BRAIN BASES FOR FIRST LANGUAGE LEXICAL ATTRITION

IN BENGALI-ENGLISH SPEAKERS

by

HIA DATTA

A dissertation submitted to the Graduate Faculty in Speech-Language-Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2010

This manuscript has been read and accepted for the
Graduate Faculty in Speech-Language-Hearing Sciences in satisfaction of the
dissertation requirement for the degree of Doctor of Philosophy.

Date	**Valerie L. Shafer, Ph.D.** **Co-Chair of** **Examining Committee**	**Loraine K. Obler, Ph. D.** **Co-Chair of** **Examining Committee**

Date

Klara Marton, Ph.D.
Executive Officer

Martin R. Gitterman, Ph.D.
Supervision Committee Member

Mira Goral, Ph.D.
Supervision Committee Member

Karen Froud, Ph.D.
External Reviewer

THE CITY UNIVERSITY OF NEW YORK

Abstract

BRAIN BASES FOR FIRST LANGUAGE LEXICAL ATTRITION

IN BENGALI-ENGLISH SPEAKERS

by

Hia Datta

Adviser: Professor Loraine K. Obler & Valerie L. Shafer

Change of first language (L1) status from the most stable language to a less accessible language over the life-span of a bilingual individual is termed ‘language attrition’. Such a shift in ease of L1 access has been reported to affect the lexicon (Pelc, 2001) more than other aspects of language. However, whether L1 attrition is affected by reduced L1-strength or increased second language (L2) interference is unresolved. This study was designed to understand the relative contributions of L1-strength (Ebbinghaus, 1885; Paradis, 2001, 2007) and L2-interference (Loftus & Loftus, 1980; Gürel, 2004) towards L1 attrition in L2-dominant bilingual individuals, and how attrition is affected by language use and proficiency.

We used a cross-modal (picture-auditory word) and cross-linguistic (Bengali-English) lexical priming paradigm in order to test the nature of L1-L2 interaction in 27 Bengali-English-speaking individuals. Participants were divided into two groups (L1-dominant and L2-dominant) varying in relative L1-L2- proficiency. Familiarity ratings for English words and their translation equivalents permitted generating four word-pair categories: HighEnglish-HighBengali, LowEnglish-LowBengali, HighEnglish-LowBengali and LowEnglish-HighBengali. Reaction time (RT) and Event related potentials (ERPs) were recorded to a syllable-judgment task for the auditory word. Participants also rated themselves on language and reported language use.

We hypothesized that if reduced L1-strength affected L1 attrition, Bengali words from all four word-pair categories would elicit longer RTs and larger negative ERPs than English words. In contrast, if L2-interference affected L1 attrition, all Bengali words except ones from the LowEnglish-HighBengali category would elicit longer RTs and larger negative ERPs compared to their English translations.

Results showed participants' L1-use and L2 self-ratings predicted performance in L1. Behavioral data showed longer RTs for Bengali than English in the HighBengali-HighEnglish category and longest RTs for English in the LowEnglish-HighBengali category. ERP data showed greater negativities to English and Bengali words from the category with low familiarity English ratings regardless of their Bengali ratings. Different results from the two measures of the lexical task suggest that each task reflects a different point in the process of lexical access. Overall, findings suggested that L2-interference into L1 plays a larger role in L1 attrition in L2-dominant individuals.

DEDICATION

This dissertation would not have been, had my parents not been who they are, so, Maa and Baba, this research is dedicated to you, for it from you that I inherited the love of science, and realized who a scientist is.

Acknowledgements

I was very fortunate to have the mentorship of two chairpersons for my doctoral dissertation, Drs. Valerie Shafer and Loraine Obler. Together, my co-chairs made a perfect mentoring team, and armed me with skills to face the academic jungle. Thank you both, immensely, for your guidance and support, not only through my doctoral research, but throughout my graduate life. Your contributions to this work are colossal, and have taught me so much about independent research, and research writing. I know that I can always count on your advice and thank you for that. Lastly, thanks so much for believing in this project, the first complete independent study that I conducted, with optimum direction, so that I could become self-reliant confident researcher in the process.

I had the opportunity to work with Dr. Martin Gitterman who also chaired our department for a substantial portion of the time I was a student here. His knowledge, patience, meticulous approach and thoughtful outlook have taught me much. I am especially grateful for his encouraging words and confidence in me.

It was my good fortune that Dr. Mira Goral agreed to be on my committee, having the exact research match in the fields of bilingualism and first language attrition. Her enthusiasm and intellectual insights were assets to my dissertation. I shall always be grateful to her for being such an integral part of my committee.

My heartfelt thanks to Dr. Karen Froud, who so generously agreed to be the external reviewer for this dissertation. Her expertise, suggestions and questions brought new lines of thinking into this research, I am so grateful for her thoughtful reading and intellectually exciting questions.

I want to thank my statistician, Dr. Arindam RoyChoudhury, for his relentless help in figuring out the complicated relationships in my regression analyses, and an educational journey in understanding the linguistic differences between statisticians and social science researchers!

I would like to thank my parents, Drs. Shompa and Salil Datta, researchers who first introduced me to science and scientific enquiry. I don't think I would have been in academia if not for them. My gratitude does not do justice to their contribution, particularly in shaping my academic career and providing continuous encouragement to remain focused on my dissertation.

A big thank you to my sister, Diya Datta who helped me a range of things like recurring data collection processes to mailing out dissertation drafts, things only a sister will do. She remains my biggest cheerleader of all. Thank you so much for believing I could finish my dissertation.

Thanks to Dr. Aniki Saha-Yannapolis and Dr. Michelle Macroy for recording my stimuli.

Thanks of course to my proofreading team, for your valuable suggestions and meticulous read. Great teamwork Yan, Jungmoon, Diya, Monica, Sanyu, Radhika, Chamu, Sangita and Arindam!

To my labmates and friends, who were there through my graduate life, cheering on, and making me believe that I could actually accomplish this daunting venture. Thank you. I have been extremely lucky to have built so many friendships through my graduate life, thanks so much Karen, Kristen, Julia, Puisan, for giving such a great start to my graduate career. Special thanks to Monica for making recruiting participants a reality. For all the intellectual, fun, involved and silly times, Jungmoon, Yan, Marcin, Nancy, Yael, Josh, Michelle, Barbara, Marie-Michelle, Malgosia, Amee, Sethu, Carol.

For being there from even before my dissertation life, and sticking by through it, thanks so much, Sanyu, Radhi, Chamu, Sangita, Srabanti, Chandan, Jui, Sukanya, , Mitul and Ruchi!

Without my participants, who gave their valuable time, this study would not be. I cannot begin to tell you how indebted I am to each and every one of you.

Thanks to all my family and friends who kept me going through the highs and lows of my graduate journey.

Lastly, thanks to my husband Arindam Roychoudhury, for putting up with my dissertation-mania for the last three years, the end is rough they say, so thanks for your unconditional support!

Table of Contents

List of Tables

List of Figures

I. BACKGROUND

The goal of this project is to examine first language (L1) attrition of lexical retrieval in Bengali-English speaking-individuals using neurophysiological (Event Related Potentials) and behavioral (reaction time) measures. We will also examine how L1 and L2 proficiencies of the speakers relate to L1 attrition.

1.1 Bilingualism and First Language Attrition

Bilingualism has been an important focus in both psycholinguistic and neurolinguistic domains for a few decades now. Mainstream research on bilingualism has largely focused on second language learning and the effects of the first language (L1) on acquisition of a second language (L2). Extensive research has been carried out on how factors such as age of acquisition, nature of L2 learning and language proficiency affect L2 output as well as language organization.

The nature of the interaction between L1 and L2 during the course of second language acquisition has triggered many controversies in this research. There is a relatively large body of literature examining lexical interference from L1 to L2 during L2 acquisition. Researchers have established that with increasing proficiency in L2, the degree of this sort of interference decreases, resulting in a more stable status of the two languages involved (Kroll & Stewert, 1994; Kroll & Tokowicz, 2001). This has led researchers to believe that language performance in bilingual individuals can become native-like in both languages over time, depending on how and when these languages were acquired (Birdsong, 2004).

However, the strength of each of the languages practiced is not only influenced by how and when they were acquired, but also how they are used and maintained. In fact, researchers (e.g. Goral, 2004; Köpke, 2004) suggest that continued native-like proficiency of both languages is rare over a prolonged period. Once the two (or more) languages achieve comparable proficiency, the dynamic nature of language-use in everyday life prevents fossilization of any particular bilingual state. That is, even if one achieves “balanced bilingualism”, due to changes in use of languages over time, this “balance” does not last over the long term. A second language can largely dominate bilinguals’ communication, especially if they reside in the L2 environment. Therefore, it is of interest to determine how L2 use affects maintenance of L1. Use of L2 may lead to a gradual decline of L1 proficiency within an individual’s lifespan in a non-native language setting. This change in one’s first language due to decline in its use or due to the influence of a second language is termed “attrition”. The phenomenon of first language attrition is important because it reveals how languages are adapted to processing needs and will provide information on how much language-use is required for language maintenance as a function of time spent in the L2 environment.

Traditionally, attrition of language in polyglots has been defined as the loss of native language abilities over the life span of a bilingual/multilingual individual, or the decline of components of L1 in bilinguals who are immersed in their L2 environment. Of theoretical interest is the broad question whether L1 attrition is a result of L1 being affected, or that of interference from L2. Effects on L1 may manifest as a reduction in its strength or as a rise in its activation threshold from infrequent use of the language. A number of sociolinguistic and cognitive factors (such as motivation and age of acquisition of L2) have also been known to contribute to the decline of L1. The current study is designed to investigate the underlying neurolinguistic mechanism of attrition in L1 with regards to these theoretical constructs and sociolinguistic factors.

1.1.1 First Language Attrition and Second Language Dominance

Because L1 attrition is a relatively sparse field of investigation, questions related to when in the continuum of gaining a second language the bilingual individual becomes attrited in the first, is not clearly addressed. Changes in the languages of a bilingual individual are largely bidirectional (i.e., L1 influencing L2 and vice versa) irrespective of the individual’s proficiencies in these languages. Most crucially to the current study, L2 influences on L1 can emerge early on in L2 acquisition. However, it is important to understand that L1 attrition is not a byproduct of adding a second language. We use two lines of arguments: 1) L1 attrition is not necessarily the loss of L1 in its entirety, rather, it is increasing inaccessibility of L1, relative to L2, modulated by changes in use of L1 and L2 over the lifespan and 2) L1 attrition has been observed relatively early in bilinguals immersed in an L2 context.

1.1.1.1 L1 attrition as inaccessibility rather than loss of L1

Typically, studies of L1 attrition have involved participants residing in the L2 environment for 10 years or more and have employed untimed sentence production or grammaticality judgment tasks. The few that have focused on lexicon were designed to examine lexical morphology. These studies have reported differences between the immigrant bilingual and the native monolingual group on L1 measures, indicating that such groups of bilinguals, who have immigrated to a country where their L2 dominates, have their L1s attrit over time.

In their discussion of what constitutes attrition, Köpke and Schmid (2004) suggest that L2 dominance, whether or not distinguishable from L1 attrition, is a phase that needs to precede L1 attrition. They cited studies by Lachman and Mister-Lachman (1976), Mägiste (1979) and Frenck-Mestre (1993) where experimental data appear to have captured L2 dominance rather than L1 attrition. Köpke and Schmid (2004) reported an emphasis on the distinction between these two phenomena in the existing literature as follows: L2 dominance has been described as a state during a short period of time in which L1 access is found to be slower than L2 access, even when L2 is not native-like in proficiency. This may be a result of intensive immersion of individuals in the L2 environment. Experiments have documented such findings in naming and lexical decision experiments and argued that such differences in L1 and L2 processing (speeds, as measured by reaction times) cannot constitute L1 attrition, as these differences do not surface as L1 difficulties in natural language situations (Lachman and Mister-Lachman 1976, Mägiste 1979 and Frenck-

Mestre, 1993). These arguments, however, do not account for those changes in L1 that do not "surface", that is, those changes that the L1-user is not aware of, or overcomes successfully while using the language.

Schmid and Köpke (2007) propose that L2 influences on L1 are no longer viewed as rare and distinct phenomena observed only in those who are completely disconnected from L1 contact. Rather, L2 influences on L1 are inevitable in individuals who start acquiring a second language. Therefore, changes in L1 in the L2 acquirer that lead to an eventual L1 attrition present themselves in a continuum over the lifespan of the multilingual speaker as a manifestation of relative inhibition and weakening of L1 with respect to L2. According to Schmid and Köpke (2009), L1 effects of using a second language emerge from two different factors: one is interference from L2, which begins as early as one starts learning a second language and the other is atrophy of L1, which is due to its disuse over time.

1.1.1.2. Early Onset of L1 Attrition

In a study of lexical attrition in American English-Hebrew bilinguals living in Israel, using narrative story telling tasks, Olshtain & Barzilay (1991) report evidence of L1 attrition as early as 8 years of immersion in their L2 (Hebrew) environment. Although their participants were able to generate lexical items to complete the story telling tasks, the authors suggested that their choice for items used in speech less frequently (i.e., pond, deer, cliff, jar and gopher) generated a larger variance for the immigrant participants than the American bilingual control participants who never left the United States. Early effects of L2 on L1 leading to L1 attrition were even more clearly demonstrated in a recent study by Goral, Libben, Obler Jarema & Ohayon (2008). These authors report attrition of Hebrew (L1) in Hebrew-English speaking individuals living in New York City, an immigration pattern reverse to that of Olshtain & Barzilay's participants. Goral and her colleagues set out to investigate the nature of language processing in older Hebrew-English bilinguals in a priming task where compound constituents (e.g., *black*) were used to prime whole compound words (e.g., *blackboard*). The goal of this study was to understand whether L1 decline observed in older adults was due to the effect of age or a result of L2 contact, or both. The control groups consisted of two younger Hebrew-English bilingual groups, one living in Israel and the other living in New York City. Although all groups reported L1 to be their dominant language, the bilingual group from New York City reported both higher proficiency and use of L2 compared to the group from Israel. This implied that even though they lived in New York City, this group was not completely disconnected from their L1-use as occurs in some other studies of L1 attrition (de Bot, Gommans & Rossing, 1991; Ammerlaan, 1996). Results indicated that not only the older Hebrew-English group, but also the younger Hebrew-English group living in their L2 environment showed slower RTs to Hebrew targets compared to the Hebrew-English group in Israel. The authors concluded that L1 attrition, as reflected by the slower RTs in Hebrew for the immigrant bilingual group, can be detected as little as an average of four years (with a range of .01 – 19 years) of immersion in the L2 environment. Notice that the group showing L1 attrition in both studies were able to successfully process (produce or comprehend) the intended L1 lexical items, but not without discernable differences from the control groups. This would suggest that the process of accessing these items was not as automatic or easy for the L1 attriters compared to the control groups, which also appears to have been the rationale for the label "attriters" by the authors.

It is clear from the discussion above that L1 attrition is not a rare phenomenon that is only detected in individuals who are completely disconnected from their L1 and are experiencing "L1 loss". Rather, there is existing evidence in the current literature to suggest that L1 attrition can a) manifest itself as inaccessibility of L1 relative to L2 and b) can emerge as early as an average of four years of residence in the L2 environment. The goal of the current study is to understand the mechanism of L1 attrition, not as loss of L1, but rather, its inaccessibility, for immigrants in their L2 environments with a broad range in length of residence.

1.2 The Mechanism of Attrition

A review of this literature shows considerable uncertainty concerning the underlying neurolinguistic/psycholinguistic mechanism(s) of L1-attrition. There are two major accounts of L1 attrition: a) Inaccessibility of L1 from loss or reduction of the L1 trace due to its disuse over time b) Inaccessibility of L1 due to interference of structures and lexical items from L2. A third and evolving account involves combining these two different psycholinguistic models of disuse and interference into a single explanation for attrition.

The first proposal, that L1 suffers loss due to lack of use, is derived from the 'Trace-decay theory' (Ebbinghaus, 1885). The Trace-decay theory states that memory traces are lost due to disuse of particular traces. In this case, loss of L1 memory traces occurs as a direct result of a decline in their use. This theory highlights that the increased difficulty in accessing L1 is a result of not using L1 enough. A few studies (de Bot et al., 1991; Köpke 1999; Gürel, 2004) have reported L1 attrition in bilingual individuals who have gradually lost contact with their L1.

In one of the earlier studies, de Bot, Gommans & Rossing (1991), tested 30 participants on the Foreign Service Interview (for pronunciation, grammar, vocabulary, fluency and comprehension) and a grammaticality judgment task. The Dutch immigrants, who had been living in France for over 10 years, were divided into 12 groups depending upon "amount of L1 contact" (few = less than once a week versus many= more than once a week) and the numbers of years spent in the L2 environment (six categories of time in years e.g. 11-15, 16-20, 31-25, 26-30, 31-35, 36+). The authors found that there was an interaction between the results for the Foreign Service Interview, amount of L1 contacts and years spent in L2 environment, such that the latter became significant only when amount of L1 contacts was "few". This study was designed specifically to test how use of language affected attrition and not so much how L2 contributed to it.

In another study focused on L1 attrition, Altenberg (1991) tested two German-English bilinguals in three untimed sentence level tasks to examine the status of their L1 knowledge. The participants were immigrants, a couple married to each other, living in the U.S. for 40 years. In one of her three tasks, which involved filling blanks in sentences, she investigated how frequency of the lexical items to be filled affected L1 attrition. She included 56 nouns (34 high frequency and 22 low frequency items) in her study. Stimuli were in the form of written sentences with blanks for the 56 selected stimuli. The participants were asked to fill in the correct gender and plural forms for these nouns. Altenberg reported that indeed the largest number of errors for her two participants involved the low frequency nouns rather than the high frequency ones, suggesting L1-use to be a factor in L1 attrition. With regards to her other two tasks that tested grammatical judgment however, she reported that phonetic similarity between L1 and L2 led to more errors in verb usage. This, by contrast, indicates that L2 influences on L1 also contribute to L1 attrition.

Yet another more complex study was designed by Pelc in 2001 that involved understanding L1 attrition from lexical, morpholexical and morphosyntactic perspectives. She also examined a number of sociolinguistic variables; namely, age of arrival in the U.S., length of stay in the U.S., language contact, language-use, level of education, language dominance and language preference. She tested 57 Greek-English bilinguals who had been in the U.S. between 10 and 40 years and 22 Greek monolinguals, on these three areas. The lexical aspect of this study involved testing two attributes: a) metaphorical verb sense of two verbs and b) opaque expressions (idioms). In both cases, Pelc reported evidence of the Greek-English bilinguals performing in a less native-like fashion than the Greek monolinguals. She also reported significant effects of age of the participants, education in Greece, age of arrival in the L2 environment and length of stay in the L2 environment on Greek (L1) performance. That is, higher age, more education in Greek, later age of arrival and shorter stay in the L2 environment were associated with better performance in Greek. In her discussion of the various factors that may have contributed to the language profiles that emerged in her bilingual Greek-English group, she does not rule out either L1-use or L2 influences. She proposes that lack of L1-use over time leads to a gradual change in the L1 system that can be characterized as a lack of L1 competence. However, she also points out that greater acceptance of ungrammatical or non-prototypical meanings of verbs or idioms by the Greek-English bilinguals relative to the Greek monolinguals also suggests a strong influence of L2 in their L1 behavior. So it is possible that both lack of L1-use and influence of L2 into L1 contributed towards Pelc's findings.

Köpke (2001) proposed that Paradis's Activation Threshold Hypothesis (ATH) was an ideal psycholinguistic theoretical framework to explain the nature of attrition. The underlying assumption in ATH is that any given linguistic item has a certain activation threshold that needs to be reached before that item is accessed for use. In a system with competing languages, the language in use (for production) can be activated easily (i.e., have a lower activation threshold) while the language not in use is less easily accessed (i.e., have a higher activation threshold) and possibly to ever be inhibited. However, the activation threshold for the language not in use at that time is not so high that it blocks comprehension in that language. Paradis described the mechanism of "differential inhibition" using the ATH such that each time a linguistic item is accessed, it leads to lowering of its threshold, while a greater time lapse between each instance it is accessed increases the threshold. Thus, activation threshold is a result of two contributing factors: the frequency of activation and recency of activation (Figure 1). A more recent and frequent activation of an item will result in a low activation threshold for that item.

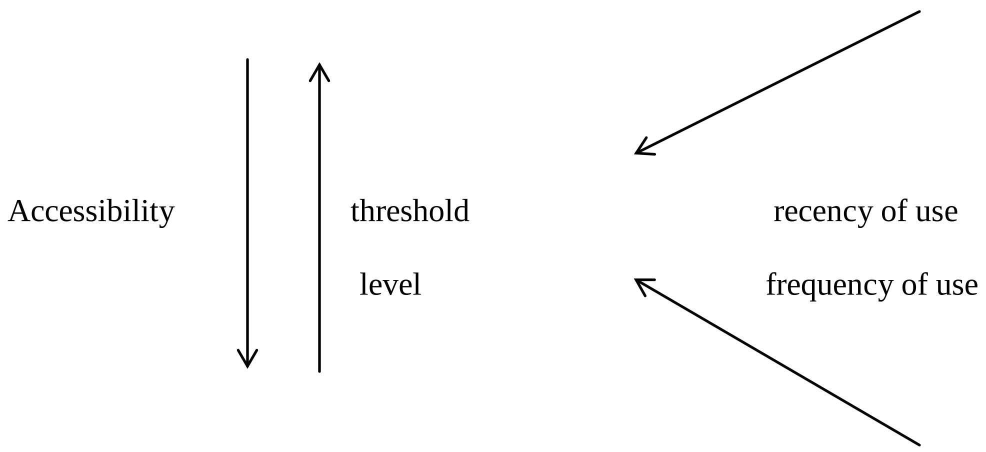

Figure 1: Effect of Recency and Frequency of Use in a Language on its Accessibility (Adapted from Köpke, 2000). This figure shows how accessibility increases as activation threshold decreases if a linguistic entity has been both recently and frequently activated

Köpke (1999) conducted a study examining morpho-syntactic attrition in French- and English-German bilingual speakers using ATH as a framework for attrition. She used contrastive morphosyntactic features between German and the two-second languages in late bilinguals in Canada (French) and the U.S (English). The tasks included two oral production tasks and a grammaticality judgment task, all involving the morphosyntactic contrasts between the languages. The results of the production data indicated that most errors were made in terms of lexical access, rather than in the morphosyntactic processing of the words and that L2 interference had also contributed towards the errors.

The results led Köpke to consider ATH a strong theoretical framework for exploring attrition, especially lexical attrition in L1. She suggested that ATH was not the best model for grammatical aspects of language-use, but could be more readily applied to lexical aspects of attrition. However, the study was not designed to investigate lexical attrition or whether ATH could be tested within the realms of attrition.

Paradis (2007) himself has also described how his "Activation Threshold Hypothesis" can be used to explain L1 attrition. Amongst his different propositions for attrition are the following: a) activation threshold for L1 is raised via its disuse over time and b) the more frequent L2 items will replace L1 items.

Here, it is important to understand that a) and b) are two different phenomena that may have independent contributions to the mechanism of attrition. While high L1 activation threshold could result from a general reduced use of L1 over time or from a loss or reduction of L1 trace itself, whether the more frequent L2 items “replace” L1 items or not depend on the impact of L2 on L1 which is described as L2 interference in this study. The latter notion, then, directs us to the understanding how much an impact L2 interference has on L1 retrieval in L1 attrited individuals.

The second account for attrition, ‘interference from L2’, stems from Interference Theory, proposed by Underwood (1957) and Loftus & Loftus (1980). Interference and transfer of L1 into L2 are well-known phenomena in the psycholinguistic literature of bilingualism (e.g., Albert and Obler, 1978). These processes include the appearance of L1 content and structure in L2 productions due to dominance (i.e., relative strength) of L1 patterns in second language learners. When this dominance is reversed, as might happen in those individuals who are at one point comparably competent in both languages but then live in L2 environments, the interference or transfer patterns might be reversed as well. This reversal of dominance may lead to high accessibility of L2, which in turn impedes the access to L1. This high impedance to L1 access can then be attributed to the attrited L1. A number of studies (Ben Rafael, 2001; Hutz, 2003; Jasper and Kroon, 1992; Ammerlaan, 1996; Gürel, 2004) report L2 interference in L1 at various linguistic levels but particularly at the lexical-semantic level.

The third explanation, accounting for attrition, emerges from a number of recent investigations of attrition where experimenters describe how psycholinguistic constructs discussed above (i.e., disuse leading to a trace reduction and interference) interact with each other to affect attrition. In the next section we discuss this third, comprehensive account of attrition with respect to a few contemporary experiments.

