English		f	25
s25	19-Nov-08	List 4	English	LATE	English		f	22
s34ML	30-Jun-09	List 1	English	LATE	English	English dom.	f	27
s36JM	06-Jul-09	List 4	English	LATE	English		f	28
s083CW	07-Dec-09		English	MONOLINGUAL	English		f	21
s084BB	16-Dec-09		English	MONOLINGUAL	English		f	23
s087SB	02-Sep-11	List 1	English	MONOLINGUAL	English		f	20
s054BM	23-Sep-09	List 4	English	MONOLINGUAL	English	not bilingual	f	17
s058MP	30-Sep-09	List 2	English	MONOLINGUAL	English	COMPUTER CRASHED: NO DATA	f	24
s060KC	30-Sep-09	List 4	English	MONOLINGUAL	English		f	19
s063AP	07-Oct-09	List 1	English	MONOLINGUAL	English		m	20
s065ER	08-Oct-09	List 3	English	MONOLINGUAL	English		f	
s066ND	08-Oct-09	List 4	English	MONOLINGUAL	English		f	19
s070SR	21-Oct-09	List 4	English	MONOLINGUAL	English		f	19
s071EF	21-Oct-09	List 2	English	MONOLINGUAL	English		f	18
s051CG	22-Sep-09	List 1	English	MONOLINGUAL	English	not bilingual	f	20
s07VB	18-Jul-08	List 2	English	SIMULTANEOUS	French	EXCLUDED	f	25
s33AL	26-Jun-09	List 2	English	EARLY	French	EXCLUDED	f	24
s39MF	17-Jul-09	List 1	English	EARLY	French	EXCLUDED	m	34
s075VD	18-Nov-09	List 1	English	EARLY	French	EXCLUDED	f	24
s078GO	26-Nov-09	List 2	English	EARLY	French	EXCLUDED	f	22
s085MC	16-Dec-09		English	EARLY	French	EXCLUDED	f	21
s18MB	08-Oct-08		English	LATE	French	EXCLUDED	f	25
s23AS	05-Nov-08	List 5	English	LATE	french	EXCLUDED	f	28
s37AL	07-Jul-09	List 5	English	LATE	french	EXCLUDED	f	24
s068CM	15-Oct-09	List 2	English	LATE	French	EXCLUDED	f	28
s077IB	19-Nov-09	List 3	English	LATE	French	EXCLUDED	f	20
s081FE	03-Dec-09		English	LATE	French	EXCLUDED	f	26
s057AL	30-Sep-09	List 1	English	EARLY	French dominant	EXCLUDED	f	18
s10AP	20-Jul-08	List 3	English	LATE	French?	EXCLUDED	f	24
s055CT	23-Sep-09	List 5	English	EXCLUDED	L1 Cantonese, L2 French, L3 English	EXCLUDED	f	22

s21	20-Oct-08	excluded	excluded	EXCLUDED	multi	EXCLUDED	f	20
s41SF	22-Jul-09		English	EXCLUDED	multi	EXCLUDED	f	19
s069TN	21-Oct-09	List 3	English	EXCLUDED	multi	EXCLUDED	f	20
s01CC	13-Jul-08	List 2	FRENCH	SIMULTANEOUS	both	EXCLUDED	f	31
s06PD	17-Jul-08	List 5	FRENCH	SIMULTANEOUS	both	EXCLUDED	m	32
s08	18-Jul-08	List 6	FRENCH	SIMULTANEOUS	both	EXCLUDED	f	25
s26	10-Jun-09	List 6	FRENCH	SIMULTANEOUS	both	EXCLUDED	f	29
s02bMF	15-Jul-08	Flist 3	FRENCH	LATE	French	EXCLUDED	m	32
s04MT	16-Jul-08	Flist 1	FRENCH	LATE	French	EXCLUDED	f	28
s05SR	17-Jul-08	Flist 4	FRENCH	LATE	French	EXCLUDED	f	24
s09HT	18-Jul-08	Flist 1	FRENCH	LATE	French	EXCLUDED	f	29
s11MB	21-Jul-08	Flist 3	FRENCH	LATE	French	EXCLUDED	m	35
s02AP	17-Jul-08	Flist 2	FRENCH	LATE	French	EXCLUDED	m	26

Appendix 8: Participant Information - Study 2

Study 2: ERP Experiment – Participant Information

PARTICIPANT	DATE	SCRIPT	VERSION	GROUP	L1	SEX	AGE	PROFICIENCY SCORE	SELF-REPORT LEVEL	NOTES
s001CD	15-Sep-10	1	English	LATE	English	M	22	18		noisy FP1, FP2
s002HV	15-Sep-10	1	English	SIMULTANEOUS	English	M	24	38	native	
s004AR	17-Sep-10	1	English	LATE	English	F	22	25	intermediate	
s006MB	20-Sep-10	1	English	EARLY	English	F	29	37	near-native	noisy VEOG
s008SB	13-Dec-10	1	English	EARLY	English	F	25	31		low impedences
s009ES	10-Jan-11	1	English	MONOLINGUAL	English	M	28	4		noisy P5, OZ, C3
s010OW	04-Feb-11	1	English	MONOLINGUAL	English	F	23	18		
s011JW	10-Feb-11	1	English	SIMULTANEOUS	both	M	23	33		
s012JC	11-Feb-11	1	English	EARLY	English	F	22			
s013RT	26-Oct-11	1	English	LATE	English	M	33	41		left handed
s014BM	09-Nov-11	1	English	LATE	English	M	22	14	intermediate	
s015TD	30-Mar-12	4	English	MONOLINGUAL	English	F	19	19	low	monolingual
s016CS	13-Apr-12	2	English	EARLY	English	F	21	11		
s017LM	02-May-12	2	English	EARLY	English	M	21	26		
s018AP	08-May-12	3	English	SIMULTANEOUS	both	f	20	34	native/near-native	
s019SG	19-Jun-12	4	English	EARLY	English	F	24	?		
s020CG	14-Jan-13	5	English	MONOLINGUAL	English	f	25	3	not bilingual	
s021RM	16-Jan-13	6	English	MONOLINGUAL	English	f	20	7		
s021RMb	16-Jan-13	3	English	MONOLINGUAL	English	f	20	7		
s022CJ	17-Jan-13	2	English	LATE	English	f	20	20		
s023EO	18-Jan-13	3	English	MONOLINGUAL	English	f	23	6		monolingual
s023EOb	18-Jan-13	6	English	MONOLINGUAL	English	f	23	6		
s024DC	22-Jan-13	5	English	MONOLINGUAL	English	m	20	11		
s024DCb	22-Jan-13	2	English	MONOLINGUAL	English	m	20	11		
s026IM	23-Jan-13	4	English	EARLY	English	f	21	27		
s027AB	24-Jan-13	5	English	SIMULTANEOUS	both	m	20	36		
s028SK	28-Jan-13	6	English	EARLY	English	f	23	21		
s029KP	29-Jan-13	2	English	EARLY	English	f	22	27		
s030CM	30-Jan-13	3	English	EARLY	English	f	21	34		
s030CMb	30-Jan-13	4	English	EARLY	English	f	21	34		
s031ET	31-Jan-13	5	English	LATE	English	f	20	26		
s032SC	04-Feb-13	6	English	MONOLINGUAL	English	f	22	1		
s033KH	05-Feb-13	2	English	LATE	English	f	20	16		
s036ES	13-Feb-13	5	English	LATE	English	f	21	19		
s037ND	18-Feb-13	6	English	LATE	English	f	22	13		
s040JM	19-Feb-13	4	English	MONOLINGUAL	English	f	24			
s041SR	22-Feb-13	2	English	EARLY	English	f	20	35		