To explore how L2 affects L1, Ammerlaan (1996) examined the nature of L1 lexical attrition in 76 Dutch immigrants in Australia. The task involved naming Snodgrass and Vanderwart (1980) pictures that were divided into nine categories depending on their similarities and differences between Dutch and English in phonological constitution, syllabic length, morphological makeup and meaning across translation equivalents. Participants were instructed to name these pictures in Dutch. Findings, reported in terms of error rates, indicated that similarity across languages (both in phonology and morphology) facilitated correct recall of Dutch names. In contrast, morphophonologically different words in English and Dutch elicited more errors in Dutch than in English, which can be accounted for by interference from the stronger and more frequently used English. The author argues that these errors in L1 for word-categories, which were different in morphophonology across the languages, indicate some level of interference from L2 into L1. That is, the morphophonemic features in the frequently used L2 could now easily interfere with their L1, as a) the same words in L1 were not used as much and b) the same words in L1 did not contain the morphophonemic features their L2 counterparts did. Thus, this study indicates that disuse of certain L1 features due to incidence of contrastive features in L2 (here: morphology, phonology and syllabic makeup), and high frequency use of these L2 features leads to interference from these features in L2 into L1.

This hybrid account was also proposed by Gürel in 2004. Using Paradis's (1989) Activation Threshold Hypothesis, she argued that disuse of L1 leads to its higher 'activation threshold' and inhibition, while frequent use of L2 results in its robust activation and hence interference into L1. In an experiment examining different syntactic elements in Turkish, Gürel tested Turkish-English bilingual individuals who had been in North America for 10 years or more. She hypothesized that of the three pronouns that she was testing, the participants would show attrition for the one that has a competing equivalent in English (i.e. overt pronominal pronoun 'o' meaning 'he' or 'she') and would preserve the two that had no English analogs or competitors. Her experimental data supported her predictions. She concluded that the high use of an L2 element, whose counterpart is inhibited in L1 because of the high activation threshold of L1, would induce interference from L2 into L1.

The direction of interference and the nature of inhibition in attrition appear to be a controversial issue. One view of interference may be that the stronger or more dominant L2 interferes with access of the now less dominant L1. Further, it can be said that this interference actively inhibits or suppresses L1. (e.g. Gürel, 2004). A different view posited by Levy and his colleagues (see below) indicates that the interference appears at an earlier time in the life span of the bilingual and from a different direction. They suggest that the dominant L1 at the time of immersion in L2 is the source of interference, such that the L1 items are actively suppressed in order to access or retrieve the L2 items, especially in those cases where these L1 concepts or items are more used in the L2 context now.

This idea was derived from another concept in psychology called "retrieval-induced-forgetting" (RIF) (Levy and Anderson, 2002), which entails suppressing or inhibiting interfering dominant memories to retrieve a weaker non-dominant memory. Levy and his colleagues carried out an experiment with second language learners exploring the idea of RIF in lexical retrieval in 2007 (described below) in order to make a case for the role of active inhibition of L1 in attrition.

The researchers examined whether phonetic or semantic probes were able to prime lexical retrieval in a recently non-practiced but overall dominant language (L1) in second language learners learning Spanish (L2) in college. In the first experiment, the participants were instructed to name line drawings in L1 and L2 up to 10 times in each language. After each block of naming the items in a language, they participated in a second experiment in which rhyming phonetic probes and non-rhyming and non-phonetically related semantic probes in L1 were presented. The participants were now asked to generate any L1 word that either rhymed with or was congruent to any word (probe) presented in this experiment. Results indicated that naming in L2 10 times in the previous experiment led to relatively poor performance in generating words for the phonetic rhyme-probes but not so for the semantic probes in the second experiment. The semantic probes led to marginally better generation of L1 words hence they facilitated L1 retrieval. Dependent measures were naming accuracy and latency. As expected, the participants experienced facilitation in generating L1 words for both phonetic and semantic probes if they had named in English before experiment 2. In fact, the participants with low proficiency in L2 were more prone to difficulty in L1 word naming (for the phonetic rhyme probes) than those who were more proficient.

The researchers took these findings as support towards phonological suppression or inhibition in the stronger L1 (in experiment 1 while naming words in L2) in order access items in the weaker L2. They proposed that those native language words that had translation equivalents in the foreign (second) language are the ones subject to RIF after learning them, particularly to enhance performance in L2. They pursue the idea that although this sort of competition and inhibition in bilinguals at the lexical level has always been demonstrated as a transitory local phenomenon in studies on second language acquisition (Green, 1998; Dijkstra et al., 1998; Kroll and Stewart, 1994), there could be long term implications for such effects. If this were true, such lexical interactions across the languages over the life-span could manifest as L1 attrition. That is, studies have shown that bilinguals experience lexical competition at the time of lexical access. However, it is feasible that this kind of lexical competition between the two languages in a bilingual individual can exercise itself more globally over the long term, leading to this sort of phonological L1 attrition.

The studies reported above support that those items or aspects of language that are not in use in L1, but are frequently used in L2, are the ones that are more prone to attrition than the ones that do not fall into this category. It follows, as Gürel (2004) suggested, that if there are sets of L1 items that are infrequently accessed, their activation threshold increases, making their access more difficult. Meanwhile, if the same items, (i.e., concepts or lemmas) are highly used or accessed in L2, they acquire a lower activation threshold and inhibit L1 items.

It is apparent from the above discussion that reduction of strength or rise in activation threshold in the first language as well as interference or inhibition from a second language into the first can lead to attrition of the first language. It is also important to understand that decreased use of a language altogether could lead to an overall reduction of the L1-strength across all L1 lexical items, while active interference from L2 would affect those items in L1 that experience high competition from L2. However, since other environmental and social factors can affect these mechanisms as well, a brief discussion of these factors appears below.

1.3 Environmental and socio-linguistic factors affecting L1 attrition

In addition to these models that are proposed to explain the mechanism of attrition of L1, a number of bio-cognitive and sociolinguistic factors that affect L1 decline have also been documented. These include age, cognitive maturity, motivation and attitude toward the languages and their speakers, social status of the languages, age of acquisition and proficiency, nature of acquisition and education level achieved for each of the languages (Köpke, 2004).

One of the factors that have been researched widely, as mentioned earlier, is use of L1, it is generally agreed that “infrequent use of L1” contributes to L1 attrition. However, what “infrequent use” entails appears to vary from one study to another. The ambiguity of what “infrequent use” of L1 may mean is highlighted by the difference in its interpretation in a number of studies (e.g., Altenberg, 1991; Major, 1992; Jasper and Kroon, 1989). Factors influencing frequency of first language-use include amount of contact in the L1 environment, length of L1 contact, whether the environment stimulates L1 input, output or both, nature of L1-use and whether individuals live in their L1 community and have a spouse that speaks their L1 with or not. In addition, the quality or the nature of L1-use such as the mode of use, (i.e., oral, written or both), may contribute to the strength of L1 trace as well. It is also imperative that we view language-use within the context of length of stay in the L2 environment, as that length of stay might be predictive of amount of attrition only if L1 language-use is limited (de Bot et al., 1991). That is, once L1-use is controlled, length of stay may be more of a contributor to L1 attrition.

In the current study, we examined a) language proficiency in L1 and L2 (as measured at the time of testing) and b) L1 and L2 use and the nature of language environment.

1.4 Lexical Attrition

Loss or reduction of L1 language abilities can occur at syntactic, lexical and phonological levels of language proficiency; however, lexical retrieval has been the most commonly observed loss. It has been reported that lexical retrieval in conversational contexts is more vulnerable to L1 loss than are other aspects of the language (Boyd, 1993; Köpke, 2001). Lexical attrition has been extensively observed at the discourse level of language production and the lexicon has been identified as "one of the first areas" to be affected by L1 attrition (Goral, 2004).

For example, in the previously mentioned study by Olshtain and Barzilay (1991), they explored lexical attrition in English-Hebrew bilinguals who were L1 speakers of American English and had immigrated to Israel 8-25 years prior to testing. The authors elicited narrative descriptions of two different "frog-stories" (Mayer, 1969) from pictures in these story books in order to examine lexical attrition in English. They reported that the 15 participants in Israel generated a larger variability in lexical selection for less frequently used words in "speech" than their five control American counterparts. They took this evidence to argue that the participants from living in Israel had more difficulty retrieving less frequently used lexical items required in the story narration, as compared to their native-English control groups (all of whom were monolingual except one) in the US.

L2 interference into L1 lexicon is reported to be largely influenced by the degree of morphological and phonological similarities shared by the two languages. Boyd (1993) reported that there was a high incidence of Swedish lexemes in the Finnish speech production of Finnish-Swedish bilinguals living in

Sweden. In contrast, she found that English-Swedish bilinguals rarely showed similar interference from their L2. She proposes that perhaps similarity of the two languages (here English and Swedish) helps preserve the languages better by means of facilitation, while dissimilar languages (e.g. Finnish and Swedish) promote competition resulting in the "decay" of the weaker language.

As discussed earlier, Ammerlaan (1996), using picture naming, demonstrated that Dutch immigrants in Australia tended to produce more errors when naming words (pictures) that were morphologically, phonologically and semantically dissimilar across translation equivalents in English and Dutch rather than those that were similar. He found that overall, most participants had least difficulty in retrieving words that were phonologically and syllabically similar between Dutch and English (especially cognates) compared to words that were partially (phonologically similar but syllabically or semantically different) or completely (phonologically, syllabically and/or semantically different) dissimilar. According to Ammerlaan, even though English words got activated faster than Dutch words, similarity across multiple levels across the languages enabled the participants to activate the Dutch words as well and hence retrieve the most similar translation equivalents successfully. However, partially dissimilar words (phonologically similar but syllabically dissimilar) elicited more errors than completely dissimilar words (phonologically and syllabically dissimilar) for certain participants. The errors involved code mixing, resulting in use of English morphological/syllabic information to encode Dutch phonology. Ammerlaan argued that these errors stemmed from the apparent similarity at the phonological level between English and Dutch for these words. Thus, for these partially similar words, the phonological similarity across the languages enabled spread of lateral activation from English into the Dutch translation equivalent in terms of phonology while the syllabic dissimilarity led to preservation of the English morphology. Furthermore, he reported that the degree of errors was related to the proficiency level of Dutch at the time of testing.

In another experimental attempt to explore lexical attrition, Sherag et al., (2004) tested three groups of German-English bilinguals and one group of native English speakers using a lexical priming paradigm. The participants were required to make a lexical decision regarding the legality of German target nouns primed by adjectives. The noun/pseudonoun-targets were presented 1100 ms after the adjective-primes followed by the lexical decision task within the next 2000 ms. The goal of their experiment was to examine whether certain morphosyntactic properties of adjectives (gender relations between noun and adjectives) were subjected to attrition in the German-English bilinguals who had immigrated to the U.S., living in the country from 6-49 years. The error rates and reaction times to the prime words for the immigrants were compared to those of a group of German visitors to the U.S., native speakers of German in Germany and native speakers of English, also living in Germany. No differences in reaction times or error rates were observed between any of the German-speaking groups, indicating lack of attrition for morphological properties. While the authors suspected that the method may not have been sensitive enough to tap into mild attrition, they also suggest perhaps the processing of “word-word” (i.e., noun-adjective) relationships, especially with regard to grammatical gender, may be part of post-lexical syntactic processes (Grodzinsky, 2002; Friederici & Jacobsen, 1999) and hence not vulnerable to lexical attrition.

The effect of attrition mechanisms on the lexicon, therefore, is a robustly observed phenomenon in bilinguals. It is important, then, to consider what properties of the lexicon facilitate and inhibit its access. Literature on word frequency effects for lexical access indicates that lexical frequency and phonological form of the lexical items are clearly two of the most researched variables in such studies.

The role of word frequency on lexical access was first reported by Oldfield and Wingfield (1965) and has been repeatedly demonstrated. In a more recent study, Jescheniak and Levelt (1994) focused on the locus of word frequency (lemma or lexeme) that affects lexical access. Results from a series of experiments demonstrated that it is the frequency of the phonological form or lexeme and not the frequency of the lemma of a word that influences its lexical retrieval. In particular, they conducted an experiment where they compared translation latencies (from English to Dutch) of homophonic words with different lemma frequencies. The experiment was designed to test whether low frequency lemmas, which were homophonous with high frequency lemmas, could be processed as quickly as the latter. Non-homophonous control items, which were also low and high in their lemma frequencies, were also included. Data indicated that the homophones as well as the high-frequency controls were all translated faster (and within similar time frames) than the low-frequency controls. Thus despite low-frequency lemmas, the words homophonous to the high-frequency lemmas behaved like the latter group indicating that it is the lexeme and not the lemma frequency which drives word processing and retrieval.

Word frequency effects have also been reported in children's lexical access. Newman and German (2002) undertook an extensive study to examine the role of a multitude of factors that affect lexical access in children aged from 7 to 12 years of age. They reported that both word frequency and age of acquisition for the word had significant contributions in determining lexical retrieval. However, effects of age of acquisition diminished as the children advanced in age whereas effects of frequency persisted. The literature on the role of word frequency in lexical access and retrieval indicates that it is a robust effect present throughout one's lifetime. More specifically, it is the frequency of the phonological form of a word or the lexeme frequency rather than the semantic-unit frequency, which affects its retrieval speed (Dell, 1990; Levelt, Roelof, & Meyer, 1999).

In sum, it is evident that lexical retrieval is indeed vulnerable to L1 attrition. Factors such as morphological and phonological similarity between L1 and L2 can contribute to the extent to which L1 will undergo attrition. Also, studies exploring the nature of lexical retrieval and access report that word-form frequency is a key factor in this process. It is reasonable, then, to examine the mechanisms involved in attrition (i.e., reduced L1-strength from L1 disuse or L2 interference into L1) via the lexicon. We were, therefore, required to design a lexical retrieval paradigm that will give us an insight as to how L1 and L2 interact in lexical retrieval of bilinguals immersed in an L2 environment. Below, we discuss methods we could use to best address such a question.

1.5 Priming paradigm using Event Related Potentials

Studies investigating lexical attrition have incorporated sociolinguistic tools such as self-report and discourse analysis as well as experimental tasks such as picture naming, lexical decision and priming. Narrative procedures provide a naturalistic way of examining lexical retrieval; however, they are not ideal in controlling the lexical items being tested across individuals in a group. Alternatively, cross-language priming is a powerful tool to investigate L1 attrition. It is popular to use orthographic stimuli in cross-language priming experiments, however, the goal of this project was to explore oral-auditory aspects of lexical access. Using a cross-modal (picture-auditory) priming paradigm was a possible solution. Even so, as observed in Scherag et al.'s (2004) experiment, reaction time alone may not have been sensitive enough to reveal small lexical retrieval time-differences across groups of participants. Thus, we proposed a cross-modal priming method coupled with a more sensitive measure of time, Event Related Potentials (ERPs). ERPs are a neurophysiological measure sensitive to the temporal aspects of language processing leading up to the behavioral response. They provide temporal information on the order of milliseconds and therefore are able to provide more fine-grained information about language processing in time, relative to behavioral measures alone.

ERPs are averaged electrical activity recorded at the scalp and time-locked to specific stimulus items in the environment. The electrical activity is generated from the firing of neurons leading to post-synaptic potentials. ERPs are a method that enables us to track neurophysiological processing with high temporal resolution. Different ERP components are known to index different types of processing depending on the stimuli and demands of the experiment. One such ERP component is the N400, which is a negative deflection peaking around 400 ms following a linguistic or conceptual stimulus of interest. Originally, the N400 was reported as an ERP component that indexed semantic integration in sentence context (Kutas & Hillyard, 1980, 1983). For example, we would expect a larger negative deflection of voltage at latency of approximately 400 ms to the word "*telephone*" in a sentence like: "I was eating a *telephone*" than in a sentence like "I was talking on the *telephone*" because the word "telephone" is not contextually primed in the former sentence.

More recently, the N400 has been elicited to the second word of semantically mismatched word pairs relative to semantically matched word pairs (Holcomb & Neville, 1990; Radeau, Besson, Fonteneau, & Castro, 1998; Anderson & Holcomb, 1995; Bentin, Kutas, & Hillyard, 1995) as well as in cross-modal presentation of prime and target (Holcomb & Anderson, 1993). In these studies, a picture or an auditory word (e.g. "*telephone*") is followed by a semantically matched (e.g. "*talk*" or "*chat*") or mismatched auditory word ("*napkin*"). The participant attends to the second word and carries out a lexical decision task on it. The average ERP responses to the matched (primed) pairs subtracted from those to the mismatched pairs (unprimed) reveals a negativity (the N400) that peaks at centro-parietal sites around 400 ms indicating more difficulty in accessing a primed words from the matched pairs than the unprimed ones.

Other researchers (Rugg, 1984; Praamstra and Stegeman, 1993; Shafer et al., 2004) have used the same paradigm on phonologically primed (e.g. *rhyme*) versus unprimed words. These paradigms have elicited an N400 between 300-600 ms post onset of the second word in both rhyming judgments (Praamstra and Stegeman, 1993) and other kinds of lexical decision tasks (Radeau, Besson, Fonteneau & Castro, 1998). For example, Shafer et al., (2004) conducted a study using same (*bad-bad or gad-gad*) versus different word (or word-like) pairs in both children and adults. The different word pairs were dissimilar in place of articulation (e.g. *bad-gad*) and voice-onset time (*bell-pell*). The participants were asked to judge whether the second word in the pair was the same or different from the first one. The experimenters observed an increased negative response between 200-300 ms after the second word in the dissimilar compared to the similar pair. In addition, the latency of this negative peak was delayed if the first word in the pair was a nonsense word (e.g. gad) since a lexical search for a non-word took longer to complete. Shafer and colleagues describe a neurophysiological model for lexical access using these data. They suggest that lexical access activates a certain set of neurons when the first word of a word pair is encountered. If the second word is different from the first, additional neural groups are activated resulting in a greater negativity than if the second word is the same as the first. Taken together, these studies reviewed above indicate that N400 is an index of lexical access. ERP studies show that the N400 is reduced in amplitude to related (semantic or phonological) as compared to unrelated word pairs and the peak latency is sensitive to the point in time at which this difference is noted.

To establish how a behavioral paradigm such as priming can be coupled with ERPs to examine phonological and semantic aspects of lexical retrieval processes without conscious task demands, Jescheniak and his colleagues, in 2002, conducted an experiment focused on phonological and semantic processing of words. It was comprised of two tasks: a) a lexical task and b) a naming task. The tasks were designed to ensure two things: a) that the phonological form of each picture was realized (at least implicitly): hence the naming task; and b) that the auditory form was being attended to: hence a lexical decision task. In their first experiment each trial consisted of the following: 1) a fixation signal ('+'), 2) the picture to be named, 3) the auditory target, 4) another fixation signal and 5) a visual cue ('!!!') to name the picture. The participants were instructed to do a two-fold task: a) decide whether the auditory target matched the picture and b) name the picture on receiving the visual cue '!!!' The auditory target was designed to match the picture 50% of the time. On the rest of the trials the participants were presented with an auditory target, which differed from the preceding picture either phonologically or semantically. The responses to the matched items and mismatched items were averaged separately and the former was subtracted from the latter to elicit an N400 component. Results indicated that both semantic and phonological mismatches led to negativities around 400 and 250 ms post word onset, respectively. The authors suggest that this procedure taps into phonological and semantic processing during lexical access more automatically than do other ERP paradigms designed to test lexical access such as the go-no-go paradigms indexed by the N200.

It is apparent that Jescheniak et al.'s paradigm is most suited to the current study as it incorporates both a) a window to automatic processing in lexical access via priming and b) a neurophysiological index of word processing via the ERP component. In the present study, we employ a cross-modal (picture-auditory word) priming paradigm, similar to Jescheniak et al. (2002) to examine the effects of attrition in lexical retrieval.

II. RESEARCH QUESTIONS AND DESIGN

2. 1 General Aim

The underlying neurolinguistic mechanism of L1 attrition involves a complex interaction of external and internal influences of the languages involved. That is, the environments in which these languages are acquired and practiced along with the nature of their interactions influence the process of L1 attrition. Above, we discussed a number of extralinguistic and psycholinguistic factors that appear to contribute to the mechanism of attrition. The aim of the current project was to determine the role of these factors, particularly the contribution of L1-strength and L2 interference towards lexical attrition of L1, using behavioral and electrophysiological methods.

2. 2 Specific Research Questions and Hypotheses

In particular, we focused on two aspects of lexical L1 attrition: 1) the effect of the relationship between L1 and L2 use on attrition and 2) the influence of language environment and language proficiency on L1 attrition. The contribution of similarity and dissimilarity between languages towards access of these languages is relatively unresolved. While it is possible that words across similar languages may compete with each, it is also possible that they phonologically prime each other. We chose Bengali (L1) and English (L2) because the literature suggests that attrition is more apparent in morphologically and phonologically different languages (e.g., Ammerlaan, 1996) and Bengali and English, though both Indo-European, differ widely in these properties. Furthermore, there is a population of L1 Bengalis speakers living in an L2 environment conducive to attrition. In addition, we wanted to avoid phonological priming across the languages (Ammerlaan, 1996; Jescheniak & Levelt 1994) since our focus is on the lexical aspects of attrition and Bengali and English share few cognates. Therefore, for the purposes of this project we tested a group of Bengali (L1) –English (L2) participants, who arrived in the US at or after the age of 12 years. We outline the specific questions that we asked in the experiment below.

Our principal question was:

1. What are the relative contributions of L1-strength and L2-interference into L1 towards L1-lexical attrition?

A second question related to socio-linguistic factors was:

2. How is L1 lexical attrition related to

a) use of L1 and L2

b) current proficiency in L1 and L2

as reported by the participants and measured during the experiment?

To test the first question, we used lexical items in English and their translation equivalents in Bengali. These items were then rated for familiarity by native speakers of each language. The stimulus categories were set up to take advantage of both contrastive and non-contrastive distribution of lexical familiarity (as rated by native speakers in their respective languages) at the level of the lexeme across the languages. More specifically, we included words in the following four categories:

1. Items with high familiarity-ratings in both languages (HighE-HighB)

2. Items with low familiarity-ratings in both languages (LowE-LowB)

3. Items with low familiarity-ratings in English but high familiarity-ratings in Bengali, (LowE-HighB)

4. Items with high familiarity-ratings in English but low familiarity-ratings in Bengali (HighE-LowB)

We predicted that decreased use of Bengali on the whole would affect access of all four word-pair categories. This would lead to reduced L1 accessibility due to decreased L1-strength or increased L1 activation threshold. As the language is not being used much, the familiarity categories of L1 would have little effect, leading to reduction of the language overall. Therefore, if we observe attrition in L1 lexical attrition in all the four word-pair categories (including the LowE-HighB category) and none of the categories show more attrition than the other, it is likely that the reduction of the L1-strength is due to its overall disuse. An alternative prediction was that interference from L2 is responsible for L1attrition. High use of L2 would lead to more distinct effects of the L2 word familiarity over time. Specifically, all the categories except the LowE-HighB category would demonstrate L1 attrition, since L2 would interfere with L1 in remaining the three lexical categories because the English words would have become more familiar relative to the Bengali words with time. A third possibility is that both reduction of L1-strength from overall disuse and interference from L2 into L1 have relatively robust contributions towards L1 attrition. If this is the case, then all word-categories would show L1 attrition. However, the effect would reflect the least on the LowE-HighB category, as this category would only be affected by reduced L1-strength and not L2 interference.

To address **question 2a)** and **b)** the participants filled out a detailed language background questionnaire (LBQ) for both Bengali and English. The LBQ (see Appendix I) included a number of questions requesting the participants to report their use of all languages and to rate different aspects of these languages. Specifically, the answers to all these questions were summarized into two sets of variables that addressed research questions 2a) and 2b). These were reported as: percent use of L1 and L2 (question 2a) and self-rating of L1 and L2 skills (question 2b). In addition, to address **question 2b)** participants were tested on their proficiency in both languages via category fluency tasks described in the method section. Thus, we had both reported and measured information to address language proficiency in our participants.

We hypothesized that decreased L1-use and increased L2 use, along with low self-ratings of L1 and high self-ratings of L2 would be related to increased attrition. Also**,** we expected to find better performance for category fluency tasks in L2 and perhaps a relationship between increasing L1 attrition and an increasing gap between L1 and L2 scores for the category fluency tasks.

2. 3 Research Design

We tested a group of 27 Bengali-English speakers who acquired their second language by 12 years of age. From this group of Bengali-English speaking individuals we selected a sub-group of 8 participants who appeared to be dominant in their L2 and poorer in their L1. This was achieved by analyzing their performance in the experimental task in relation to their language proficiency, self-ratings and use. Information about participants' language-use and self-ratings was collected on the Language Background Questionnaires administered before the experimental procedure. Language proficiency was determined through a category fluency measure. Specific methods for selecting this target group will be addressed further in the method section as well as in the results section below.