s042SS	05-Mar-13	3	English	LATE	English	f	23			
s043PD	11-Apr-13	4	English	SIMULTANEOUS	both	M	37	35	native – both	
s043PDb	11-Apr-13	5	English	SIMULTANEOUS	both	M	37	35		
s044CG	15-Apr-13	6	English	LATE	English	M	32	9		
s045ST	16-Apr-13	2	English	SIMULTANEOUS	both	f	37	37		
s046SB	17-Apr-13	3	English	MONOLINGUAL	English	f	21			
s047CC	17-Apr-13	4	English	SIMULTANEOUS	both	f	36			data a bit noisy
s003JB	17-Sep-10	1	English	EXCLUDED	French	M	26			L1F
s005ND	17-Sep-10	1	English	EXCLUDED	French	F	30	35		L1F
s007LW	22-Oct-10	1	English	EXCLUDED	English	F	29	10		L3
s025EM	23-Jan-13	3	English	EXCLUDED	both	f	20	28		French dominant
s034MB	06-Feb-13	3	English	EXCLUDED	English	f	22	0		L2 ASL
s035WH	11-Feb-13	4	English	EXCLUDED	English	m	28	?		L3
s038PJ	18-Feb-13	2	English	EXCLUDED	French?	f	18	9		French dominant
s039RJ	18-Feb-13	3	English	EXCLUDED	French	f	21			L1F

Appendix 9: Percentage of Items Removed by LG in RT Analysis

% of removed items ± 2 stdev	monolinguals	simultaneous bilinguals	early bilinguals	late bilinguals	TOTAL %
Condition 1	5	8.57	4	5.71	5.58
Condition 2	5	4.76	4.67	9.52	5.77
Condition 3	5	5.71	6	7.62	5.96
Condition 4	3.74	3.81	3.33	3.81	3.65
Condition 5	5	3.81	2.67	0.95	3.27
Condition 6	2.5	3.81	2.67	4.76	3.27
Condition 7	3.75	2.86	5.33	4.76	4.23
Condition 8	5	5.71	4	4.76	4.81
Condition 9	3.13	3.81	7.33	5.71	5
Condition 10	2.5	2.86	1.33	1.9	2.12
Condition 11	2.5	3.81	2	2.86	2.69
Condition 12	3.75	2.86	2.67	1.9	2.88
TOTAL %	3.91	4.37	3.83	0.05	4.1

Appendix 10: Means by Language Group

	monolinguals		simultaneous bilinguals		early bilinguals		late bilinguals		Total	
Condition	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
synsub	784.0635	135.6175	727.3800	117.0481	744.7292	122.2262	746.7540	106.3509	753.7377	122.7155
syndom	714.9987	103.3950	705.9878	105.4148	754.3762	132.3055	772.5632	163.7912	736.1617	127.2972
synunr	708.3002	107.8798	693.2503	108.6692	716.8531	144.9286	774.3973	133.2478	721.0750	126.2955
semsub	736.9079	112.8860	735.2838	173.3189	744.9561	141.9698	779.7626	143.4356	747.5549	140.0620
semdom	703.9933	111.5320	670.9190	96.8324	743.8018	125.0490	695.2459	102.9789	707.0317	112.7711
semunr	736.6905	125.7025	710.6577	117.0148	720.4607	107.0522	732.1547	117.5762	725.8363	115.8684
synsub control	756.0717	131.6879	750.9965	66.3601	812.8564	133.9401	735.9767	90.1896	764.7990	114.9451
syndom control	714.5744	100.7452	753.6773	81.9944	710.9958	69.1783	678.0964	74.9217	710.4162	84.8678
synunr control	740.1100	110.7072	698.2327	105.0799	726.4676	117.5080	663.6628	81.4932	709.9863	106.2896
semsub control	737.7544	129.3974	726.0800	98.4409	758.0947	153.8520	688.0232	96.9213	728.2449	123.7062
semdom control	709.3145	107.6471	654.1588	66.1514	713.2873	125.7243	711.3278	95.9442	702.0460	103.6622
semunr control	735.9605	131.4945	713.8543	61.3178	720.5479	113.9099	695.3101	91.1214	717.8471	106.2438
RT pseudoword	821.3078	135.4484	826.1831	114.5580	851.3264	167.5296	846.9278	101.6767	836.7052	136.8224
RT Overall	95.9259	4.5575	98.0498	2.5947	96.7702	4.1923	97.0486	3.5543	96.8209	3.9435
Accuracy homonyms	93.3224	5.4476	96.1769	3.6860	95.3774	3.9226	92.9667	8.7591	94.5098	5.4952
Accuracy pseudowords	95.8609	3.6843	97.3947	2.9076	96.3414	3.0935	96.3155	3.6018	96.4010	3.3518
Accuracy overall	739.7787	97.6496	720.0112	99.9697	751.3354	115.3549	758.3178	98.6531	742.8643	103.0817
% questions answered	87.3938	10.3113	85.9167	12.7621	81.9755	10.8491	77.0985	18.0154	83.4134	13.2269

Appendix 11: Results of 4-way ANOVA in the ERP Statistical Analysis of the Priming Condition by Time Window

FACTOR / TIME	anteriority x LG	anteriority, laterality x LG	condition x anteriority x LG	condition, anteriority, x laterality	LG	multiple comparisons
400-450ms	(F(15,200)=3.211, p<.001)					
450-500ms	(F(15,200)=.2.267, p=.006)			(F(90,3600)=1.237, p=.066)		
500-550ms						
550-600ms						
600-650ms	(F(15,200)=1.618, p=.071)					
650-700ms	(F(15,200)=2.362, p=.004)				(F(3,40)=2.845, p=.050)	LG2 vs. LG3 (p=.072)
700-750ms	(F(15,200)=1.977, p=.018)				(F(3,40)=2.599, p=.065)	
750-800ms	(F(15,200)=1.027, p=.037)	(F(90,1200)=1.227, p=.080)				
800-850ms	(F(15,200)=2.472, p=.002)				(F(3,40)=2.300, p=.092)	
850-900ms			(F(45,600)=1.457, p=.030)			
900-950ms	(F(15,200)=1.824, p=.033)		(F(45,600)=2.060, p<.001)			
950-1000ms	(F(15,200)=2.142, p=.009)		(F(45,600)=1.815, p=.001)			

Appendix 12: Results of Synsub Priming and Non-priming Condition by Time Window

FACTOR / TIME	laterality x LG	anteriority x LG	condition x anteriority	anteriority x laterality x LG	condition x lat x ant. x LG	LG	multiple comparisons
400-450ms	(F(15,200)=3.447, p<.001)		(F(6,240)=2.3100, p=.035)		(F90,1200)=1.213, p=.093)		
450-500ms	(F(15,200)=3.196, p<.001)						
500-550ms	(F(15,200)=2.330, p=.004)						
550-600ms	(F(15,200)=2.182, p=.008)						
600-650ms	(F(15,200)=2.207, p=.007)		(F(6,240)=1.868, p=.087)			(F(3,40)=3.313, p=.030	LG2 vs. LG3 (p=.025)
650-700ms	(F(15,200)=3.227, p<.001)					(F(3,40)=4.723, p=.006)	LG3 vs. LG2 (p=.006) LG3 vs. LG5 (p=.091)
700-750ms	(F(15,200)=2.662, p=.001)					(F(3,40)=3.602, p=.021)	LG3 vs. LG2 (p=.036) LG3 vs. LG5 (p=.077)
750-800ms	(F(15,200)=2.673, p=.001)			(F(90,1200)=1.269, p=.050)			
800-850ms	(F(15,200)=3.353, p=.001)						
850-900ms	(F(15,200)=2.830, p<.001)			(F(90,1200)=1.251, p=.062)			
900-950ms	(F(15,200)=1.501, p=.090)	(F(15,200)=3.829, p<.001			(F(90,1200)=1.338, p=.022)		
950-1000ms	(F(15,200)=4.037, p<.001)			(F(90,200)=1.274, p=.048	(F(90,1200)=1.27138, p=.050)		

Appendix 13: Series of Figures 35-38 of Grand Averaged Responses to Pseudowords vs. Real Words