The experimental task required participants to implicitly name a picture that was presented on a monitor and make a syllable-related decision about an auditory word that followed. The auditory stimulus named the picture in one of the two languages with a fifty percent probability for each language. The picture was expected to prime the auditory word. The amount of priming was expected to be larger if the participants' language of implicit naming matched the language of the auditory word than if there was a mismatch between the two languages (see Table 1). Magnitude of priming was measured using reaction times to a syllable-decision task and the amplitude of the N400 ERP component to the auditory word.

Previous ERP research has shown that the amplitude of N400 is modulated by the amount of relatedness (both semantic and phonological) within stimulus pairs presented in a priming paradigm, i.e., the maximum N400 amplitude is indexed by the most mismatched pairs. So, a mismatch of the implicitly named picture and the auditory word (if in a language different than the language of implicit naming) would result in a larger negativity (N400) relative to a match because less phonological priming will occur. To elaborate, the picture was expected to trigger a lexical search leading to access to a lexical representation and its corresponding phonological form. Such a lexical search presumably leads to a set of neurons firing. When the auditory word is encountered, another neural activation is likely. Therefore, if the picture and the auditory word matched in all respects, it would be likely that the second neural activation would involve the same set of neurons as the first and hence, the lexical search process would end faster, leading to a smaller N400. However, if the following auditory word mismatched the word that was retrieved by the participant, a new set of neurons would be activated and the lexical search process would be longer, leading to a larger N400. In sum, lexical search is completed faster when the following auditory form matches the phonological form implicitly accessed, relative to when there is a mismatch.

Language of lexical access	***Language of auditory word***	***Magnitude of Priming***	***Reaction time for Syllable Task***	***N400 amplitude***
Bengali	Bengali	more	short	small
English	Bengali	less	long	large
Bengali	English	less	long	large
English	English	more	short	small

Table 1: How language of the lexical access interacts with language of the auditory word to influence reaction time and N400 amplitude

We proposed that the selection of language for picture naming was largely influenced by interaction of the word familiarities across the languages and the underlying mechanism of attrition, which we outline in the Table 2 below:

Stimulus category	*Mechanism of attrition*	*Language of lexical access for picture naming*
HighE-HighB	L1-strength reduction	likely to be English
HighE-HighB	L2 interference	likely to be English
HighE-HighB	both	likely to be English
LowE-LowB	L1-strength reduction	likely to be English
LowE-LowB	L2 interference	likely to be English
LowE-LowB	both	likely to be English
HighE-LowB	L1-strength reduction	likely to be English
HighE-LowB	L2 interference	likely to be English
HighE-LowB	both	likely to be English
LowE-HighB	L1-strength reduction	likely to be English
LowE-HighB	*L2 interference*	*likely to be Bengali*
LowE-HighB	*both*	*could be either*

Table 2: How categories created from the familiarity-ratings in L1 and L2 influence language of lexical access for the pictures; each row is a prediction for each of the three possible attrition mechanisms introduced above.

Taken together, Tables 2 and 3 describe how this experiment was designed to answer the designated research questions. The goal of this research was to understand why L2-dominant individuals appear attrited in their L1. We argued that if reduced access to L1 is a result of decreased L1-strength due to disuse overall, then in all combinations of familiarities across the languages (i.e., in all four word-categories) there would be evidence of poorer L1 performance. On the other hand, if L2 interference was responsible for reduced L1 access, then L1 disadvantages would appear in all but the LeHb word-pair category, as it would be difficult for low-familiarity L2 words to interfere with high familiarity L1 words. As for the other categories, L2 would easily interfere in the two word-categories with similar familiarities across the languages, since time spent in the L2 environment would make it stronger in these categories. Likewise, it would also be easy for L2 words to interfere with L1 words in the HeLb category where L2 already had a familiarity advantage. In all cases, poor performance would be indexed as longer reaction times or larger N400 amplitudes in the data.

In general, the stimulus category served to test which model of attrition is acting on lexical access for naming. All but one category (LowE-HighB) increases the likelihood of interference, but all the categories could reflect attrition from trace reduction via disuse. If participants retrieved English (L2) names for the pictures in all stimulus categories, including the LowE-HighB category, then we would predict that the data are consistent with the model of L1 trace reduction from disuse. Conversely, if they accessed English (L2) names in all categories but Bengali names in the LowE-HighB category, we would suggest that L2 interference is playing a key role. Finally, if both mechanisms contribute to attrition relatively equally, we would expect the HighE-LowB category to be attrited the most, as both L1 decay and L2 interference will operate on this word-pair category.

III. METHODS

3.1 Participants

We included 27 healthy Bengali-English speaking individuals (see Table 4), between the ages of 19 and 62 years. Twenty-two were living in the United States and 5 were living in India. Those from the United States had arrived in the country at the age of 10 years or later. All participants had L1 as Bengali, and were exposed to English in their school. One participant was exposed to English in her environment (outside home) before school age, and one participant was exposed to Hindi in her environment before school age. From this larger group, we selected a smaller group of participants who served as our L2-dominant experimental group. It was important to have both L2 and L1-dominant participants in order to demonstrate that L1 attrition is not a by-product of being an early bilingual, as discussed in the first chapter. The experimental group consisted of participants who showed poorer performance in L1 than in L2 (as measured by overall reaction times for the languages in the experimental task and a category fluency task, both conducted in L1 as well as L2). We primarily used this group to address our research question 1 concerning the attrition mechanism. The remaining participants constituted the L1-dominant control group and showed the opposite pattern, i.e., better performance in L1 than in L2 (by the same measures as the experimental group). While we collected reaction time data from all 27 participants, only 17 of the 27 participants were able to take part in the ERP experiment.

Also, it was not possible to find participants of Indian origin who did not use a third language the effects of which have been addressed in the results and discussion section. However, for the experimental aspect of this study we focused only on L1 Bengali and L2 English.

After piloting, we conducted a power analysis to ensure that we had sufficient number of participants in each selected group to answer our research questions, given our research design. The power analysis indicated that we need approximately 9 participants in each group for a power of >.95 (see Figure 2) to answer our research question concerning the mechanism of attrition.

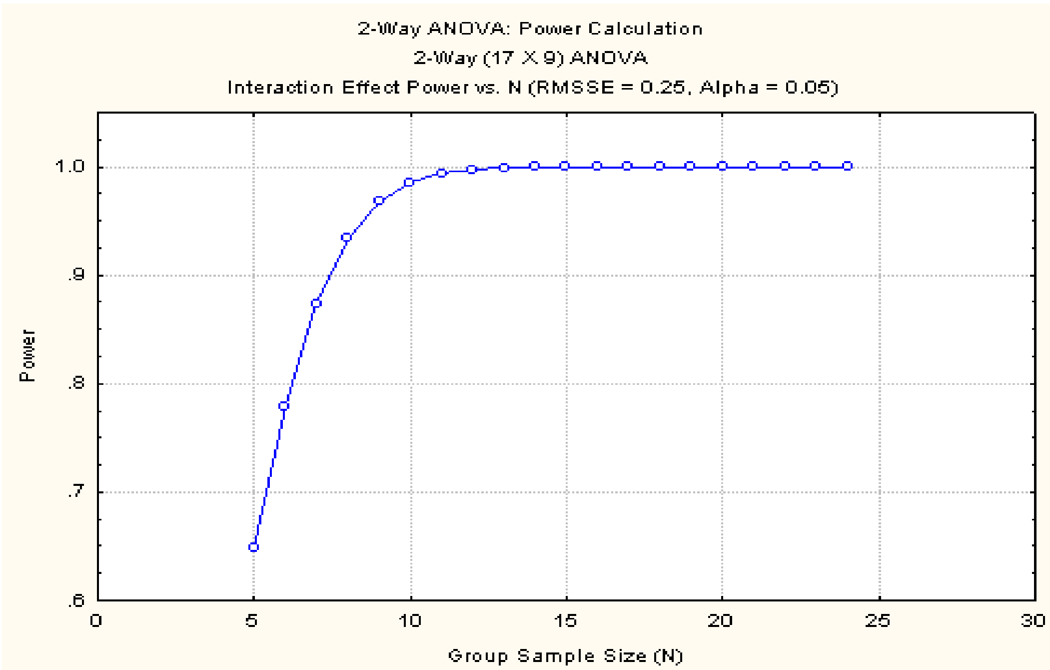

Figure 2. Power calculation for number of participants desired statistical effect. Figure depicts a requirement of 9 participants for a power greater than .95

3.2 Stimuli

Stimuli included 115 pictured Bengali lexical items and their English translation equivalents that have been rated for familiarity by six native speakers in each language living in their native language environments. The twelve raters were asked to rate 364 words on a scale of 1 to 7, where '1'= least familiar and '7'= most familiar. "Familiarity" was defined as "how often the raters came across the word in their environment and how often they used it".

The items were chosen such that half of them had relatively similar familiarity-ratings in the two languages while the other half had dissimilar familiarity-ratings across translation pairs. These lexical items were classified into the following categories discussed above:

1. Items with high familiarity-ratings in English as well as Bengali,

(HighE-HighB), e.g., ‘*bread’* and /pauruti/

2. Items with low familiarity-ratings in English as well as Bengali

(LowE-LowB), e.g., ‘*arrow’* and / ti:r/

3. Items with high familiarity-ratings in English but low familiarity-ratings in Bengali,

(HighE-LowB) e.g., ‘*airplane’* and /biman/

4. Items with low familiarity-ratings in English but high familiarity-ratings Bengali,

(LowE-HighB) e.g., ‘*gourd’* and /lau/

Raters’ responses were divided into “high” and “low” based on a pooled median rating for each word in each language group. Words with median ratings 5.5 or higher in both languages were categorized as high familiarity (HighE-HighB) and those with median ratings 2.5 or lower in the two languages were categorized as low familiarity (LowE-LowB). Word-pairs across the languages were categorized under contrastive familiarity if they had a median rating difference of 2.5 or higher (i.e., HighE-LowB and LowE-HighB)**.** These groups of words constituted the four lexical categories that were used to examine our first research question (see Table 3).

We also included semantic control items of pictures and words that are neither phonologically nor congruent to each other in each language. These words, presented with incongruent pictures (e.g. the word tiger with the picture of a butterfly) formed two more categories; the Semantically-unrelated Bengali words and the Semantically-unrelated English words (see Table 3). The Semantically-unrelated word-categories served two purposes. First, they acted as a control categories in which the expectancy violations (here a semantic mismatch between the word and the picture on screen) were much more robust than just a language violation. We expected that these salient semantic word-picture mismatches would elicit extremely slow reaction times and large negative voltage responses. This enabled us to verify that the participants’ reaction time and electrophysiological responses were sensitive to stimulus expectancy violations set up by a picture context, at least to large degrees of mismatch. Second, they were used to bridge the gap in syllabic length between the two languages. Since Bengali has more multisyllabic words than English, there was a significant difference in syllabic length across the words in the two target-word groups (English: 1.73; Bengali: 2.10). Syllabic length was controlled across the languages by adding 38 monosyllabic words in Bengali (the Incongruent Bengali category) and 36 multisyllabic words in English (the Incongruent English category) to balance this property across languages (see Table 3.). The role of the Incongruent categories relative to the rest of the words will be described in more detail later in this chapter.

In addition, cognates or words that share more than 70% of phonemes across the translation equivalents were not included in the Congruent category, except one word, “sari” as it was one of the words which was clearly High-Bengali but Low-English in familiarity. In addition 8/115 words in this category also shared the first phoneme, but were not cognates. The Semantically-unrelated category contained more words that could be cognates, shared phonemes, or were borrowed words, but these words were never heard in both languages (i.e., pictures in this category were paired with unrelated words for that picture only in English or in Bengali, but never both).

The words were selected such that for a lexical retrieval task, they would either trigger competition between translation equivalents across Bengali and English or not. Whether these words across the languages are in competition or not would be determined by the interaction of attrition mechanism and the difference in familiarity-ratings across them.

The distribution of responses to the stimulus categories described above, should, then, resolve the theoretical conflicts.

Category	*# of items*
HighE-HighB	27
LowE-LowB	33
HighE-LowB	29
LowE-HighB	26
Incongruent B	38
Incongruent E	36

Table 3: Lexical categories used in the experiment

Two female speakers, one in each of the languages, recorded the auditory stimuli, which included 151 English and 153 Bengali words (See Appendix II for word lists). Care was taken to ensure that the rate of speech, overall fundamental frequency, prosody and loudness were comparable across the words. The recordings were done using Sound Forge software version 4.5 digitized at a sampling rate of 22050 Hz. They were then normalized in root mean square amplitude to match each other. Any word beyond 1000 ms of length was discarded.

Four different types of pictures for each item were included so that a) trials can be repeated and b) repetition priming effects can be partially controlled. That is, even though the participants hear the same words twice and are set up to elicit them four times, the use of four picture-exemplars to do this reduced the amount of visual priming that would have been generated by repeating the same picture exemplar four times. Thus each item in the visual stimuli was repeated four times in total, twice with English auditory targets and twice with Bengali auditory targets. The picture stimuli were taken from Wikipedia-photos, Microsoft Clipart, Clipart.com and hand-drawings. All pictures were colored drawings outlined in black and photos colored. They were piloted with three individuals in a naming task to ensure that the intended referent was accessed. The pictures were presented on a computer screen against a white background scaled to a size of approximately 5 X 5 cm (Jescheniak et al., 2002).

The experimental task was set up to obtain cross-modal (picture to word) and cross-language (L1 to L2 or vice-versa) priming. The stimuli included the set of concrete words (nouns and verbs), divided into the six categories described above, presented visually (pictures) as well as auditory (words). The auditory words included translation equivalents in both languages (e.g. ball - /golok/). We presented the stimuli in the following sequence: first, participants saw a picture and then heard the name of the picture, in Bengali (L1) or in English (L2). The probability that they heard it in each of the languages was 50%, randomly distributed across the trials. The objective was to examine whether the pictures primed the English or the Bengali auditory word forms more strongly, as a function of the L1-L2 familiarity level.

3.3 Procedure

3.3.1 Pre-Experimental Procedures

Participants were familiarized with all the items using one set of Clipart pictures. They were asked to sort the four exemplars for each lexical item from a set of eight pictures (four distracters) and were always provided with the correct answer following each trial. A sorting task was chosen so as to avoid any language bias induced by a naming aloud response. Next, the participants were given a) detailed language background questionnaire and b) Category fluency task (for animals, clothing and food) in each language. They were screened for hearing as well. The language background questionnaire (compiled by Signorelli, 2007, Appendix II) ensured a detailed investigation of the participant's language acquisition, use and maintenance across lifespan. It also incorporated a self-rating procedure for speaking, understanding, reading and writing domains. The category or verbal fluency task is a procedure which entails the participant producing as many lexical items as possible within a restricted category, here "animal", "clothing" and "food" within 60 seconds (Hurks et al., 2006). This task has been extensively used in research to assess how individuals are able to access and retrieve items from their lexicon and or semantic/memory using both linguistic and executive functions. We used this task in this experiment as a means of comparing intensive lexical and timed retrieval skills across each of the participant's two languages. Scores were assigned by counting the number of items generated in the first 30 seconds, as well as within the full minute of the task for each language. All participants performed this task in English first, before the language background questionnaire was completed. There was at least an hour or more time span between this task and the experiment to ensure that the items accessed as part of the CF task in English before the experiment did not affect the participants. The CF task in Bengali was performed after the experiment. The procedure was kept the same across all the participants, that is, any bias for a language would have affected the L2- as well as the L1-dominant participants equally. All instructions during the experimental session was provided in English so as to keep the language environment constant across all participants whether L1- or L2-dominant.

3.3.2 Experimental Procedures:

The participants were seated in a comfortable chair in a sound treated room. The visual stimuli were presented on a PC monitor (17" screen) placed approximately 1 meter distant in the center, at 0 degrees to the participant. The auditory stimuli were presented through two free field speakers that are suspended above the participants. One speaker was placed at a distance of 1.5 meters from the participant at a vertical angle of 45 degrees in the front while the other was 0.5 meters at 25 degrees behind the participant. The stimuli were presented through a preamplifier at a comfortable hearing level. The experimental trials (comprising both visual and auditory stimuli) were delivered through E-Prime software version 1.1.

The stimuli, distributed into Bengali or English translation equivalents across the four stimulus categories, were presented as **a)** pictures followed by **b)** auditory words in Bengali or English. Each participant received all 460 (115 X4) trials. Each picture was followed by an auditory presentation of the picture name. The participant heard the names of the pictures 230 (115 X2) times in English and 230 (115 X 2) times in Bengali across all stimulus categories. There were 74 filler items for balancing syllable length across languages. This resulted in a total of 534 trials (4 stimulus categories X 2 languages + 74 items). The stimuli were randomly presented within each block. These stimuli were distributed into 15 blocks of 36 trials each, in order to create an confortable length for each block (about four and half minutes) and an optimum number of blocks. This resulted in about 8 stimuli randomly being repeated, one in each of 8 of the blocks. No lexical item was repeated within a block to avoid repetition priming. Each block was approximately three minutes forty-five seconds long, resulting in a one and half hour experiment.

3.3.2 .1 Experimental Paradigm

The experimental paradigm was adapted from Jescheniak et al.'s (2002) study as explained previously. We modified Jescheniak et al.'s experiment to change both the auditory and naming task to suit our experiment.

Each experimental trial in our experiment included the following sequence of events (Jescheniak et al., 2002) in time (see Figure 3) : a) a visual fixation signal ('+') for 500 ms b) the picture to be named for 400 ms c) the fixation signal again for 150 ms d) the auditory target for 1000 ms or less (depending on the length of the spoken word) e) a blank screen for 2000 ms.

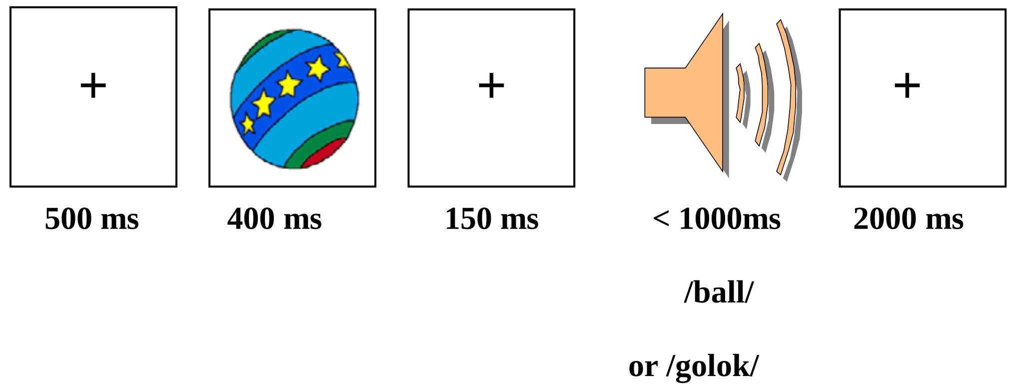

Figure 3. Timeline for a single trial as used in the current experiment

3.3.2 .2 Behavioral Procedures

Participants were instructed (in English) to carry out two tasks: 1) a picture-naming task and 2) a button press task to the auditory target. Each participant was asked to implicitly name each picture that appears on the screen, in whichever language they could access, as quickly as they could. Then they were asked to listen to the auditory target that followed and press a button labeled '1' if the auditory target contained one syllable and a button '5' if it contained more than one.

Each participant was provided with the opportunity for extensive practice (with 200 trials) in English, keeping with the English environment during the experimental procedure. The practice-trials were common concrete nouns different from the experimental trials (both in terms of the visual and auditory parts of the experiment) so as not to have a training effect on the experimental trials. The pictures and their auditory cohorts in the practice blocks were not semantically matched as in the experiment and each block of trials contained 50 of them. Trials were increased in difficulty to facilitate learning the experimental task. The participants were asked to do the following tasks sequentially: for each trial (constructed in the same fashion as the experimental trials), a) for the first block, they only name the picture on the screen overtly (aloud) as quickly as possible, ignoring the auditory stimulus that followed b) for the same block, they name the picture on the screen covertly as quickly as possible c) for the same block, they name the picture and pressed button “1” for monosyllabic stimuli and “5” for multisyllabic stimuli when the auditory stimulus followed and finally d) repeat the task c) for a different block of stimuli. For each practice task, the participants were instructed differently. Specifically they were instructed in the following manner: a) You will see a picture on the screen followed by someone naming the picture. The names of the picture can be correct or incorrect. Your job is to name what you see on screen aloud as quickly as possible, even before you hear the name if possible. b) You name the pictures on the screen just like you were naming, very quickly, but now name them inside your head, i.e., do not name them aloud. c) Now you have to juggle two tasks: name the picture you see on screen as you were, in your head, then listen to the name of the picture that follows and decide if the word contains one syllable or more than one syllable. Press 1 if the word contains 1 syllable and 5 if it contains more than one syllable. You have to make sure you press the buttons as quickly as you can, but be careful not to press it so quickly as to miss the response window. You will receive feedback on screen to tell you if you are correct, incorrect or missed responses. Please try not to miss any chance to respond d) you do the same things as you were in the last block, but now try to sit still and don’t blink too much. If you have to blink, please do so after you press the button and before the next picture comes on screen.

For the experimental part of the procedures, the participants were given the following instructions: “You will continue doing the same type of tasks you were doing in the last block of practice run. The only differences are as follows: 1) the pictures you will see now are those that you saw at the beginning of your session here, i.e., the ones you sorted out. 2) the word that follows the picture will be in either Bengali or

English, you will count syllables for this word irrespective of the language 3) you can name the picture in your head in any language that you access it in- the important thing is to name it 4) you will not get any more feedback except for when you miss responses. So please try never to miss a response".

3.3.2 .3 Electrophysiological Procedures

We recorded electroencephalograms (EEG) at 65 scalp sites using Net Station Software version 4.1. The electrodes were arranged as a sensor net and sheathed in sponge-encasings. The sponges were soaked in a potassium chloride solution to increase conductivity. The impedances of the electrodes were maintained below 50 KOhms. Vertical and horizontal electrode montages near the eyes were used to monitor eye movement and eye blinks. The recordings were referenced to vertex (Cz) during data acquisition, but changed to an average reference for data analysis. The recordings were sampled at 250 Hz and then amplified with a band pass filter of .1 and 30 Hz using a 64-channel Net Amps.

3.4 Data Preparation and Overview

3.4.1 Selecting L2-dominant participants

The 27 bilingual participants tested in this study presented with a broad range of characteristics related to language-use and language environment. To answer the research questions presented earlier, it was important to select a group of participants who showed better performance in L2 than in L1 now, but were expected to be L1 dominant or relatively balanced before being immersed in L2. The goal of this analysis was to use reaction time and performance on the category fluency tasks in the two languages to establish two different groups of language dominance.

Specifically, we examined the reaction times in the priming experiment as well as performance on the category fluency task for L1 and L2 to determine which participants should be added to the experimental group (L2-dominant attrited) and which should be added to the control group (L1-dominant non-attrited). In addition, utilized information from the Language Background Questionnaire (Signorelli, 2007) especially a) amount of L1 & L2 use and b) self-ratings on L1 and L2 to corroborate our groupings.

The reaction time data for each participant (except B04, see next section) was examined for L1 and L2. Better performance in a language was defined as shorter reaction time in that language compared to the other. In order to be objective in this approach, since each participant had different numbers of missed trials, 100 trials from each participant were randomly selected for each language. The averages of the reaction time to these 100 trials were then calculated.

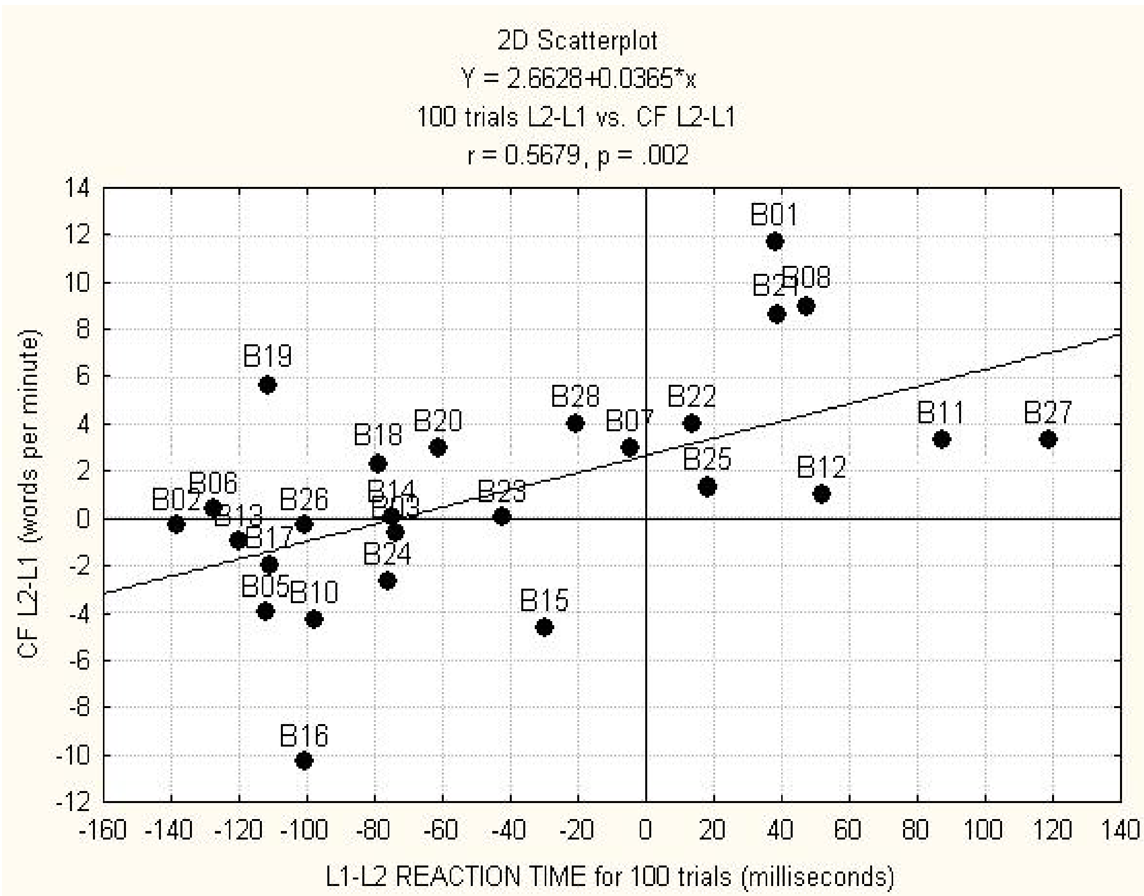

Figure 4. Difference between L1 and L2 in the category fluency task compared to reaction times for each participant. Difference between performances in the languages is measured as L1-L2 for RT and L2-L1 for category fluency so that the better performers in L2 had positive numbers for this difference

Next we examined each participant's performance on the Category fluency task (one-minute duration) in each language. The difference between L2 and L1 for both the reaction time (RT) data (for 100 trials) and the category fluency (CF) task were then correlated with each other. We expected that participants with a high score for L2-L1 in the CF task, (that is those who were better in L2) would also show a longer reaction time for L1-L2 (as they would be poorer on L1). The difference in CF performance between L2 and L1 correlated significantly with the difference in RT for L2 and L1 ($r = .57$, $p < .01$) in a product moment correlation (see Figure 4) in the expected direction. Two groups were created on the basis of this analysis. All participants in the upper right quadrant of Figure 4 constituted the L2-dominant group. A Repeated Measures ANOVA of the CF scores for the two languages from the two groups revealed an interaction of Language and Group [$F(1, 24) = 13.52$; $p < .01$] such that the L2-dominant group showed significantly (Tukey HSD $p < .01$) poorer performance in the L1 CF task compared to L2 (see Figure 5).

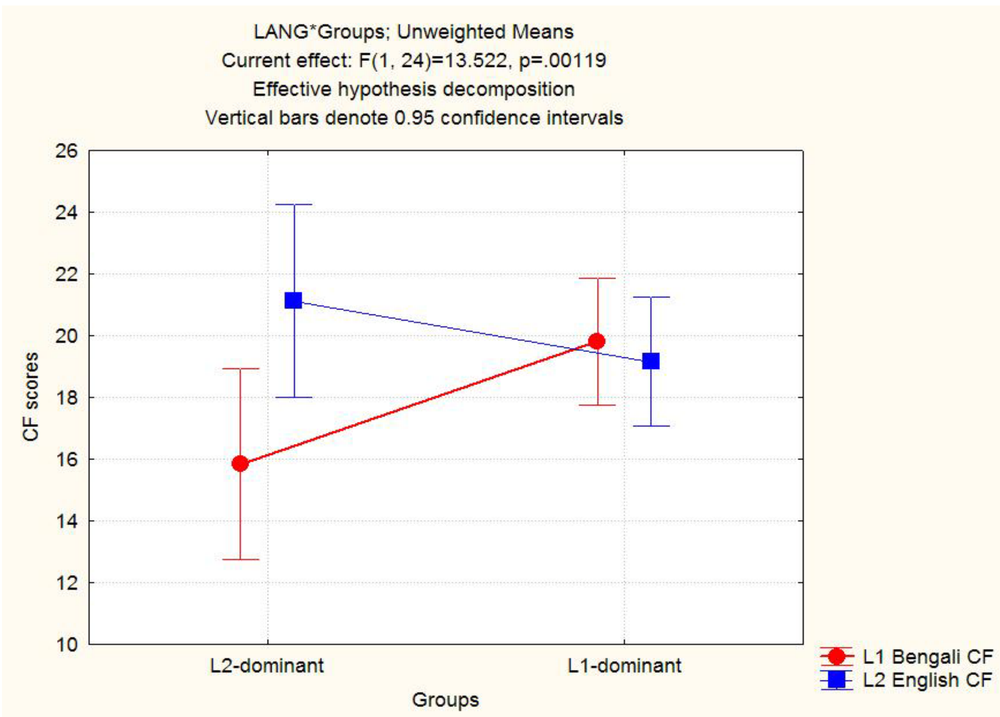

Figure 5: Category fluency scores of the L1-dominant and L2-dominant groups demonstrating poorer scores for Bengali than English in the L2-dominant group

We also scrutinized how these eight participants self-reported fluency on the language background questionnaire. We present these data in Table 1., where it is evident that five out of eight of these participants rated themselves poorer in L1 than in L2. Also, all of them reported more exposure to L2 than L1 for speaking, listening and reading. The rest of the participants constituted a second group, which we will refer to as "L1-dominant". However, it is important to note that this group consisted of participants who were significantly better in L1 than in L2, as well as those who were more balanced. We performed T-tests for each of the participants' reaction time data for all English and Bengali trials. Nine of the nineteen participants in the "L1-dominant group" showed significant differences between L1 and L2 in the direction of L1 being better in paired t-tests, whereas the rest showed no statistical difference between the languages.

3.4.2. Reaction Time Data

We tested 27 Bengali-English speakers altogether, on two performance tasks; a category fluency task and a cross-modal, cross-language priming experiment. They were also required to fill out a language background questionnaire (Signorelli, 2007), which provided information about their language-use and experience. All participants considered Bengali their first language and English their second language. Each participant was also at least a trilingual and fifteen of them were being currently exposed to a third language (Hindi) to varying degrees, however all participants reported conversational comprehension skills in this language.

The mean reaction times across the participants ranged from 693 ms to 1405 ms. The overall mean reaction time for all participants across the two languages was 958 ms with a standard deviation of 321 ms. Figure 5 shows a distribution of each participant mean reaction times across all trials. Any response time greater than or less than three standard deviations from the group mean response was excluded from the analyses. All participants (except one) were able to respond to at least 75% of the trials. One participant, who responded on only 50% of the trials, was not included in the analysis. Figure 6a shows the mean reaction time for L1 and L2 for each participant after removing outliers and, Figure 6b shows the mean reaction times with standard error of the means for the two groups and languages.

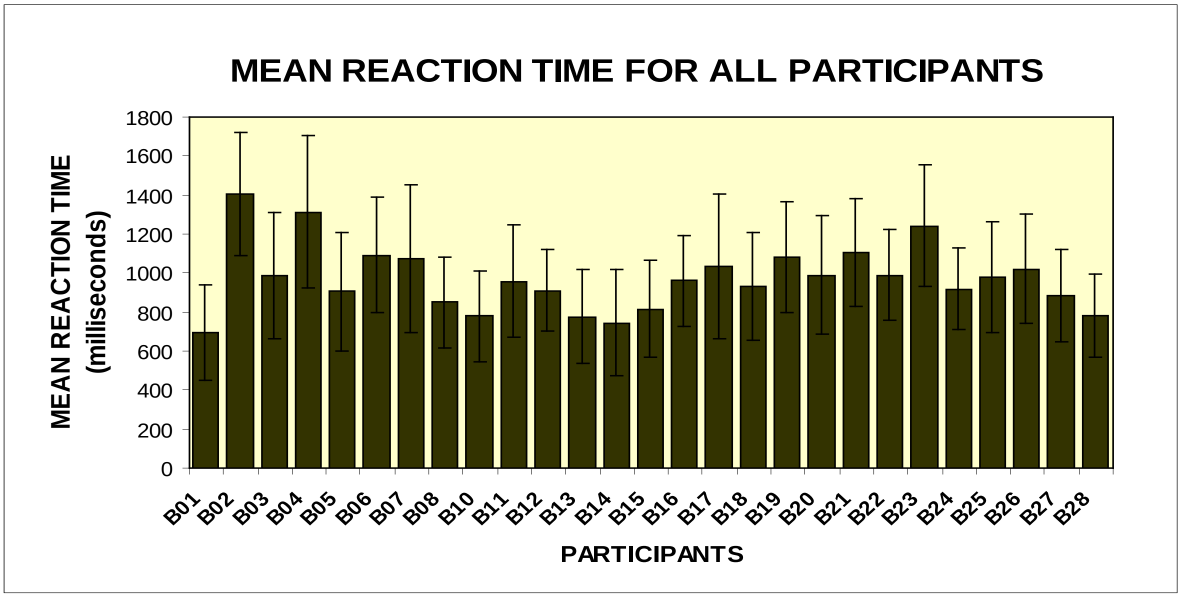

Figure 5. Individual participants' overall reaction times collapsed over L1 and L2 (Error bars denote standard deviations)

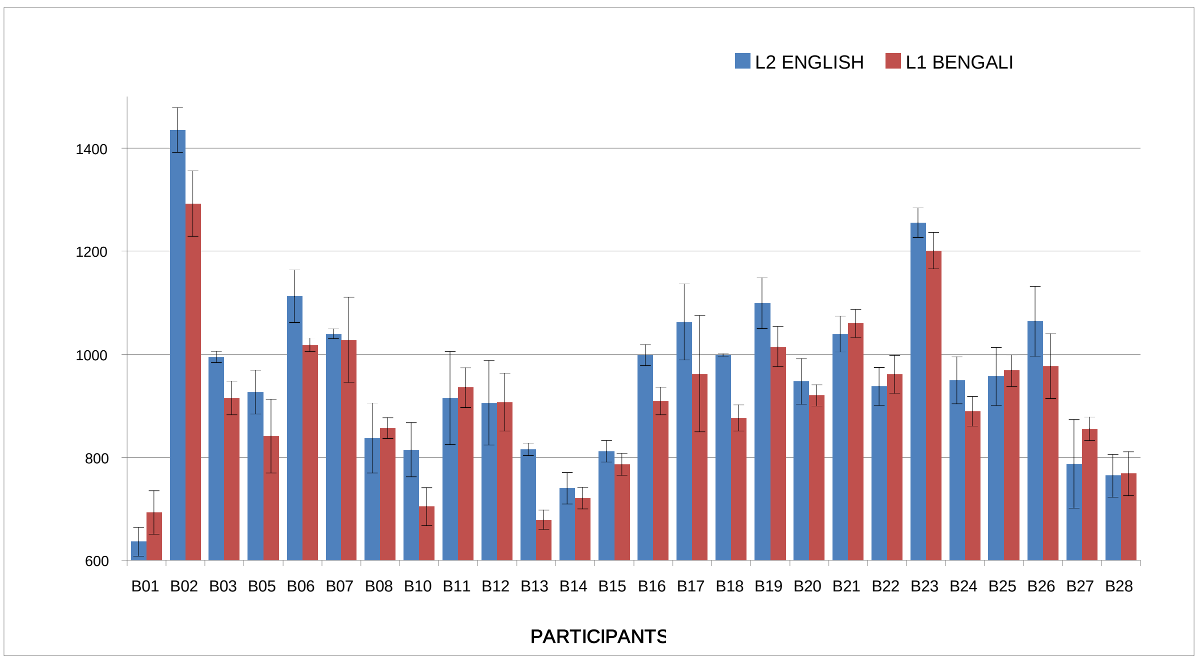

Figure 6a. Individual participants' reaction time for L1 and L2. (Error bars denote standard deviations)

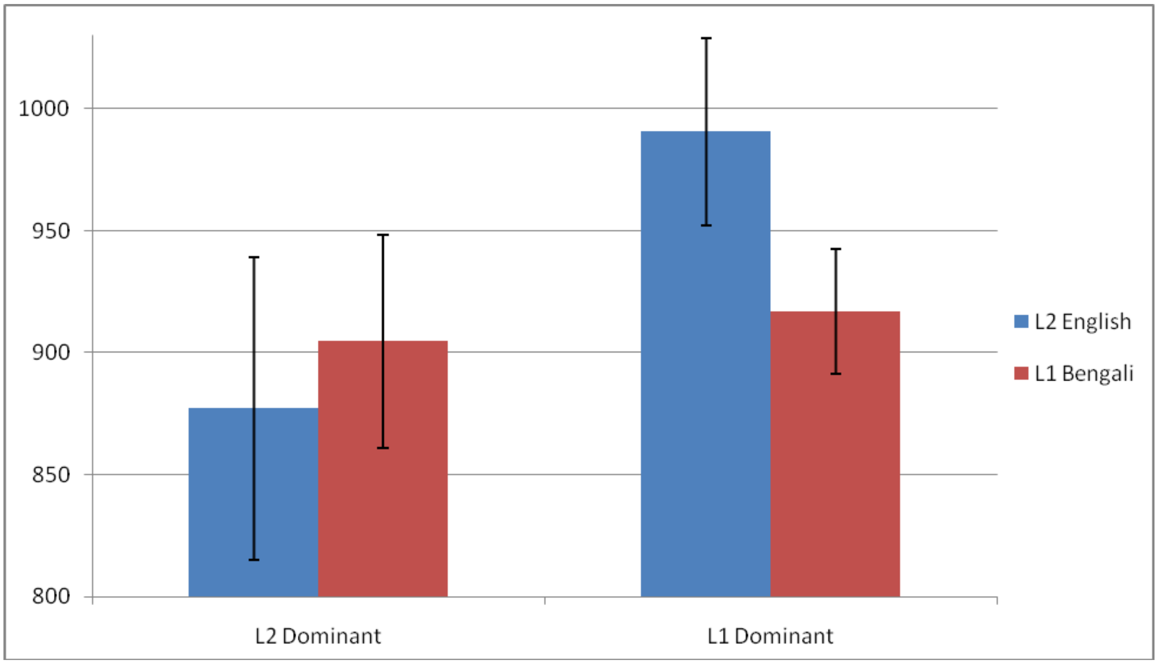

Figure 6b. Mean reaction times for L1 and L2 for the L1 and L2-dominant groups. Error bars show standard deviations.

3.4.3 Electrophysiological Data

A subset of the participants participated in the electrophysiological experiment as well. The L2-dominant group of 8 participants remained the same as that used in the analysis of RT data. Nine out of the remaining eighteen in the L1-dominant group also participated in the ERP experiment.

Data from these 17 participants were then processed for further analysis. The continuous data were segmented for a 1200 ms window at the stimulus onset with a prestimulus baseline of 200 ms beginning 200 ms before stimulus onset. The epochs were then averaged within each of the stimulus categories for each language. Epochs with artifact greater than 70 microvolts (mostly blinks and eye movements) were excluded from the average. Further, channels with more than 15% of epochs with artifacts were replaced with data interpolated from the surrounding channels. Similarly, if 15% of the channels have artifacts detected in a certain epoch, it is also excluded from the average.

Since the experiment consisted of visual stimuli, many of the trials were contaminated by eyeblinks and rejected from the average data for each person. The percentage of trials rejected for eyeblinks was as high as 80% for certain individuals. In order to overcome this issue of reduced number of trials, we performed an extra process where the data were subjected to removal of the eyeblinks before averaging the trials. This process was carried out using the EEGLAB version 3.0 software with a program written by Delorme and Makeig (2004). Delrorme and Makeig's method of removing eyeblink entailed a two-step process 1) decomposing the raw (unaveraged data) using Independent Component Analysis and then 2) modeling a human eyeblink from time course and topographical data that are written into a matlab program. To take advantage of this eyeblink correction program, we first segmented data from each participant into single trials and processed them for artifact detection. These data were then subjected to the matlab eyeblink correction program and further processed for artifact detection and bad channel replacement before averaging them. The data, reprocessed using the same specifications reported earlier, resulted in many fewer trials that were rejected for eyeblinks.

Next we provide an overview of the averaged electrophysiological data for each group. The experiment contained a set of control items that were included for two reasons: a) to control for syllable length across the languages and b) to verify that all participants in the electrophysiological experiments were able to elicit an increased negativity to words that mismatched their expectations, compared to those matching their expectations. These items, approximately half in L1 and half in L2 (longer words in English and shorter words in Bengali) were paired up with pictures that were the incorrect referent of the word. The participants were therefore expected to obtain a large negativity around 400 ms, on encountering highly unexpected incongruent words to the pictures. Figure 7a and b (below) display the two groups' responses to the set of incongruent items compared to the congruent items in each language. The L1-dominant group showed smaller negativities to both English and Bengali relative to the L2-dominant group. The L2-

dominant group showed a large N400 (-8.5 μV) to the incongruent targets in English and a much smaller one to those in Bengali. Thus both groups generated large N400s and in particular, the L2-dominant group showed the largest N400 to the English mismatched word-referent to the pictures.

The primary experiment consisted of auditory words in L1 and L2 that were congruent to the preceding pictures. Here, the participants were expected to obtain a greater negativity when the language of the auditory target word was not in their expected language. Expected language was modulated by the language dominance of the participant. This negativity, which we refer to as the phonological N400 in this section, peaked between 160 and 400 ms and then continued as a sustained negativity until 800 ms. Figure 8 displays the responses to the auditory target words in L1 and L2 for each of the two groups at Pz34 (site 34). It is apparent that L2-dominant group (Figure 8a) showed a larger negativity to L1 words than L2 words, while the opposite was true for the L2-dominant group (Figure 8b).

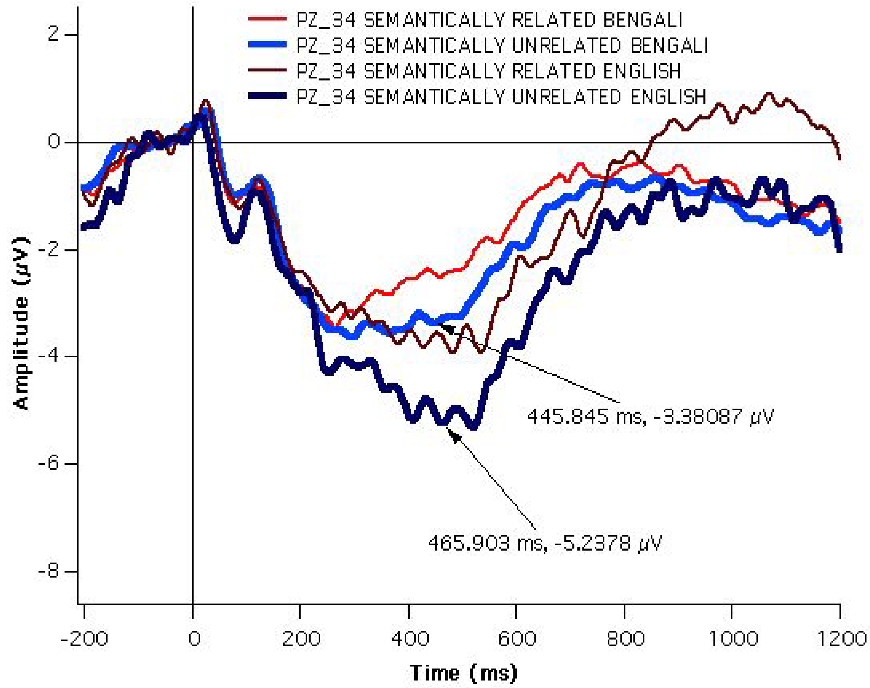

Figure 7a. Responses to incongruent auditory targets for L1-dominant group in L1 and L2

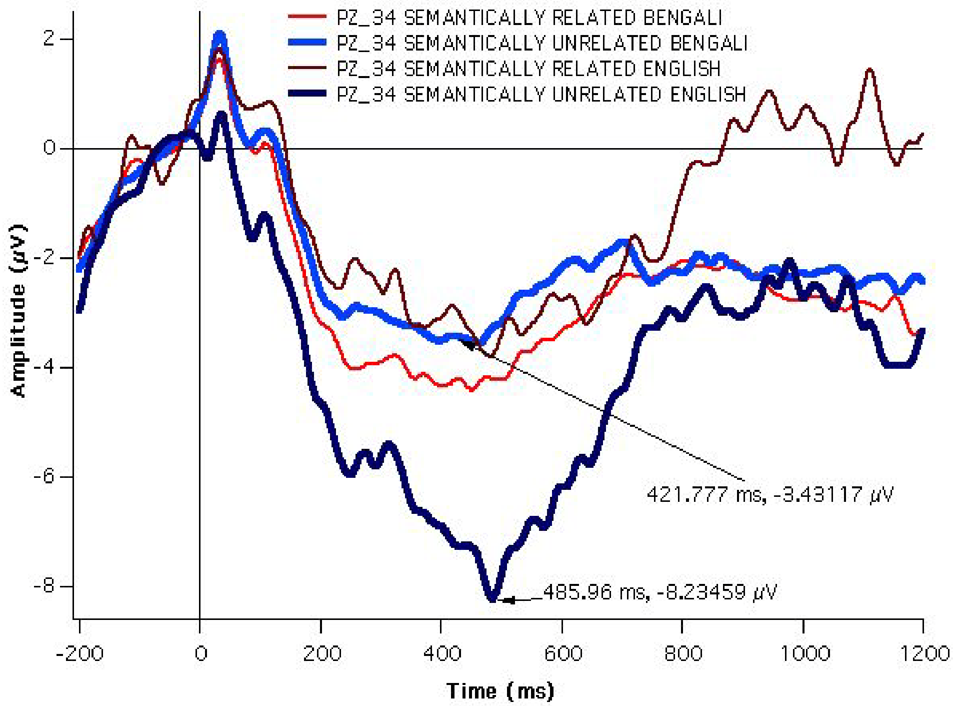

Figure 7b. Responses to incongruent auditory targets for L2-dominant group in L1 and L2. Magnitude of Semantic N400 bigger to English in the L2-dominant unlike the L1-dominant group

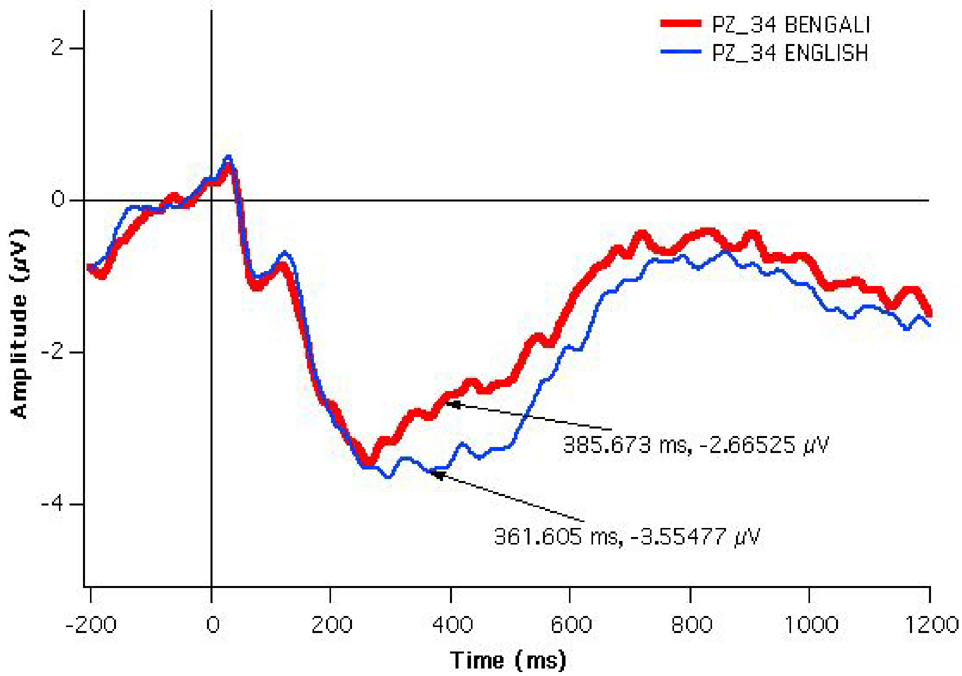

Figure 8a. Phonological N400 to L1 Bengali and L2 English for the L1-dominant group to the Pz electrode. L2 responses appear negative relative to L1 responses

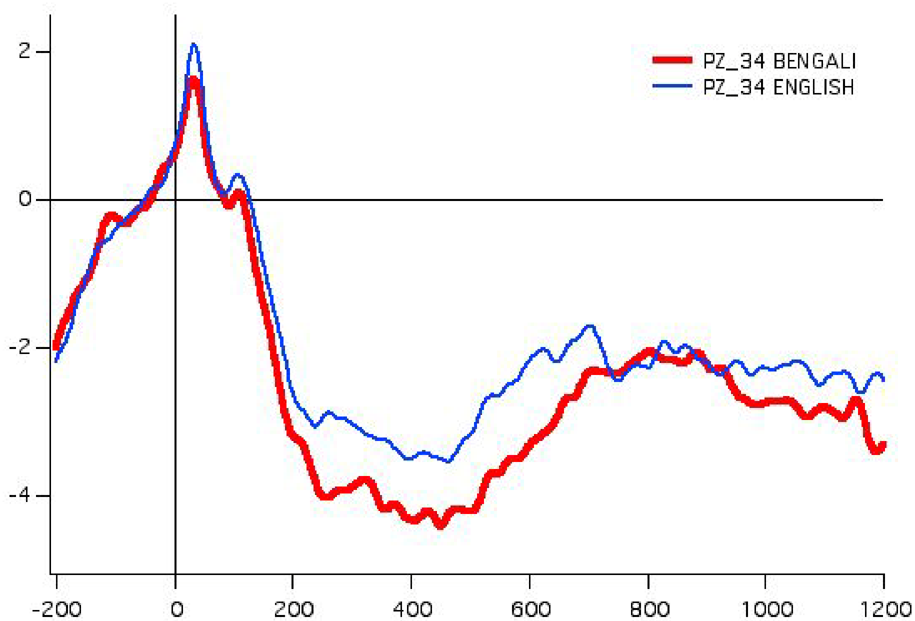

Figure 8b. Phonological N400 to L1 Bengali and L2 English for the L2-dominant group to the Pz electrode. L1 responses appear negative relative to L2responses

3.5 Data Analyses

3.5.1 Reaction Time Data

Reaction time data from participants was incorporated in a Repeated Measures ANOVA in order to address the research question on mechanism of attrition. To do so, we examined the effect of the four stimulus categories on the reaction times to English and Bengali targets in the two groups of participants.