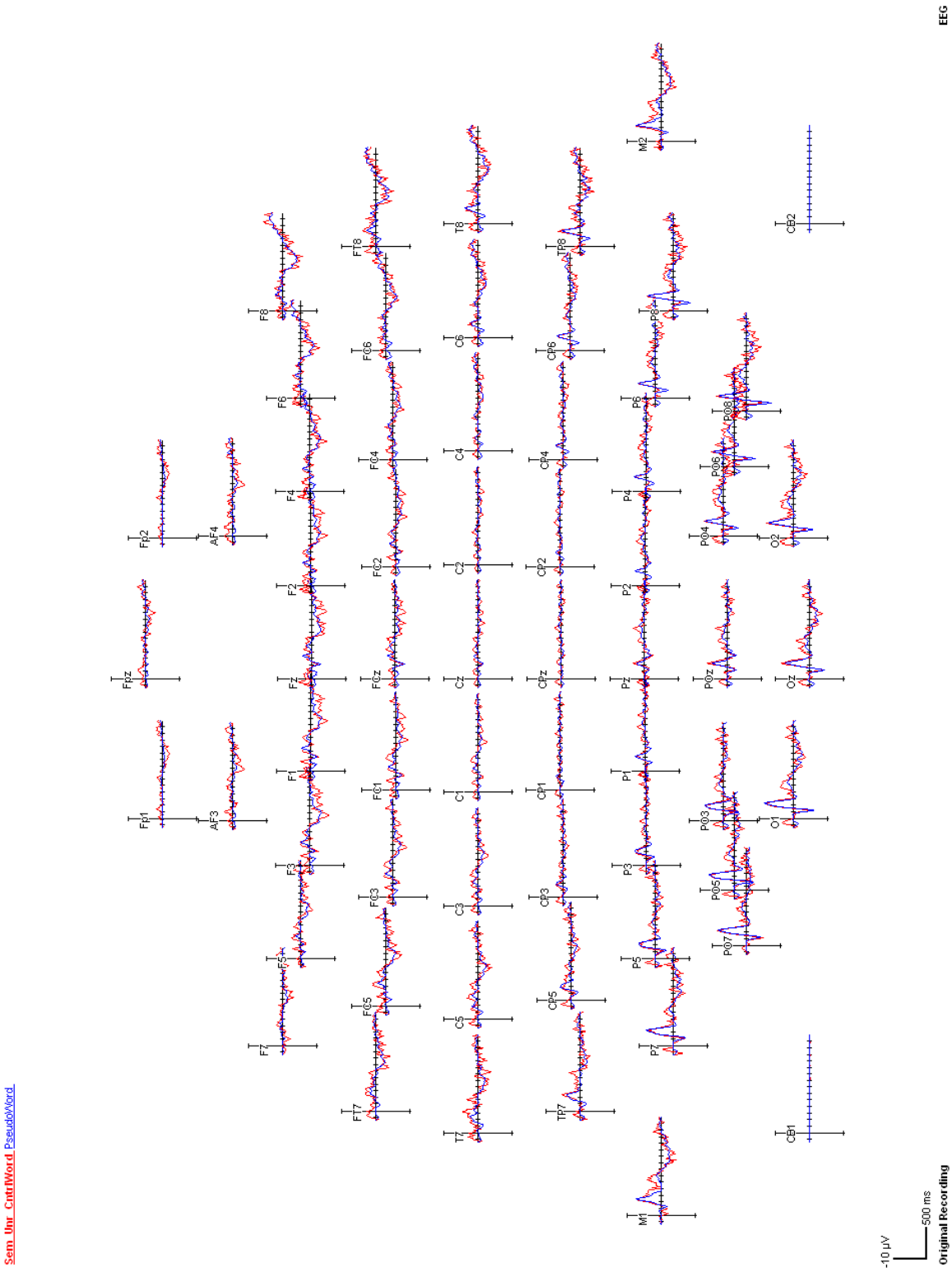

Figure 44: Monolingual Responses to Pseudowords vs. Real Words