A mean reaction time was computed for each participant in both L2-dominant attrited and L1-dominant non-attrited groups for 8 separate groups of responses, i.e., 4 stimulus categories: LowE-LowB, HighE-HighB, HighE-LowB and LowE-HighB each, for Bengali and English targets. These mean reaction times were then subjected to repeated measures ANOVA (Group X Language X Stimulus Category). An interaction of Group and Language was expected if the two groups showed opposite patterns with respect to L1 and L2. Any main effects or interactions involving the stimulus categories informed us which of the three different models of attrition contributed towards attrition, provided that indeed L1 performance (here RT) is longer than L2 performance. ANOVAs for the L2-dominant group alone were also planned as the answer to the research question regarding mechanism of attrition could better be answered from the group performing worse in L1 compared to L2. If the faster performance in L2 over L1 is driven by L1-use alone, leading to a reduction of L1-strength, we expected to see a main effect of Language in the direction of L1<L2. On the other hand, if it is L2-interference over L1 that is driving the slower performance in L1, then we expected to see a significant interaction such that L1 will be poorer than L2 in all stimulus categories except the LowE-HighB category. A third possibility, that both mechanisms contribute to attrition would be supported if all categories showed L2 > L1, but a lesser effect in the LeHb category.

3.5.2 Electrophysiological data

3.5.2.1 Incongruent words

Selection of sites and epochs for statistical analysis with the semantic N400 was guided by previous literature but also involved inspecting topographical maps and examining amplitude-time plots with the selected sites. Topographical distribution of the semantic N400 for both L2 and L1-dominant groups (Figure 9a and b) was strongest at the mid-parietal sites Cz, Pz (sites 34 and 38). An amplitude by time plot of these electrodes revealed a broad negativity for the incongruent items (relative to the related items) from 200 to 700 ms. This large epoch was then divided into five 100 ms time bins for analysis of variance to provide more fine-grained temporal information.

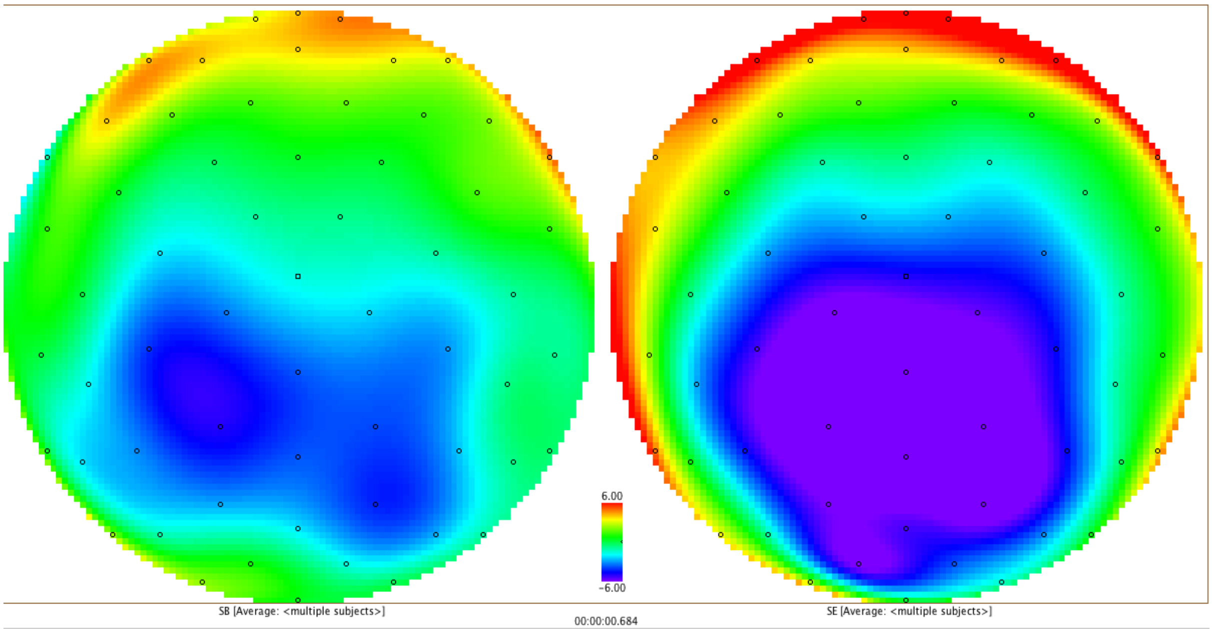

Figure 9a. Topographical maps to Bengali and English incongruent words at at 483 milliseconds for the L2-dominant group. Responses show a bigger negativity for the English than Bengali words for this group

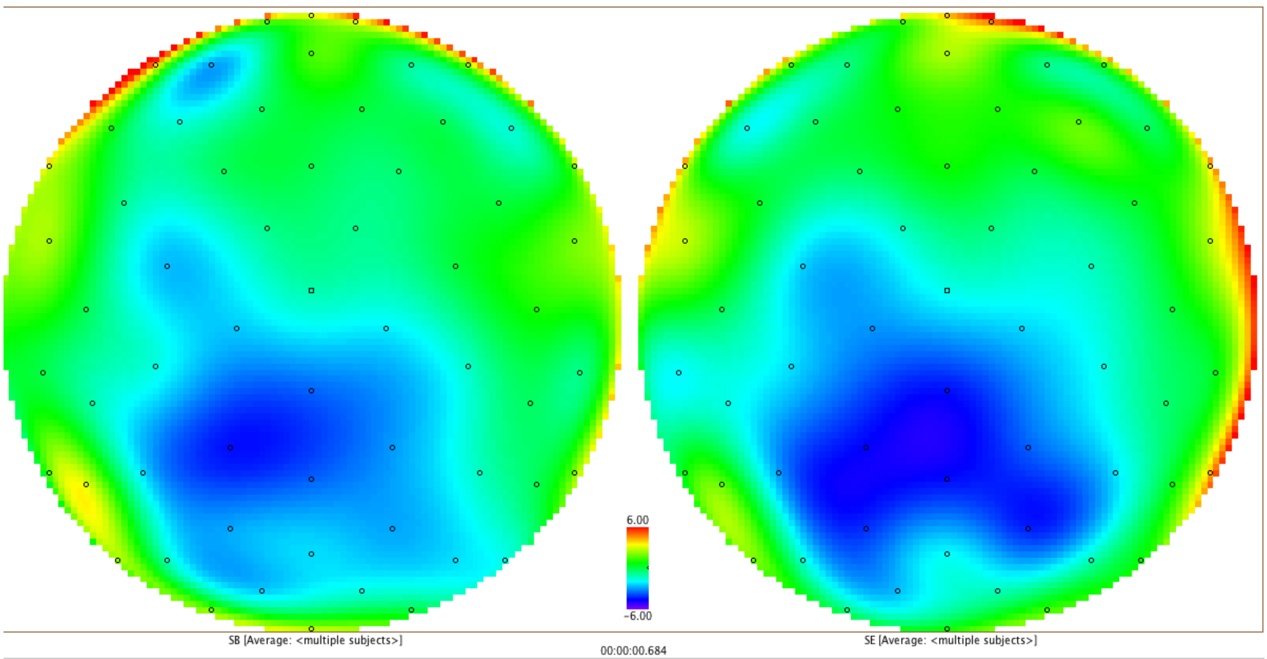

Figure 9b. Topographical maps to Bengali and English incongruent words at at 483milliseconds for the L1-dominant group. Responses show a smaller difference between English than Bengali words for this group

3.5.2.2 Congruent words

Data from the primary experiment (involving four word-categories and two languages) were plotted in amplitude and time as well as using topographical maps in order to select the appropriate time windows and electrode channels for analysis. Figures 9a and 9b show topographical maps at two different time points for the two groups for L1 targets minus L2 targets. Figure 9c demonstrates that the L2-dominant group showed a mid to right lateralized posterior negativity of approximately of 1 microvolt that was not there for the L1-dominant group in the earlier time point (256 ms). This negativity in the L2-dominant group was sustained until 700 milliseconds, but with a small decrease in amplitude around 400 milliseconds. The topographical maps for the later time point (600 ms) presented in Figure 9d demonstrate this sustained negativity in the L2-dominant group, in contrast with a developing positivity in the L1-dominant. This pattern indicates that it was easier for the L1-dominant group to access Bengali than English words.

From the topographical maps it was determined that centro-parietal sites (34 and 38) as well as right-lateral sites (41, 42, 45, 46) showed the largest difference between L1 and L2 words. That is, the largest N400 as a function of language mismatch was greatest at these electrode sites, in the direction of L1 targets showing a larger negativity than L2 targets. In their 2002 study (on which the paradigm used in this study is based) Jescheniak and his colleagues also suggested a "phonological N400" to be stronger in the centro-parietal and right parietal regions as compared to the left parietal sites. Together with the findings of their study and the topographical distribution of data found in this study, we identified six different sites as best capturing the phonological N400 effect. These include midline (Pz sites 34 and 38), mid-right (41 and 42) and right (45 and 46).

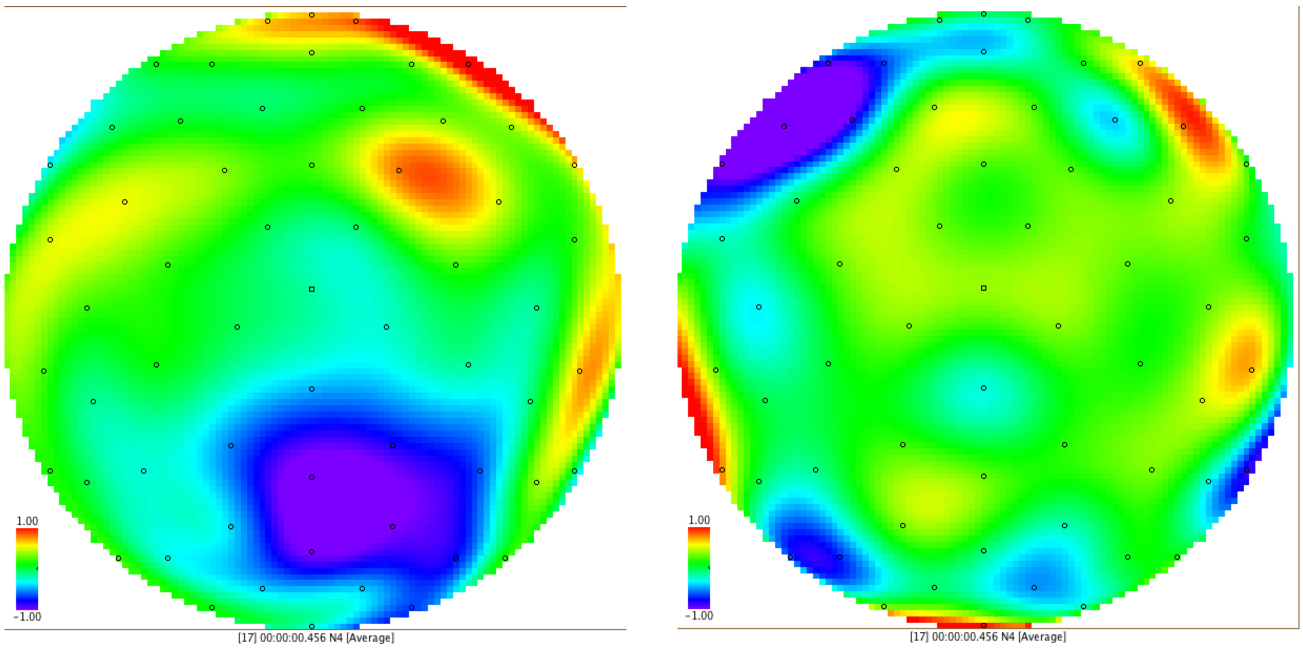

Figure 9c. Topographical maps for the difference between Bengali and English responses (Bengali-English) at 256 milliseconds for the L2-dominant (left) and the L1-dominant group (right). Responses show a negativity for the L2-dominant group in the parietal sites but not for the dominant group, indicating L1 was more difficult to access for the L2-dominant group than the L1-dominant group.

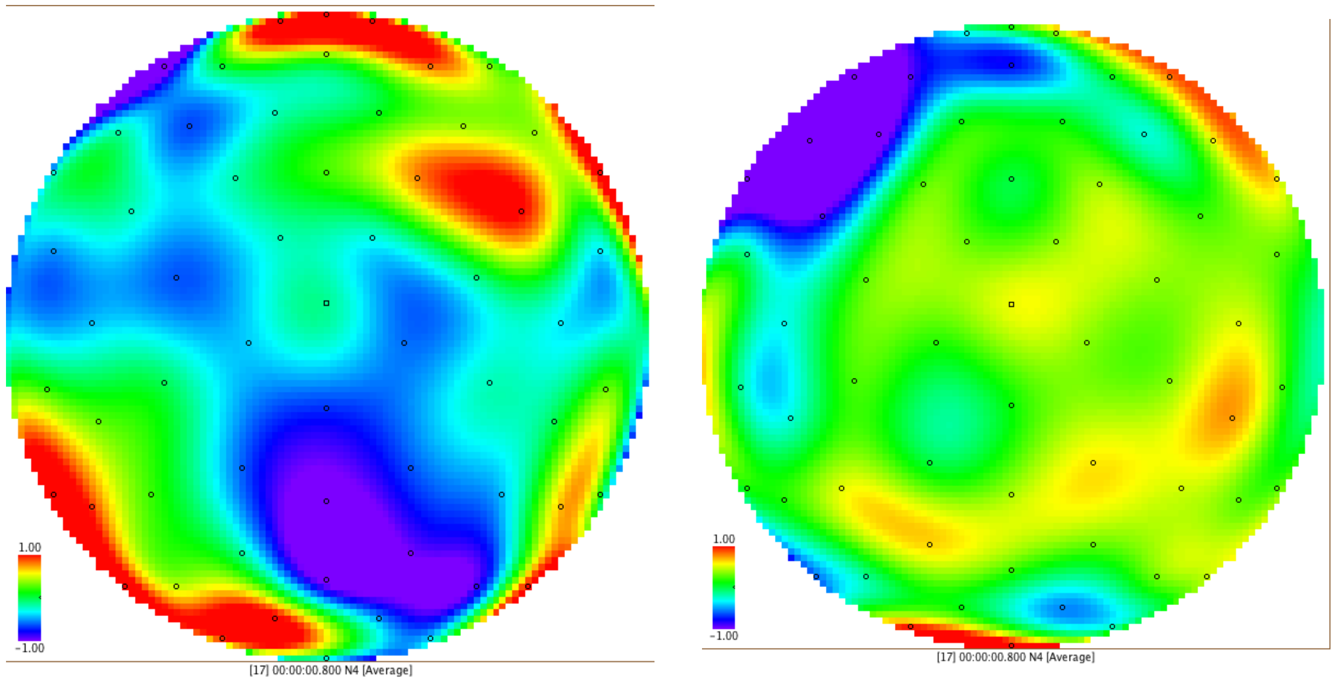

Figure 9d. Topographical maps for the difference between Bengali and English responses (Bengali-English) at 600 milliseconds for the L2-dominant (left) and the L1-dominant group (right). Responses show a negativity for the L2-dominant group but a positivity for the L1- dominant group, indicating L1 was more difficult to access for the L2-dominant group while L2 was more difficult for the L1-dominant group.

The epochs for the analyses were also chosen based on the nature of data obtained from this study as well as previous findings from Jescheniak et al.'s study (2002). Figure 10a below shows an average of six electrode sites for the L2-dominant group for Bengali and English, followed by a subtraction of responses to L2 targets from L1 targets in Figure 10b. As described in the previous paragraph, these graphs demonstrate two peaks of negativity, one between 160 and 440 ms and the other between 440 and 800 ms. Jescheniak et al. (2002) had reported that the phonological N400 they obtained appeared in the earlier time frame between 250 ms and 400 ms of stimulus onset. We undertook two different analyses, one in the earlier, shorter time frame of 160-440 ms with 40 ms time bins and one in a later, longer time frame from 400 to 800 ms with 100 ms time bins. We used 100 ms time bins for the later time frame because using 40 ms time bins for 400 ms (400 – 800 ms) would yield too many levels for the ANOVA analyses decreasing power per time bin. Since the subtracted responses (to the English from the Bengali words) showed overlapping, complex peaks, we overlapped the early and late epochs in time (160 - 440 and 400 – 800) in order to include the offsets and onsets of the peaks in these epochs across participants.

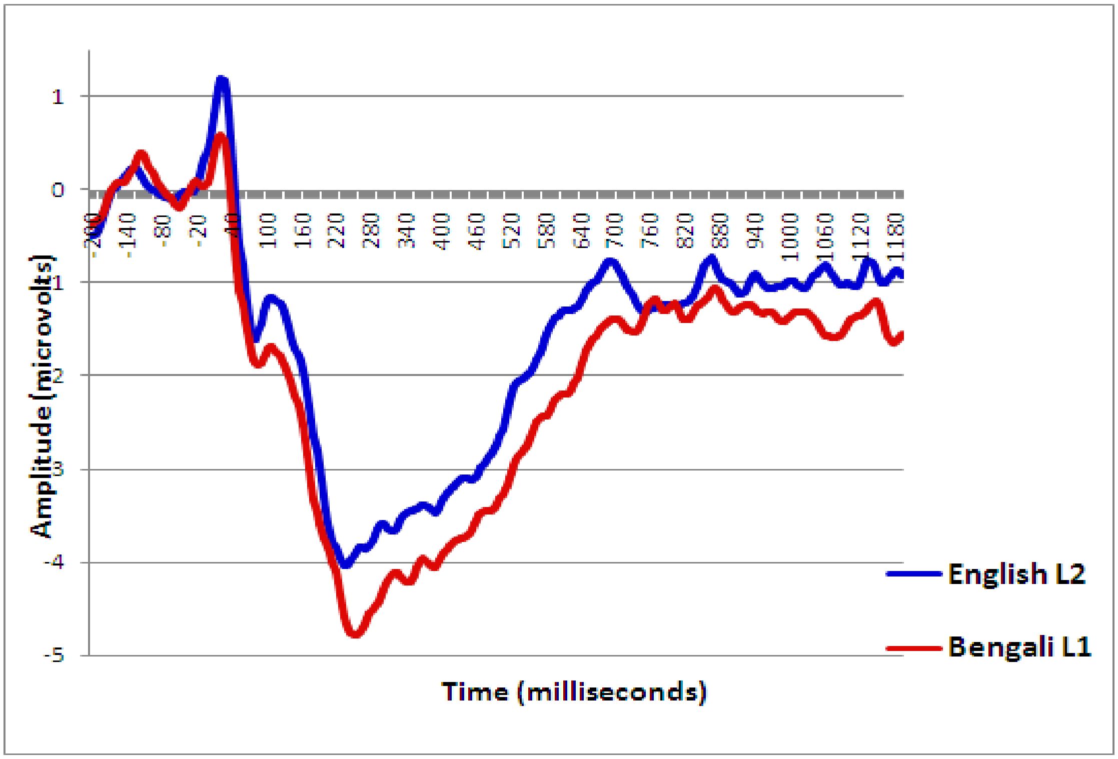

Figure 10a. Responses to L1 Bengali and L2 English averaged over six electrode sites (Pz34, Pz38, 41, 42, 45 and 46) for the L2-dominant group.

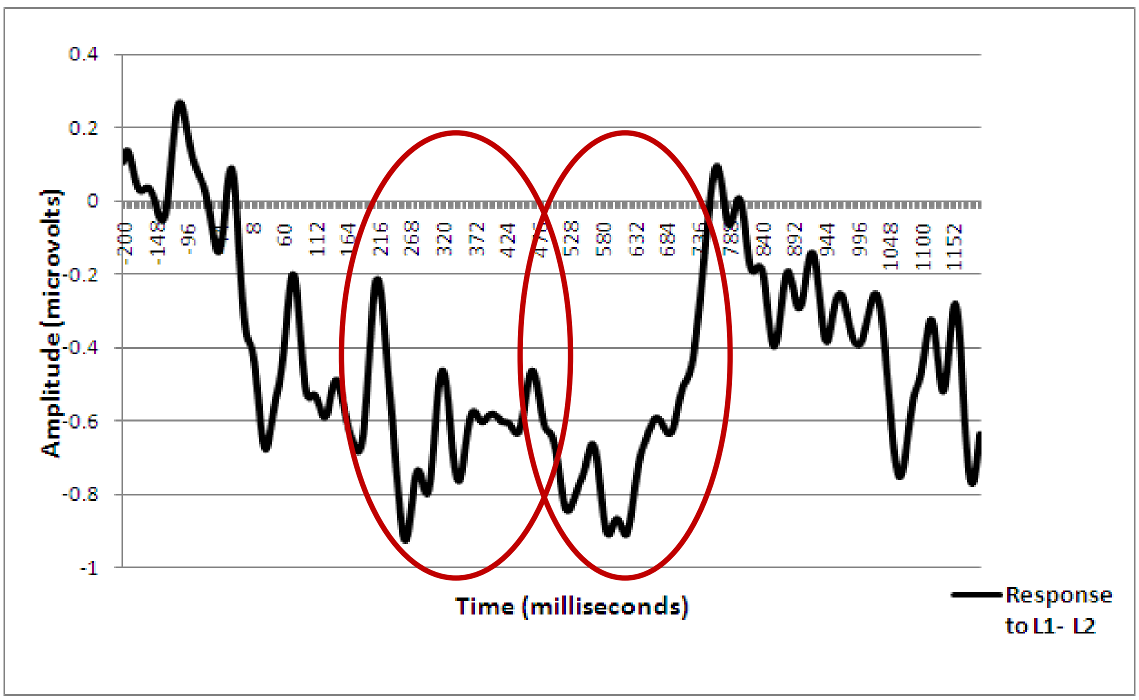

Figure 10b. Difference between L1 and L2 responses (L1-L2) averaged over six electrode sites (Pz34, Pz38, 41, 42, 45 and 46) for the L2-dominant group.

The effects of each language as well as the effect of the semantically mismatched targets in each language were examined. To determine the effect of semantic mismatch, the groups were examined with an ANOVA of Group X Semantic relatedness X Language X Site X Time. The analyses for the phonological mismatch were designed to mirror the RT analyses. For each epoch (both the early and the late) the following set of analyses were carried out. Each participant's electrophysiological responses were averaged for the time bins being analyzed for each language, word-pair category and site (4 stimulus categories each for Bengali L1 and L2 targets). The voltage responses to Bengali targets were statistically compared to those for the English targets in an ANOVA of Group X Language X Laterality X Site X Time. And finally, to examine the effect of each word-pair category, another ANOVA of Group X Language X Category X Laterality X Site X Time was performed. Interactions and Main effects that are significant at .05 levels or less were followed up with step down ANOVAs. Two-way significant ANOVAs were followed up with post hoc Tukey HSD tests. Main effects of Language or interactions of Language and Time indicated whether there was a larger N400 for L1 over L2. Any interactions involving the stimulus categories informed us about which attrition model contributes in what way to attrition, if N400s to L1 are larger than to L2. In discussing the results, the N400 component is referred to as a negativity so as not to commit to a strict label within the constructs of this experiment.

IV. RESULTS

The results of the study including a detailed description of data analysis are presented in this chapter. A description of the overall data for all participants is presented, followed by section on how the participants were divided into groups for further analyses. Next, descriptions of data analyses and results for reaction time (RT) and electrophysiological (ERP) data based on a priori research questions are presented. Accuracy was not an important aspect of the task because it was used as a measure to ensure that the participants were attending to the complete word, rather than to inform us about how well they were able to count syllables. The participants were instructed to be extra careful about not missing any trials, to ensure they were listening to the words that were presented. Nonetheless, overall, all except one participant, who had 50% accuracy, obtained more than 70% accuracy on the task.

4.1 RT Data

4.1.1 Congruent Words

4.1.1.1 Group Effects for RT data

The reaction time responses to L2 and L1 for the L2-dominant and L1-dominant group were subjected to a Repeated Measures ANOVA in order to examine whether they were significantly different in terms of their language performance as a group or not. Results showed a significant LANGUAGE X GROUP interaction [F (1,25) = 37.91; $p= < .01$, $\eta_p^2 = .612$]. Figure 11 illustrates that the groups demonstrated opposite patterns for their L1 and L2 skills. A Tukey HSD test to examine the interaction revealed a significant difference between the languages for the L1-dominant group only ($p < .01$), suggesting faster RTs for Bengali than for English.

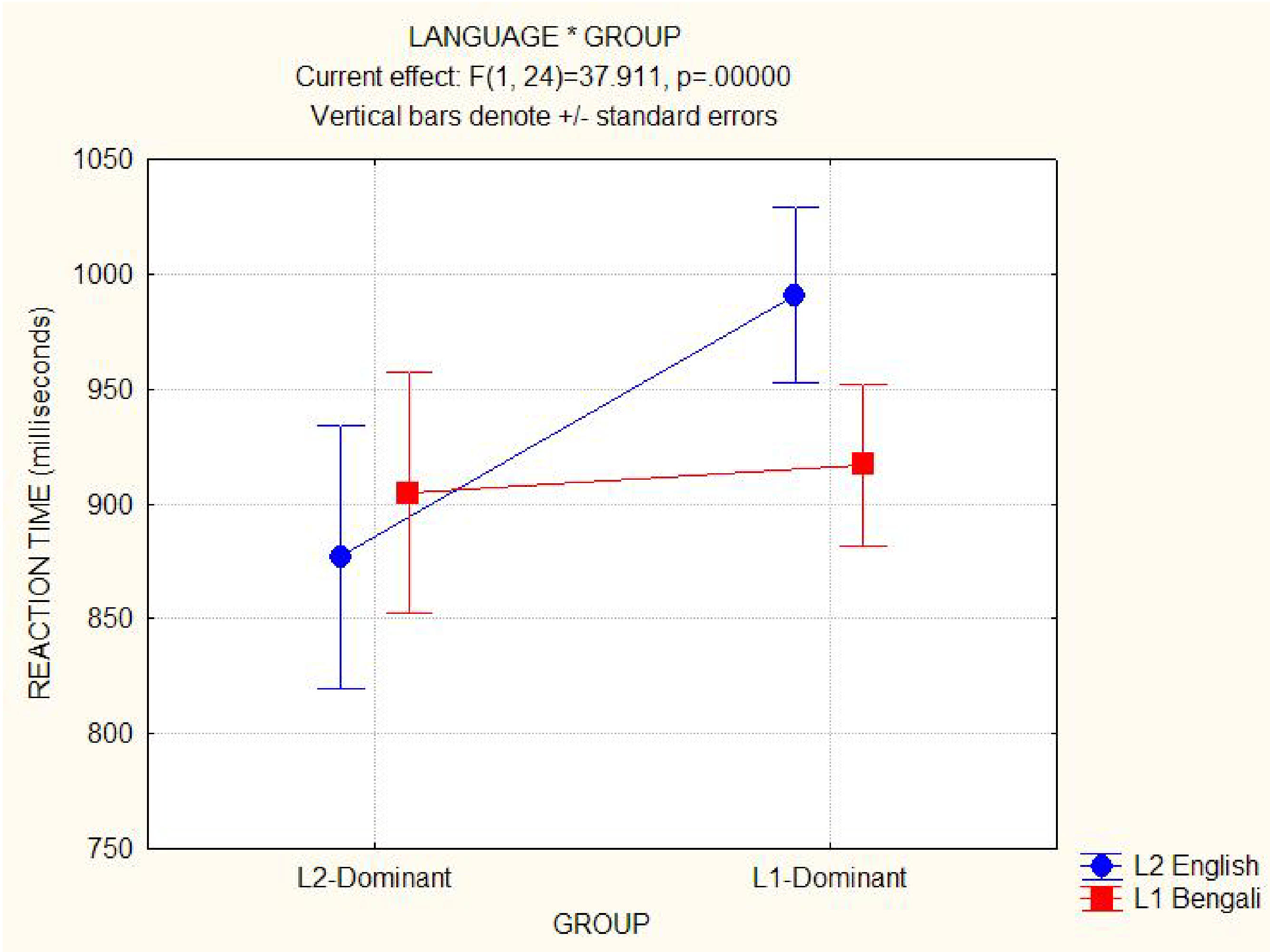

Figure 11. RTs (in ms) for language (L1, L2) for each group (L1-dominant and L2-dominant) showing different patterns for the two languages

In sum, the groups showed significantly different behavior for their L1 and L2 as demonstrated by the interactions of language and group reported above. The L1-dominant group is significantly faster in L1 than in L2 and therefore warrants the label “L1-dominant”. In the next section using word-pair category effects, we will examine whether the L2 interference model or the L1-strength models account for L1 lexical attrition.

4.1.1.2 Word-pair Category Effects for RT data

4.1.1.2.1 Word-pair Category Effects for the L2-dominant group in the RT data

One of the two research questions investigated in this study was whether reduced L1-strength due to decreased use, L2 interference into L1, or both contributed most towards L1 lexical attrition. To answer this question we examined each group separately. We performed a four-way Repeated Measures ANOVA involving LANGUAGE (L2-English, L1-Bengali) X WORD-PAIR CATEGORY [HighE-HighB (HeHb), LowE-HighB (LeHb), LowE-LowB (LeLb), HighE-LowB (HeLb)] and using RT as the dependent variable. We had argued that faster RTs for L2 than L1 in all four word-categories by the L2-dominant group would indicate more contribution to attrition from L1-use. By contrast, faster RTs in L2 versus L1 for all but the LeHb category would suggest more contribution to attrition from L2- interference. No interaction between WORD-PAIR CATEGORY (CAT) and LANGUAGE (LANG) was expected in the L1-dominant group.

A significant interaction between WORD-PAIR CATEGORY and LANGUAGE (see Figure 13) was obtained for the L2-dominant group [$F(3,21) = 3.37$; $p = .04$, $\eta_p^2 = .325$]. We also obtained a main effect of LANGUAGE [$F(1,7) = 11.70$; $p = .01$, $\eta_p^2 = .626$] (see Figure 12) in this analysis, despite the nonsignificant Tukey HSD between L1 and L2 for the L2-dominant group ($p = .21$) following up the LANGUAGE X GROUP interaction in the last analysis. This discrepancy in results may be due to the small numbers of participants in our group. A follow-up of the interaction using Tukey HSD test revealed that RTs were significantly faster for L2 than L1 in the HeHb category ($p = .05$) only. In addition, there was a significant difference in RTs for the HeHb and LeHb categories in L2 ($p = .01$).

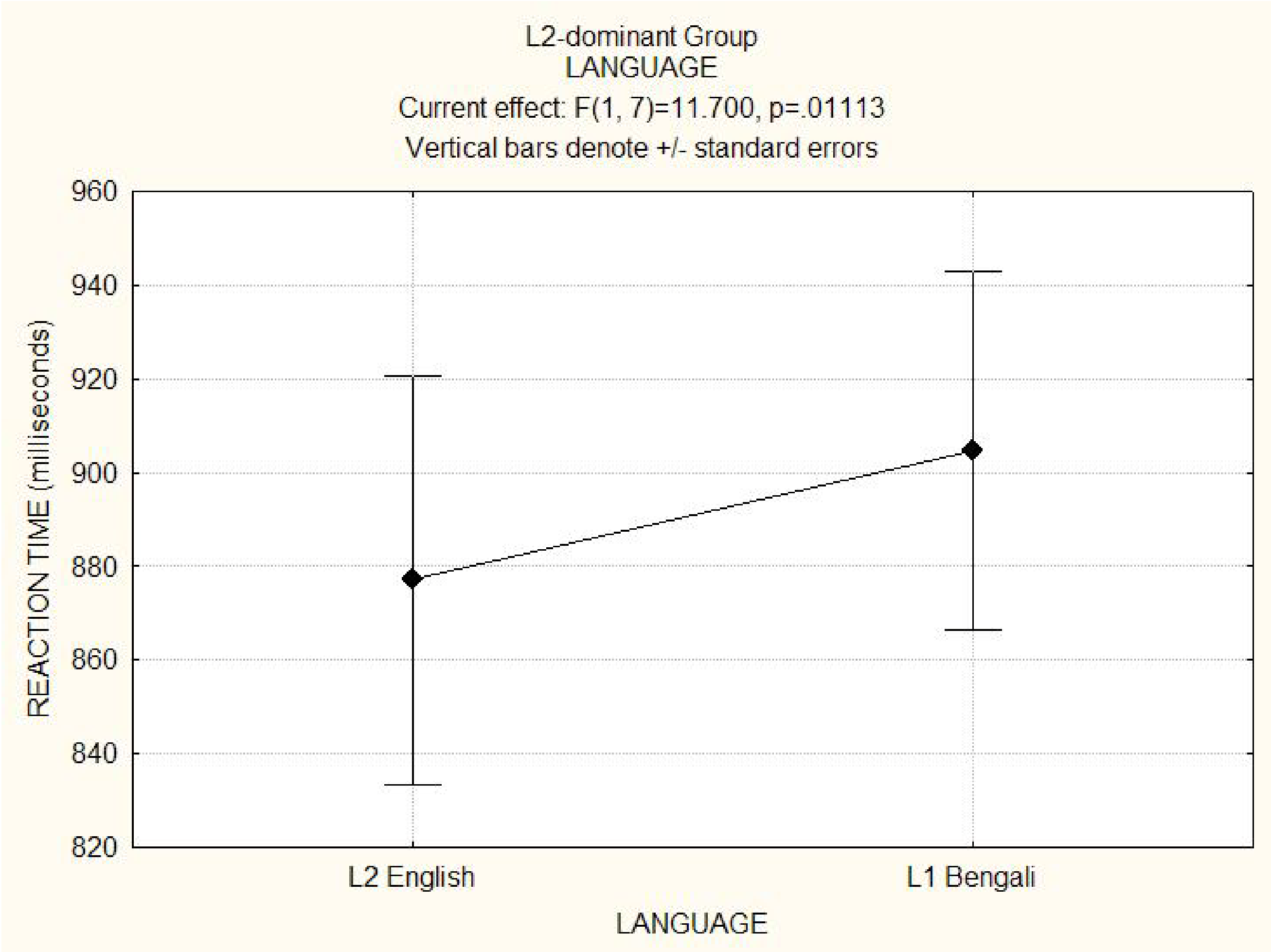

Figure 12. RTs to L1 and L2 for the L2-dominant group indicating that they are faster in their L2 than in L1

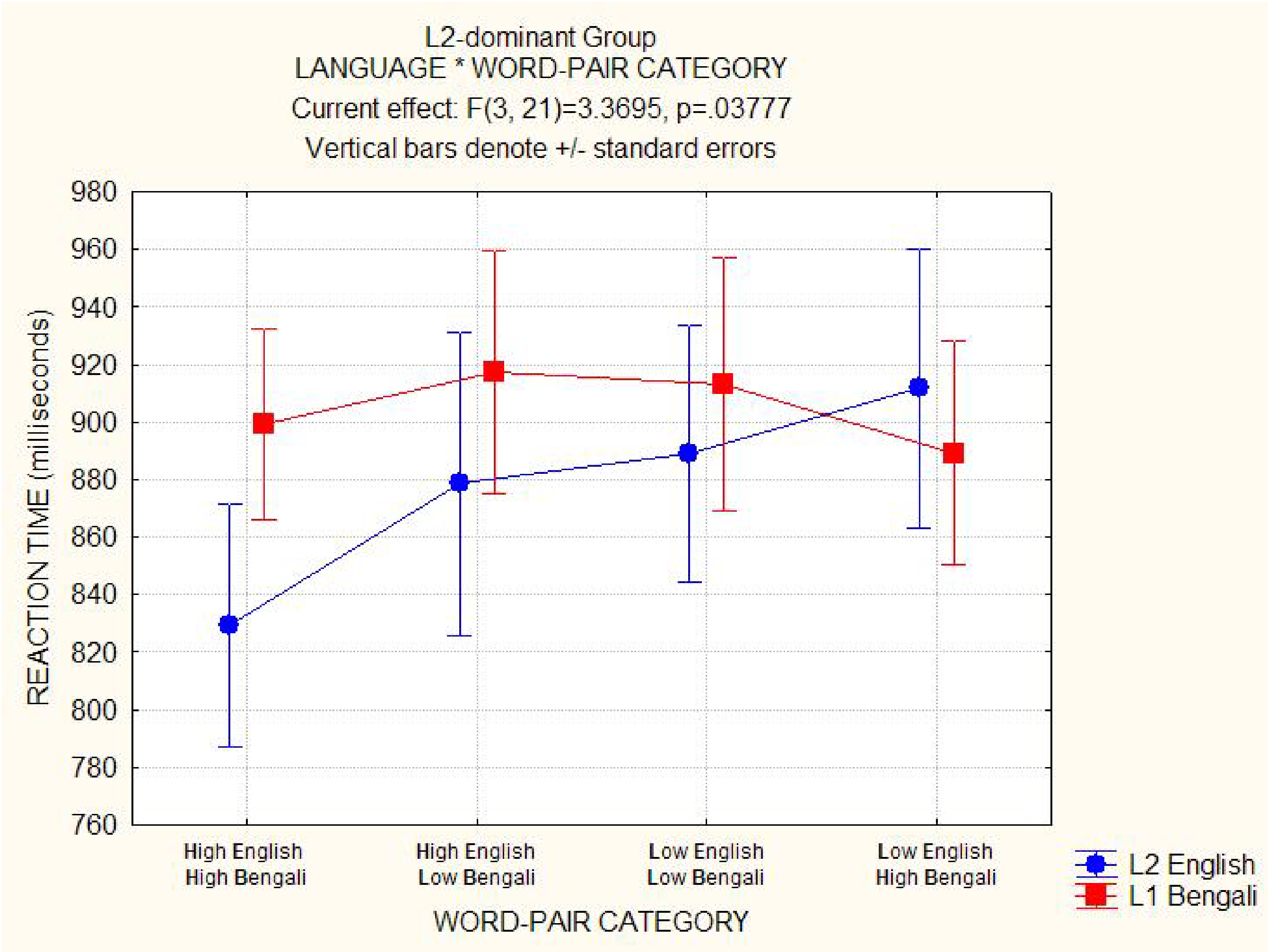

Figure 13. RTs for each of the two language and four word-categories for the L2-dominant group indicating a reversal in the pattern between L1 and L2 for the LowEnglish-HighBengali category compared to the HighEnglish-HighBengali category

Overall, the L2-dominant group showed significantly faster performance in L2 (as reflected by their RTs) than in L1. Specifically, as a group, they performed the fastest in L2 for HH words and slowest in LeHb words. Their performance in L1, however, was slower overall than in L2, but remained comparably stable across word-categories. These findings, together with the significant interaction between language and word-pair category, suggest that L1 and L2 are not affected in the same way by the four word-pair categories.

4.1.1.2.2 Word-pair Category Effects for the L1-dominant group in the RT data

We also conducted an analysis for the L1-dominant group by itself, in order to investigate whether its members showed a different pattern from that of the L2-dominant group. Repeated measures ANOVA of LANGUAGE X WORD-PAIR CATEGORY for this group showed a main effect of LANGUAGE [$F(1,17) = 51.38$; $p < .01$, $\eta_p^2 = .751$] (see Figure 14) but no significant interaction between LANGUAGE and WORD-PAIR CATEGORY. The L1-dominant group performed significantly faster in L1 than in L2. We also found a main effect of WORD-PAIR CATEGORY [$F(3,51) = 2.91$; $p = .04$, $\eta_p^2 = .146$] for this group (see Figure 15). A Tukey HSD showed that the reaction time for the HH category was significantly different from that of the LL category ($p = .04$). Since this was a main effect with no interaction with language ($p = .26$), it follows that RT was faster for the HH category compared to the LL category for both languages, suggesting that this group showed sensitivity to the level of word familiarity in both languages.

This main effect of WORD-PAIR CATEGORY is consistent with the prediction that higher familiarity will facilitate lexical access.

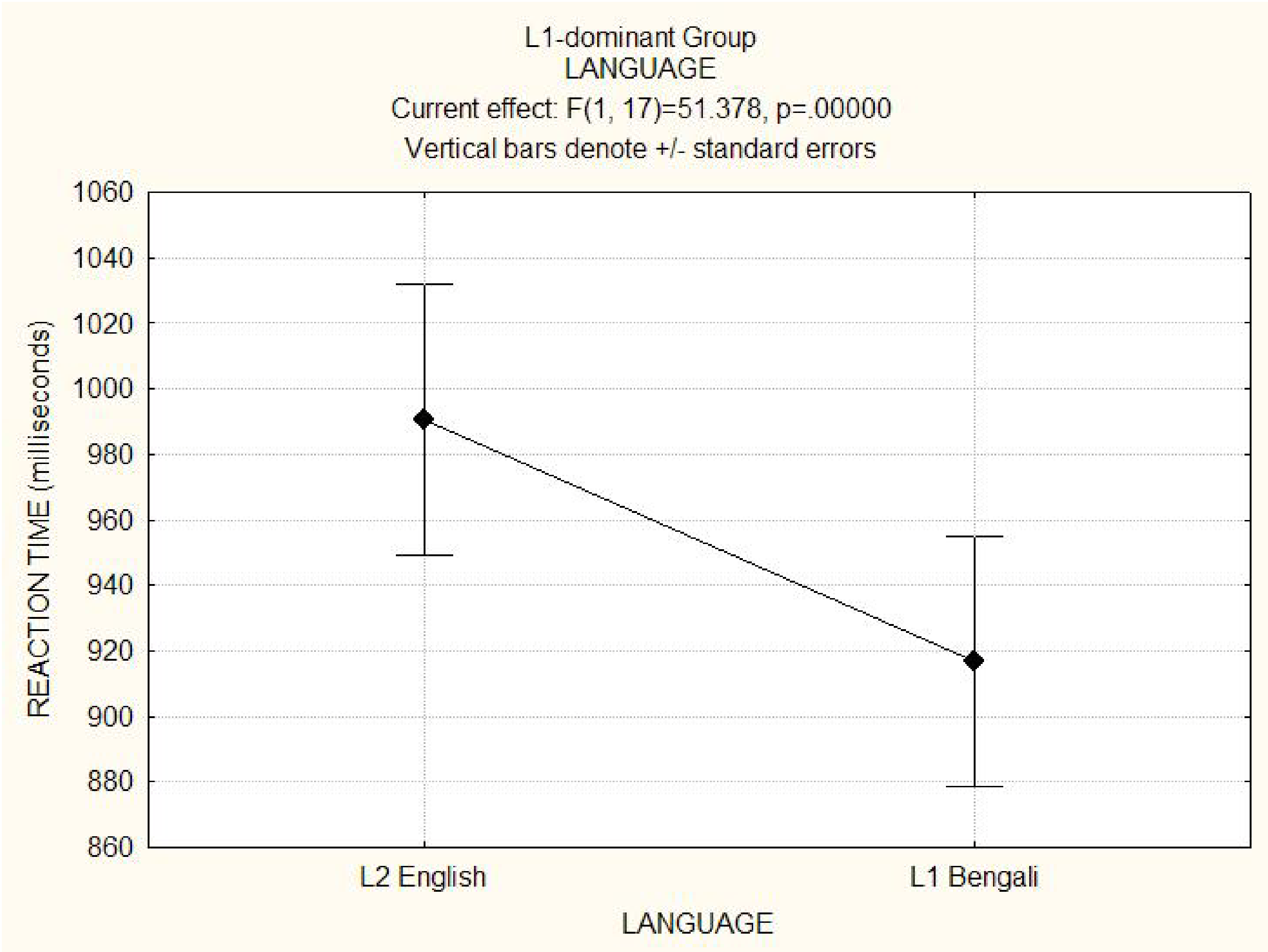

Figure14: RT to Bengali versus English words, revealing faster RTs to Bengali for the L1-dominant group

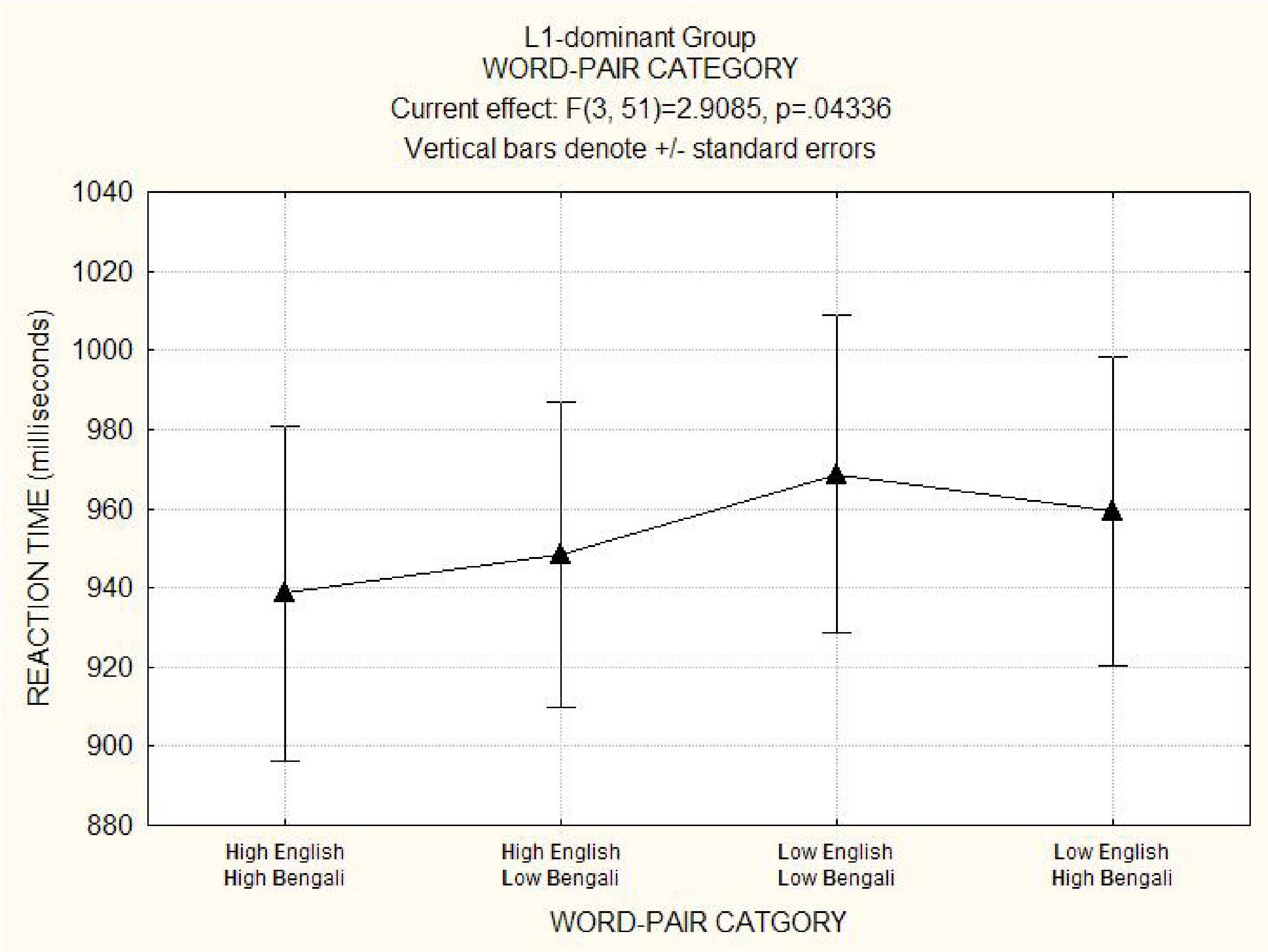

Figure 15. RTs for the four word-categories in the L1-dominant group showing that the overall responses to the high familiarity words were faster than low familiarity words

4.1.2 Incongruent Words

We conducted a repeated measures ANOVA comparing the RTs to the incongruent vs the congruent words (all word-pair categories collapsed) in English and Bengali. This 3-way ANOVA of CONGRUENCY (Incongruent, Congruent) X LANGUAGE (L1, L2) and GROUP (L2-dominant, L1-dominant) led to significant interactions of language and group [$F(1,24) = 18.63$; $p < .01$, $\eta_p^2 = .437$] (see Figure 16) and language and congruency [$F(1,24) = 19.30$; $p < .01$, $\eta_p^2 = .446$] (see Figure 17) as well as a main effect of congruency [$F(1,24) = 46.05$; $p < .01$, $\eta_p^2 = .657$]. A post-hoc follow-up of the language and group interaction confirmed significant differences ($p < .01$) between Bengali and English in the L2-dominant group. The follow-up analysis to the language and congruency revealed differences between the Bengali and the English RTs for the incongruent but not the congruent words for both groups combined.