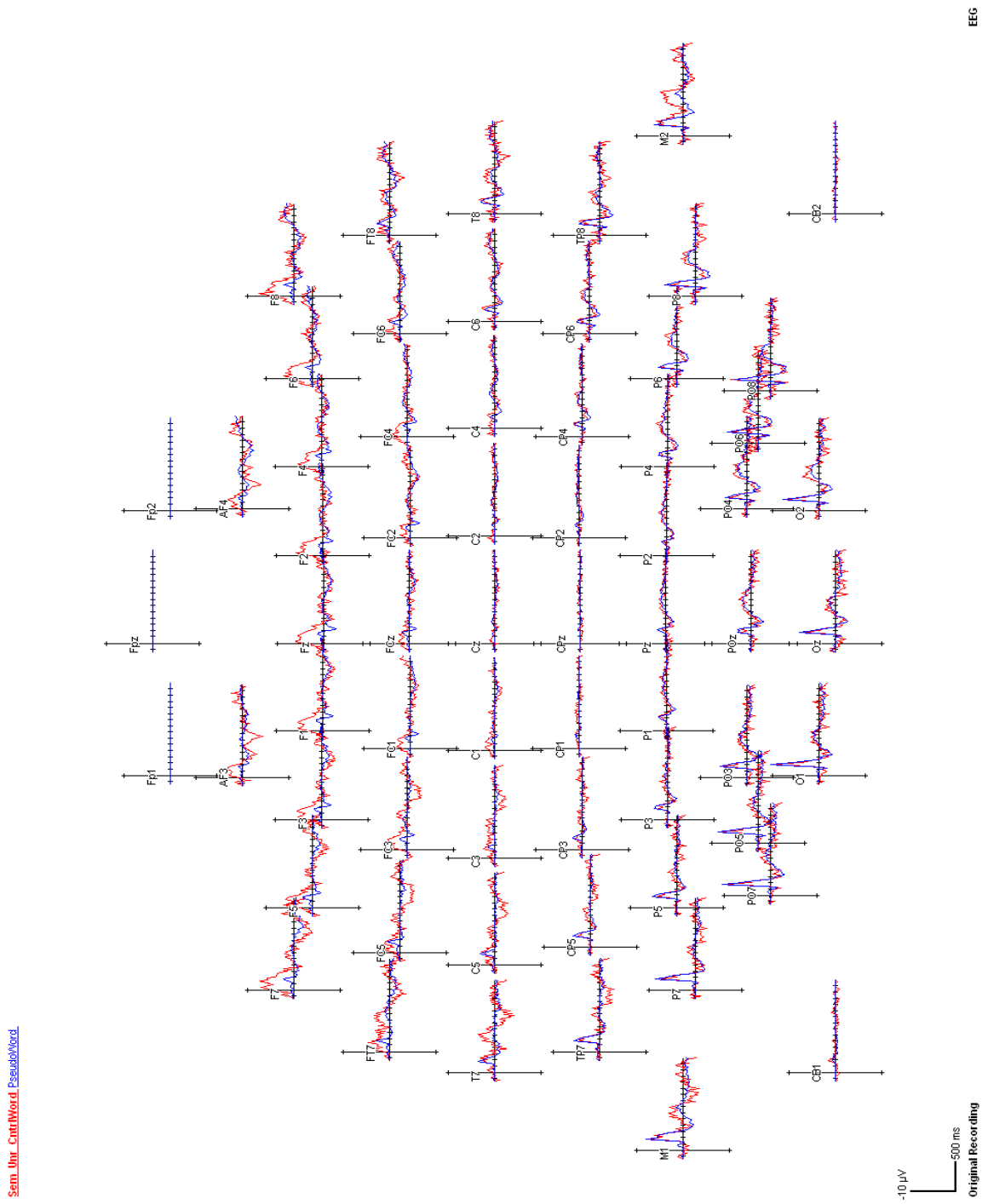

Figure 45: Simultaneous Bilinguals' Responses to Pseudowords vs. Real Words

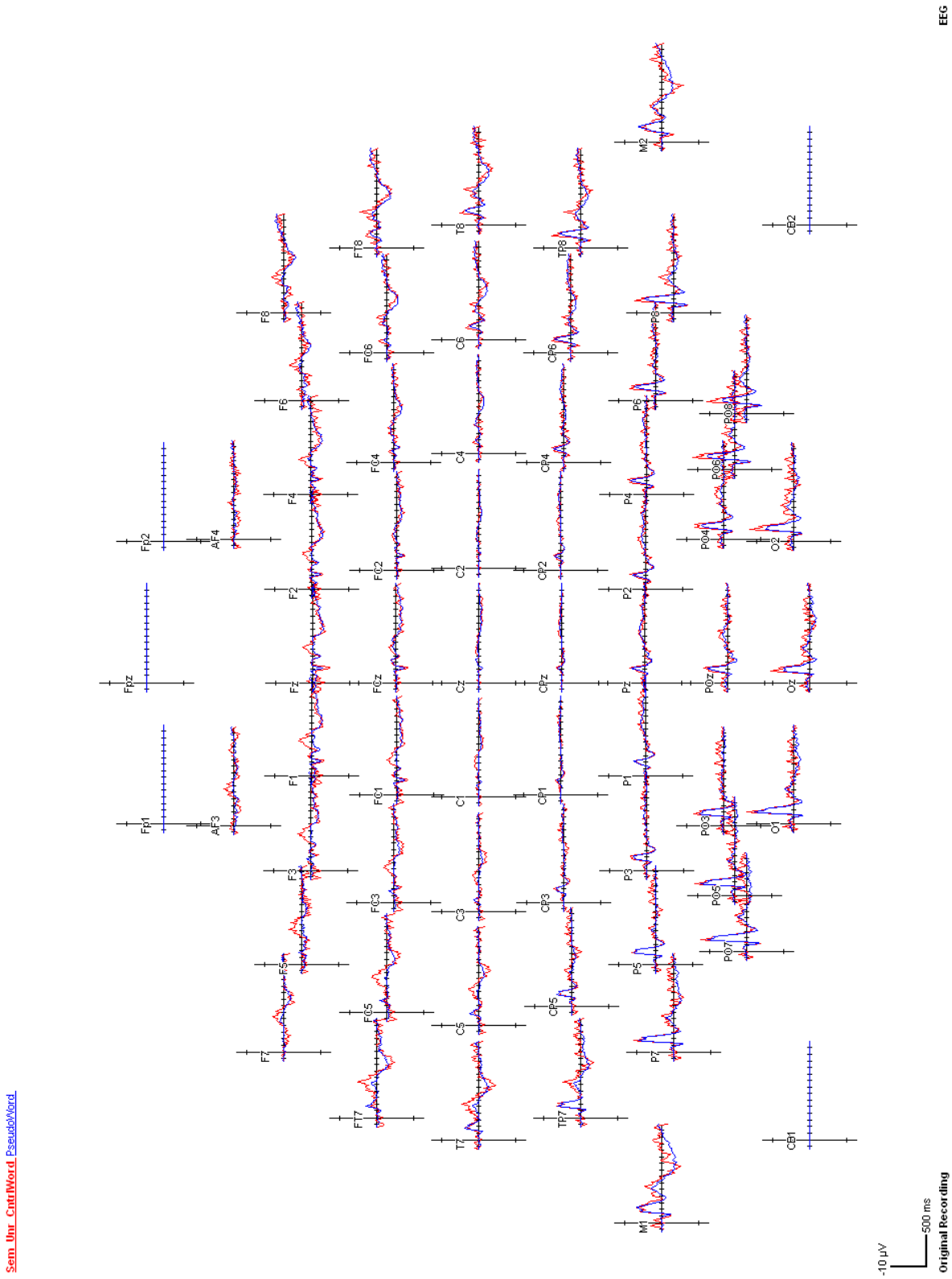

Figure 46: Early Bilinguals' Responses to Pseudowords vs. Real Words