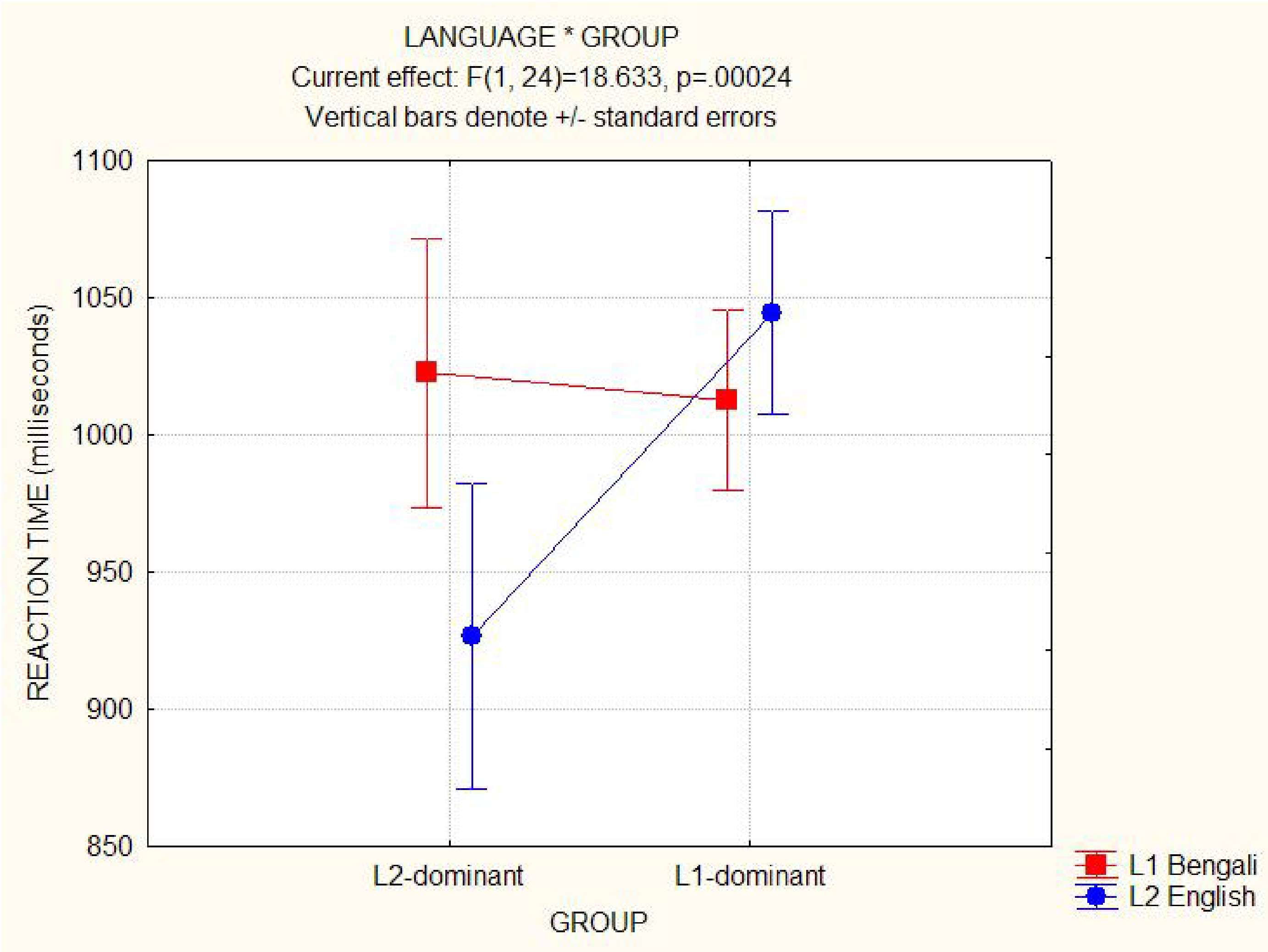

Figure 16: RT to incongruent and congruent words combined, revealing faster RTs to English relative to Bengali for the L2 dominant group

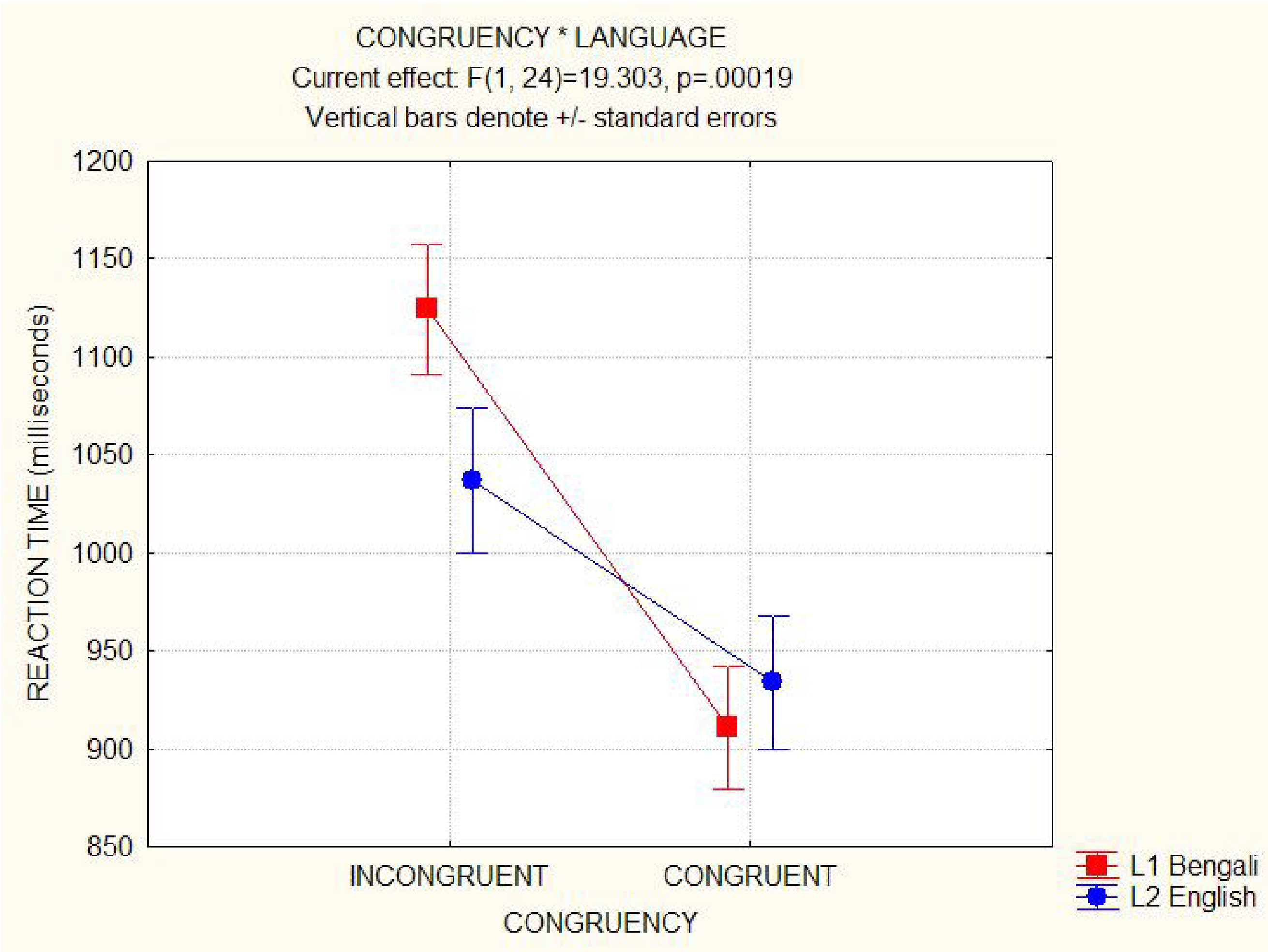

Figure 17: RT to incongruent and congruent words, showing faster RTs to English relative to Bengali for incongruent words for L2- and L1-dominant groups collapsed

4.1.3 Summary: RT Results

The behavioral paradigm involved our participants first naming a picture presented on the screen, then making a syllabicity decision on the word that they heard 150 ms after seeing the picture. The word was most often the name of the picture (congruent) or less often another word (incongruent), half the time in Bengali and the other half in English. The decisions were marked by button-press responses and their RTs were recorded. Priming of the target word by the picture was expected to facilitate access of the word.

Overall, for the congruent words, the RT data indicated that the L1-dominant and the L2-dominant groups behaved differently with respect to their L1 and L2. While the L1-dominant group generated faster RTs in their L1 than in their L2, the L2-dominant group showed the reverse pattern. Also, the L1-dominant group elicited slower RTs to the LL category compared to the HH category in both their L1 and L2. In contrast, the L2-dominant group showed differences in their L1 versus L2 for different categories. Specifically, RTs to English words were slower for the LeHb category than for the HH category, but not so for Bengali. Additionally RTs to Bengali words were slower than to English ones for the HH category, and not for other categories. These interactions between the word-pair categories and languages for the L2-dominant group only demonstrate the influence of L2 on L1 processing.

The incongruent words elicited slower RTs relative to the related words for both languages and groups combined. In addition, the incongruent and related words together elicited faster RTs in English than in Bengali for the L2-dominant group. Semantic relatedness did not appear to affect the two groups differently as measured by RT. In order to understand what happens at the onset of the auditory target word that follows the picture before the participant has to make a syllabicity judgment, we turn to our electrophysiological (i.e., ERP) data.

4.2 ERP Data

4.2.1 Language effects in the ERP data for congruent words

4.2.1.1 Early ERP epoch: 160 to 440 ms

4.2.1.1.1 Early Group Effects for Language in ERP data

Next we wanted to examine if the L2-dominant group obtained a larger negativity for L1 than for L2 words as compared to the L1-dominant group. In order to address this, we performed a 5-way ANOVA of GROUP (L2-dominant, L1-dominant) X LANGUAGE (L1, L2) X LATERALITY (Midline, Mid-Right,

Right) X SITE (Pz34, Pz38, 41, 42, RP45, P446) X TIME (160-200, 201-240, 241-280, 281-320, 321-360, 361-400, 400-440). Results revealed a significant GROUP X LANGUAGE X TIME interaction [$F(6, 90) = 3.43$; $p = .04$; $\eta_p^2 = .186$] (see Figure 18). To follow up this interaction we conducted another ANOVA of LANGUAGE X GROUP for each time bin. We found significant interactions of LANGUAGE X GROUP in the 321-360 ms [$F(1, 15) = 4.97$; $p = .04$; $\eta_p^2 = .250$], 361-400 [$F(1, 15) = 3.71$; $p = .07$; $\eta_p^2 = .198$] and 400-440 [$F(6, 90) = 10.26$; $p < .01$; $\eta_p^2 = .406$]. Generally the L2-domiant group showed greater negativity for the Bengali words than for the English and the L1-dominant group showed the reverse pattern.

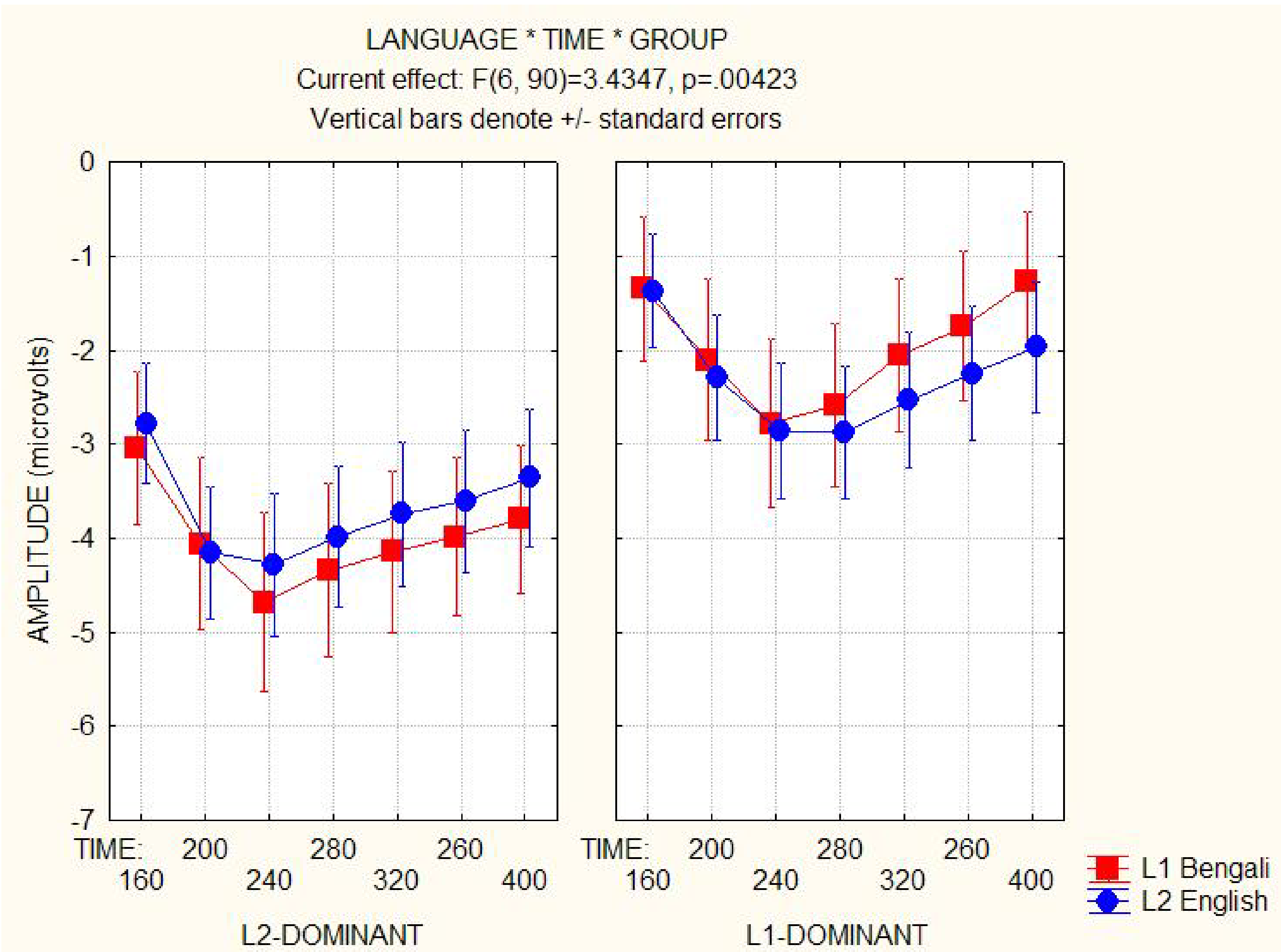

Figure 18. ERP responses for language, group and time showing opposite patterns for the L1- and L2-dominant groups for L1 Bengali and L2 English between 160 and 440 ms

Thus, results exploring language effects on the two groups revealed that indeed the L2-dominant group was significantly different in brain response from the L1-dominant group as a function of their first and second language. In particular, we found that the groups show reversed patterns of neural responses to L1 and L2 words. In the next set of analyses we will explore whether relative frequency of the words in the languages influenced the access.

4.2.1.1.2 Early Word-pair Category Effects for Language in ERP data

To further examine the nature of lexical attrition, next we examined the word-categories for the two languages for each group separately. (Figure 19). We conducted a LANGUAGE (L1, L2) X WORD-PAIR CATEGORY (HH, HeLb, LL, LeHb) X LATERALITY (Midline, Mid-Right, Right) X SITE (Pz34, Pz38, 41, 42, RP45, P446) X TIME (160-200, 201-240, 241-280, 281-320, 321-360, 361-400, 400-440) for each group.

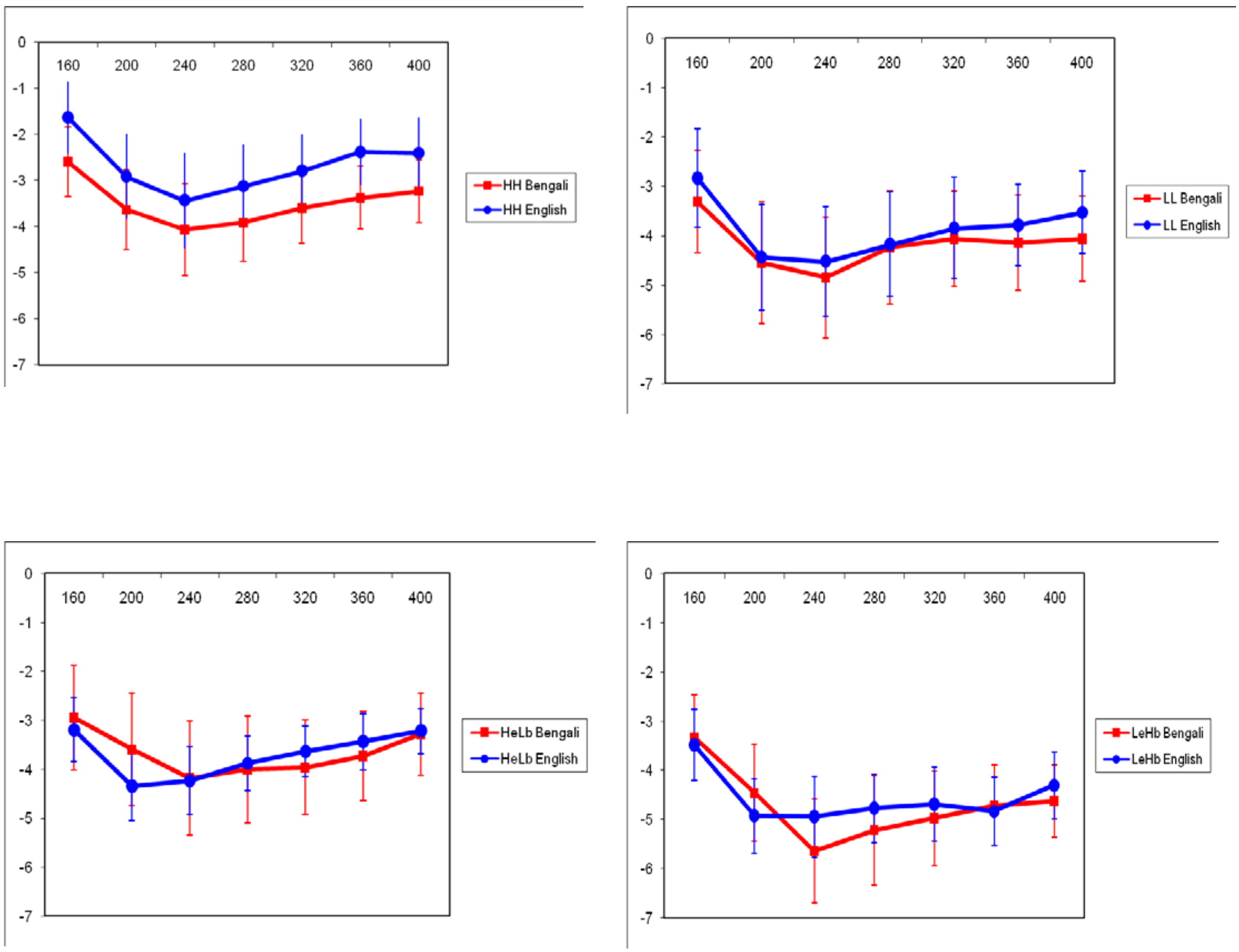

Figure 19a. ERP responses for language (Bengali, English) and Word-pair Category (HighEnglish-HighBengali, LowEnglish-LowBengali, HighEnglish-LowBengali and LowEnglish-HighBengali) for L2-dominant group

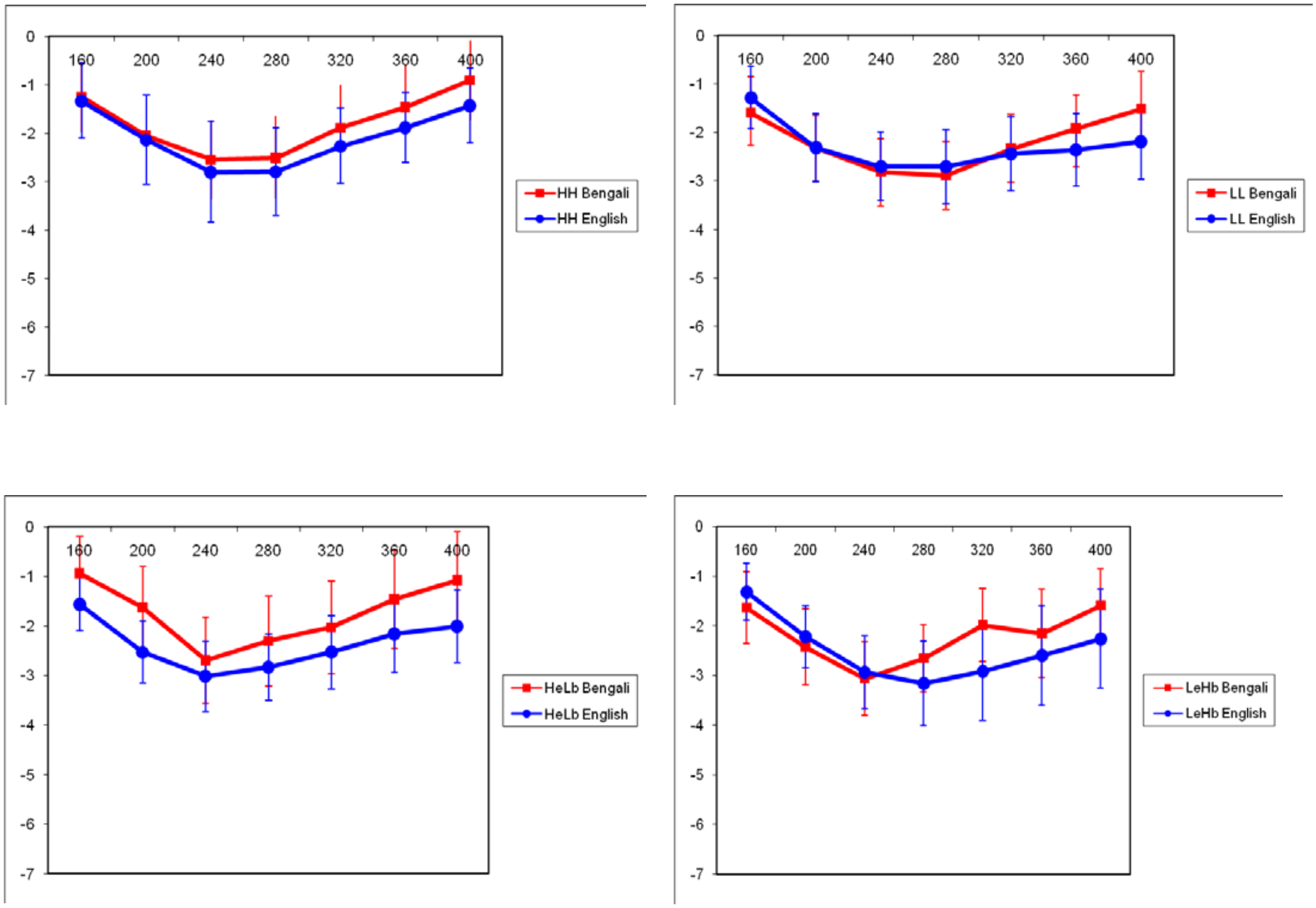

Figure 19b. ERP responses for language (Bengali, English) and Word-pair Category (HighEnglish-HighBengali, LowEnglish-LowBengali, HighEnglish-LowBengali and LowEnglish-HighBengali) for L1-dominant group

4.2.1.1.2.1 Early Word-pair Category Effects for the L2-dominant group in ERP data

The L2-dominant group showed a main effect of word-pair category [$F(3, 21) = 6.51$; $p = .02$; $\eta_p^2 = .464$]. A follow up Tukey HSD test demonstrated that the LeHb category was significantly more negative than the HeLb category across the two languages ($p < .01$). This category was also more negative than the HH category although the difference did not quite reach significance ($p = .08$). On examining the individual languages for this group, the results showed a main effect of word-pair category for both languages. For Bengali, this main effect of category [$F(3, 21) = 6.27$; $p < .01$; $\eta_p^2 = .472$] followed up with a Tukey revealed that the LeHb category elicited significantly more negative responses than both the HeLb ($p = .01$) and the HH ($p < .01$) categories (Figure 20a). For English, a main effect of word-pair category [$F(3, 21) = 3.09$; $p = .05$; $\eta_p^2 = .304$] was also obtained. Tukey HSD showed that the LeHb category elicited significantly more negative responses than the HH ($p = .03$) category (Figure 20b).