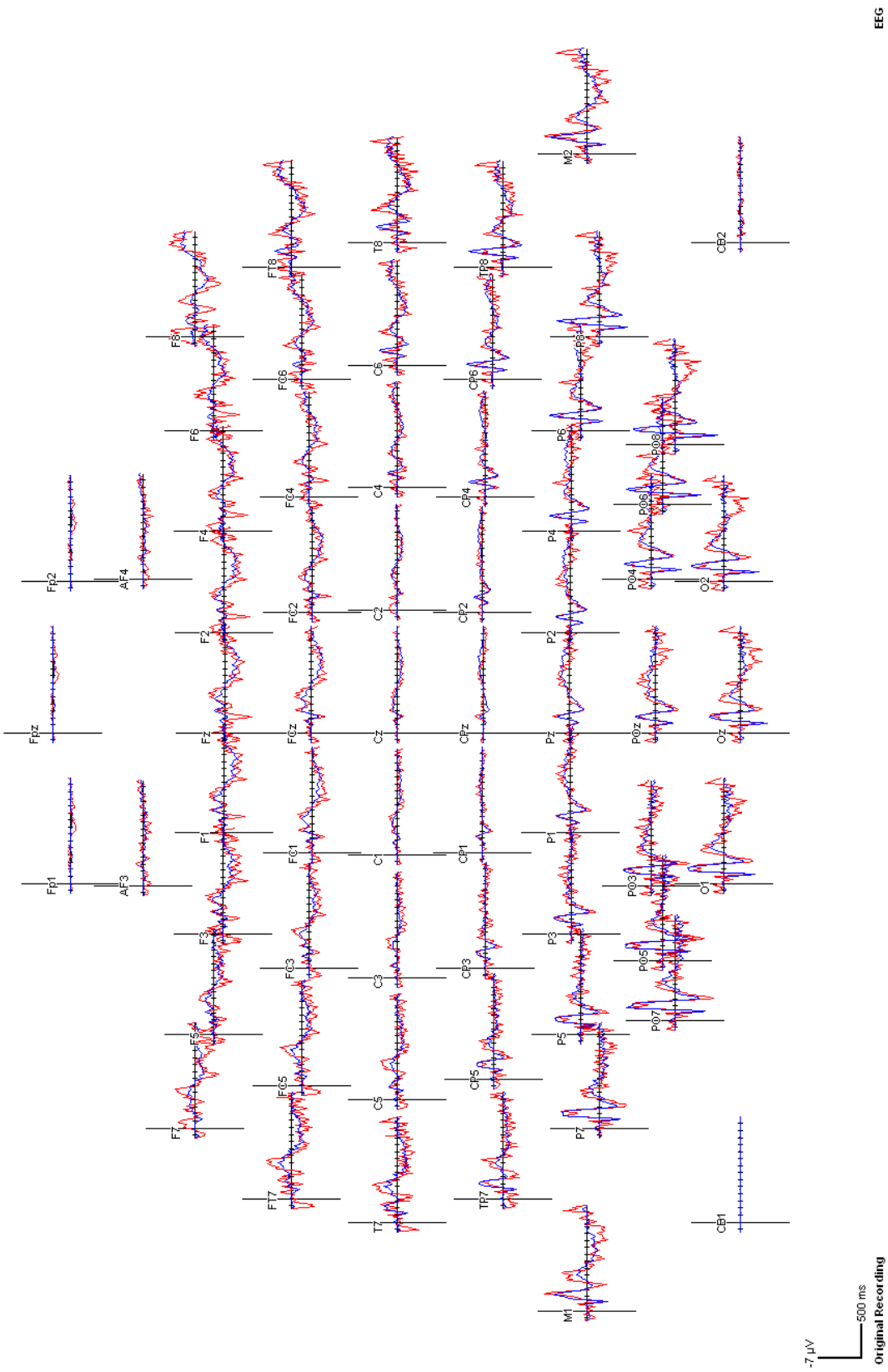

Figure 47: Late Bilinguals' Responses to Pseudowords vs. Real Words