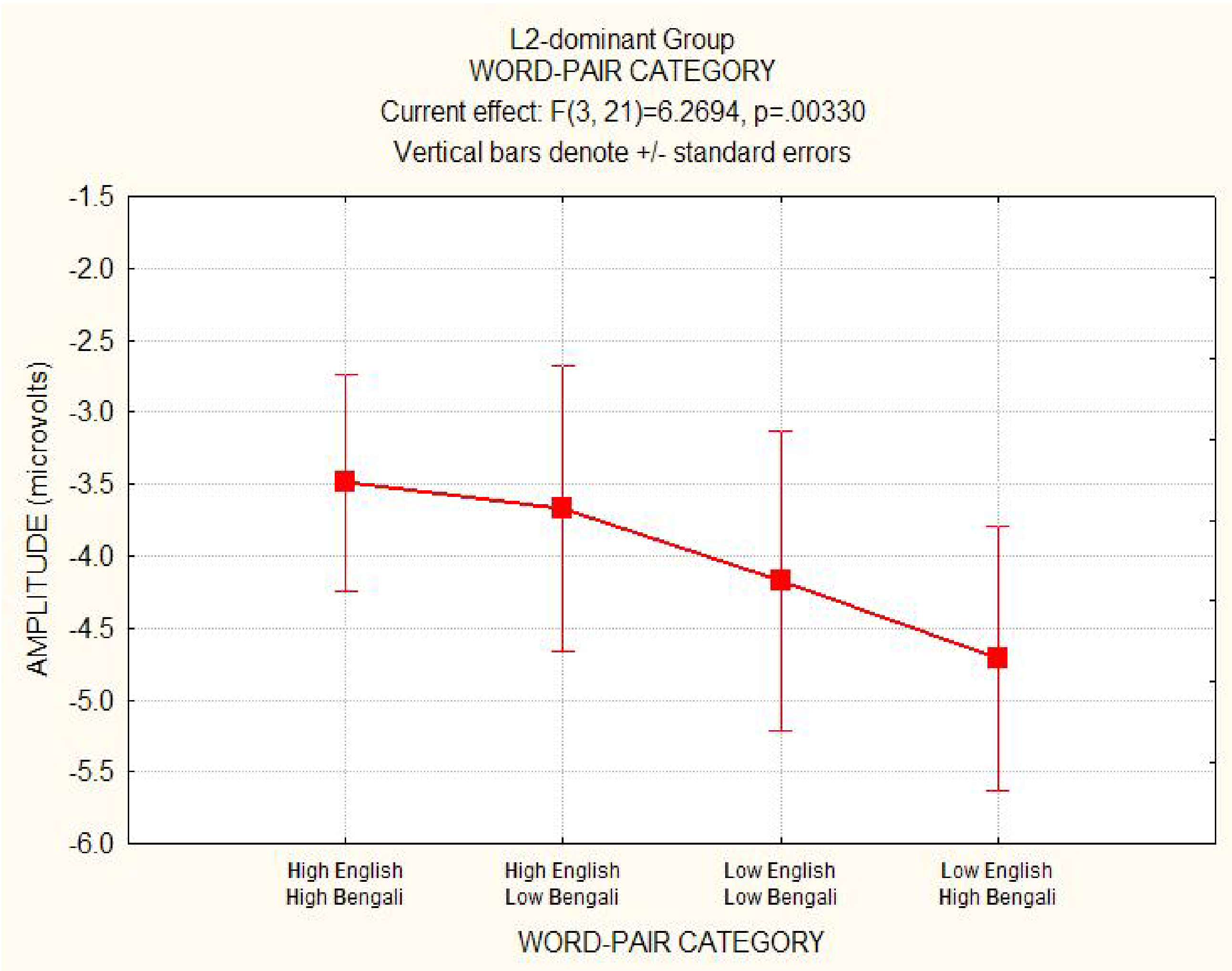

Figure 20a: ERP responses for the four Word-pair Categories to Bengali for the L2-dominant group between160 and 440 ms

Overall, the word-pair category factor influenced the amplitudes of the ERP responses in both English and Bengali for the L2-dominant group. The participant obtained the most negative responses for both English and Bengali in the LeHb category, especially compared to the HH and HeLb categories.

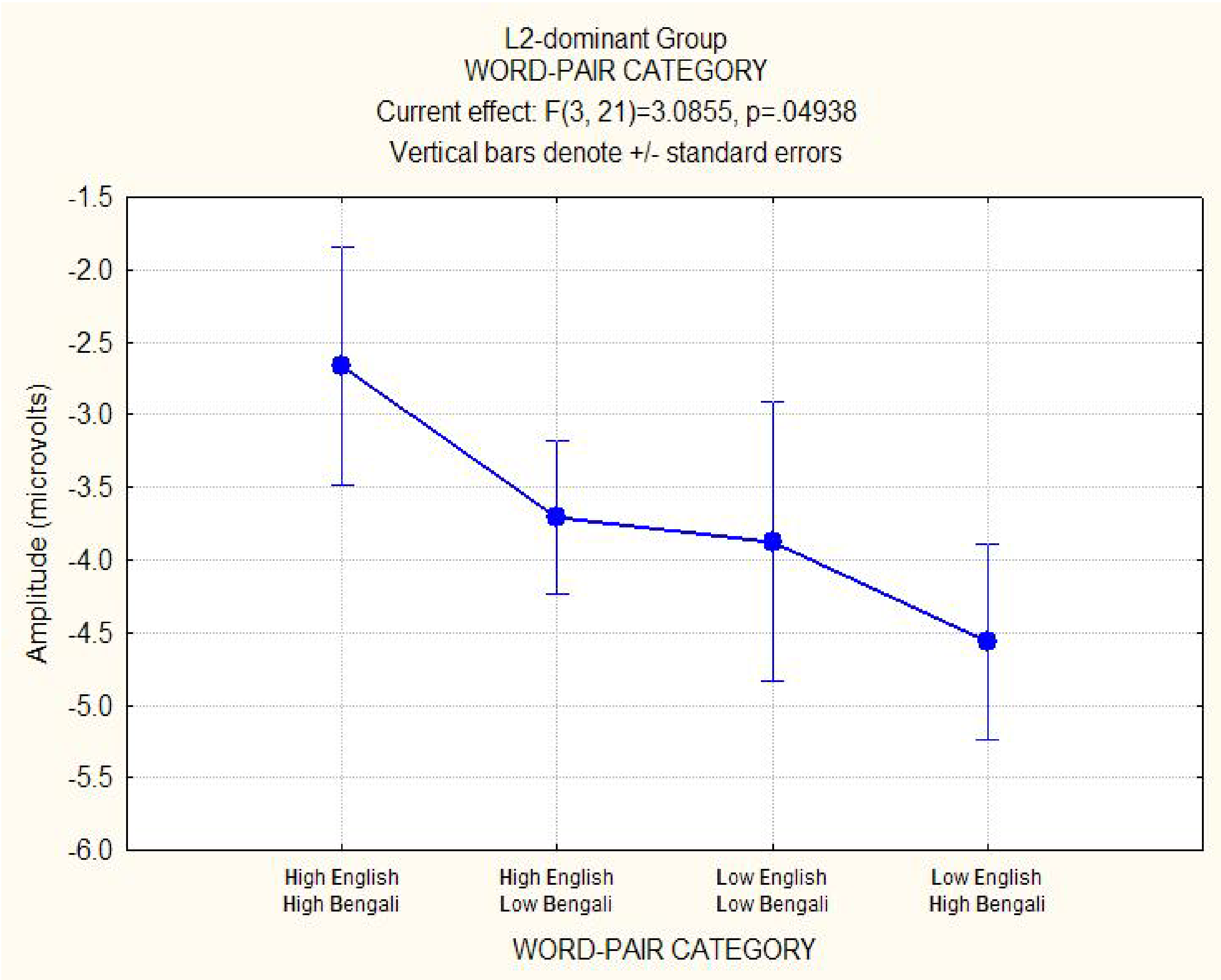

Figure 20b: ERP responses for the four Word-pair Categories to English for the L2-dominant group between 160 and 440 ms

4.2.1.1.2.2 Early Word-pair Category Effects for the L1-dominant group in ERP data

By contrast to the L2-dominant group, the L1-dominant showed no effects of word-pair categories ($p = .27$). This group demonstrated a significant interaction of LANGUAGE X TIME [$F(6, 48) = 3.09$; $p < .01$; $\eta_p^2 = .377$]. A Tukey HSD showed that the L1 dominant group elicited more negative ERP amplitudes for English compared to Bengali in the time bins between 280 and 440 ms ($p < .01$).

In a follow up analysis, we compared the two groups using familiarity in English (High English i.e., HH and HeLb categories collapsed versus Low-English i.e., LL and LeHb categories collapsed) and then familiarity in Bengali (High-Bengali i.e., HH and LeHb categories collapsed versus Low-Bengali i.e., LL and HeLb categories collapsed). In the first analysis of LANGUAGE (Bengali, English) X WORD-PAIR CATEGORY (High-English, Low-English) X Time (160-200, 201 WORD-PAIR CATEGORY -240, 241-280, 281-320, 321-360, 361-400, 400-440) X GROUP (L2- dominant,, L1-dominant), we obtained a significant WORD-PAIR CATEGORY X GROUP [$F(1, 15) = 6.32$; $p =.02$; $\eta_p^2 = .297$] interaction (Figure 21) as well as a main effect of WORD-PAIR CATEGORY [$F(1, 15) = 22.70$; $p < .01$; $\eta_p^2 = .602$]. A follow up Tukey HSD showed a significantly greater negativity ($p < .01$) to the Low familiarity English categories than to the High familiarity English categories for the L2-dominant group and not the L1-dominant group ($p = .74$). Further, no such significant effects were obtained with High and Low-Bengali categories ($p = 1.00$).

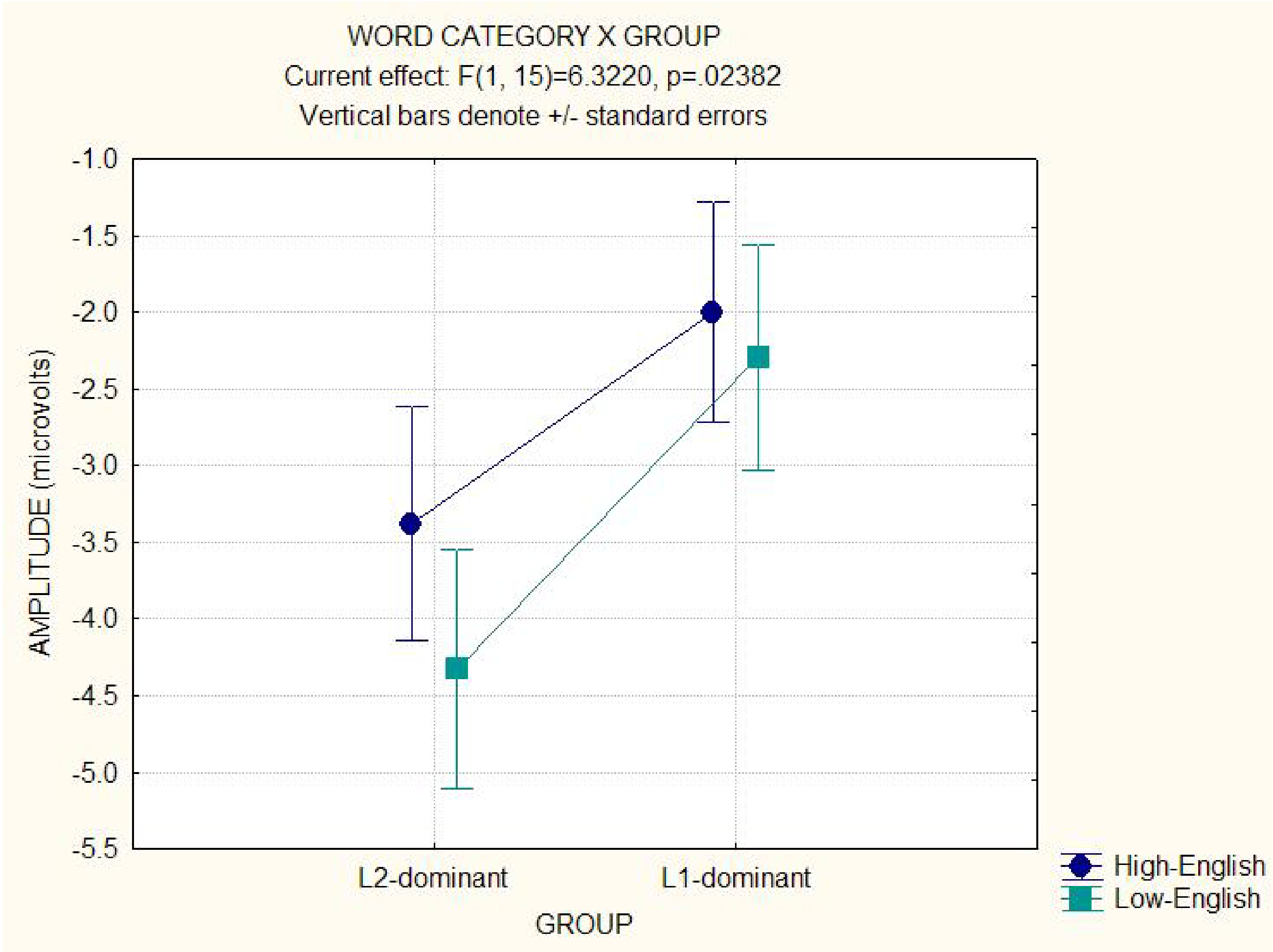

Figure 21: ERP responses for the High and Low familiarity English categories collapsed for the L1- and L2-dominant groups between160 and 440 ms

In summary, the L2-dominant group demonstrated greater negativities to the Low-English word-categories than the High-English word-categories across both languages. The L1-dominant group however, did not show any effect of English word-categories in the earlier time frame. No such effects of word-pair category on ERP amplitude were found on grouping the word-categories according to Bengali familiarity (i.e., High Bengali versus Low Bengali categories) for either group.

4.2.1.2 Late ERP Epoch: 400-800 ms.

4.2.1.2.1 Late Group Effects for Language in ERP data

We conducted a LANGUAGE (L1, L2) X LATERALITY (Midline, Mid-Right, Right) X SITE (Pz34, Pz38, 41, 42, RP45, P446) X TIME (400-500,500-600, 600-700, 700-800) ANOVA for each group. We obtained a significant LANGUAGE X GROUP (Figure 22) interaction [$F(1, 15) = 6.91$; $p = .02$; $\eta_p^2 = .315$] as well as a LANGUAGE X TIME X GROUP (Figure 23) interaction [$F(3, 45) = 5.31$; $p < .01$; $\eta_p^2 = .261$]. A post hoc test for LANGUAGE X GROUP revealed no significant pairwise differences ($p > .20$).

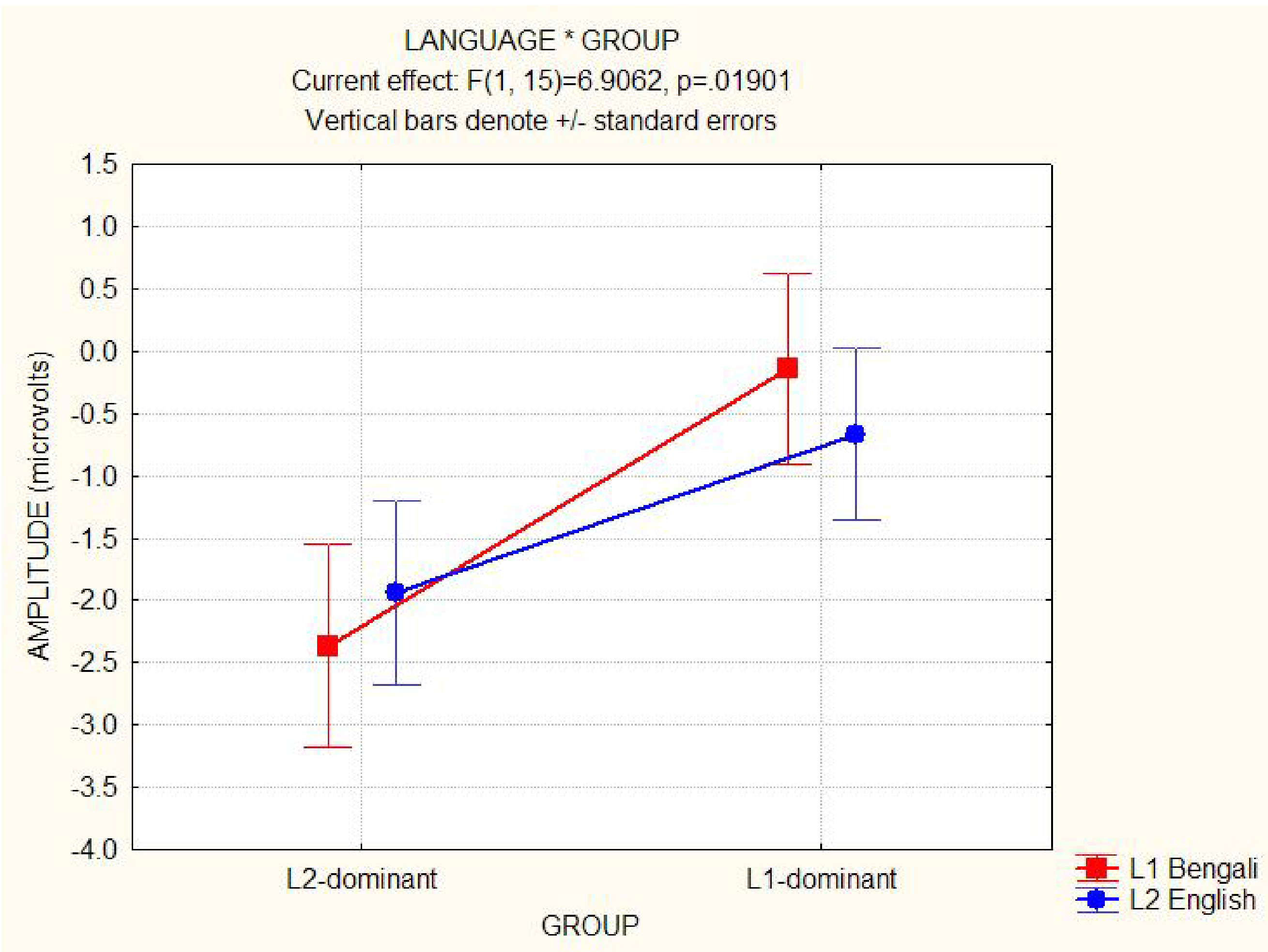

Figure 22. ERP responses for language and group showing opposite patterns for the L1- and L2-

dominant groups for L1 Bengali and L2 English between 400 and 800 ms

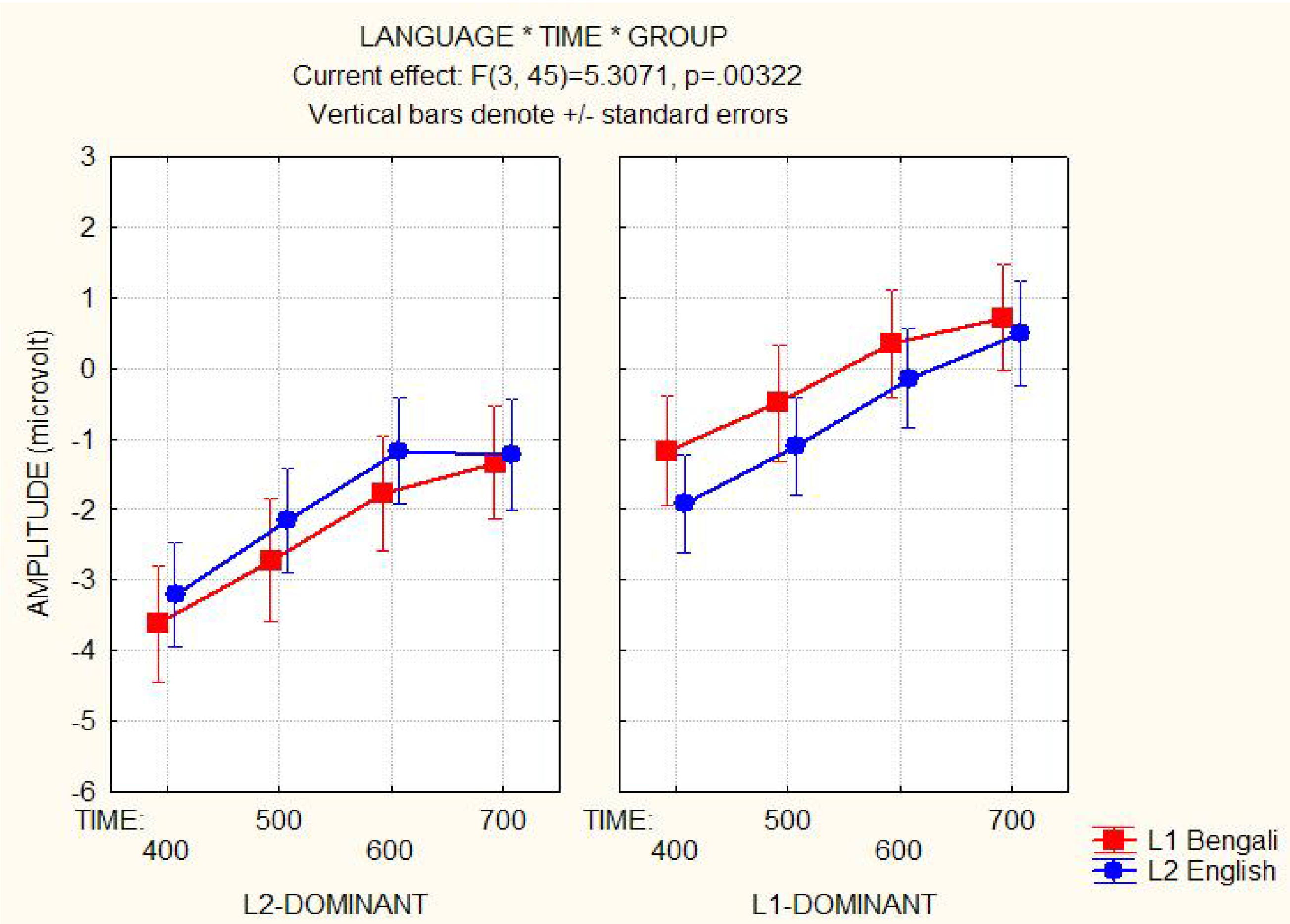

Figure 23. ERP responses for language, group and time showing opposite patterns for the L1- and L2- dominant groups for L1 Bengali and L2 English between 400 and 800 ms

In summary, we obtained a similar pattern to the earlier time frame, with ERPs to Bengali tending to be more negative than to English, for the L2-dominant group and the reverse for the L1-dominant group. In order to understand the contributions of the word-pair categories in each language we conducted further analyses described below.

4.2.1.2.2 Late Word-pair Category Effects for Language in ERP data

To examine the Word-Pair Category effects in this later time frame (400-800 ms), we conducted a LANGUAGE (L1, L2) X WORD-PAIR CATEGORY (HH, HeLb, LL, LeHb) X LATERALITY (Midline, Mid-Right, Right) X SITE (Pz34, Pz38, 41, 42, RP45, P446) X TIME (400-500, 500-600, 600-700, 700-800) ANOVA for each group separately.

4.2.1.2.2.1 Late Word-pair Category Effects for the L2-dominant group in ERP data We obtained a significant interaction of LANGUAGE, WORD-PAIR CATEGORY and TIME [$F(9, 63) = 3.16$; $p = .03$; $\eta_p^2 = .311$] (see Figure 24) as well as a main effect of category [$F(3, 21) = 6.50$; $p < .01$; $\eta_p^2 = .481$] (see Figure 25). A follow-up of the 3-way interaction with a Tukey HSD showed that Bengali elicited greater negativities than English only in the HH word-pair category.

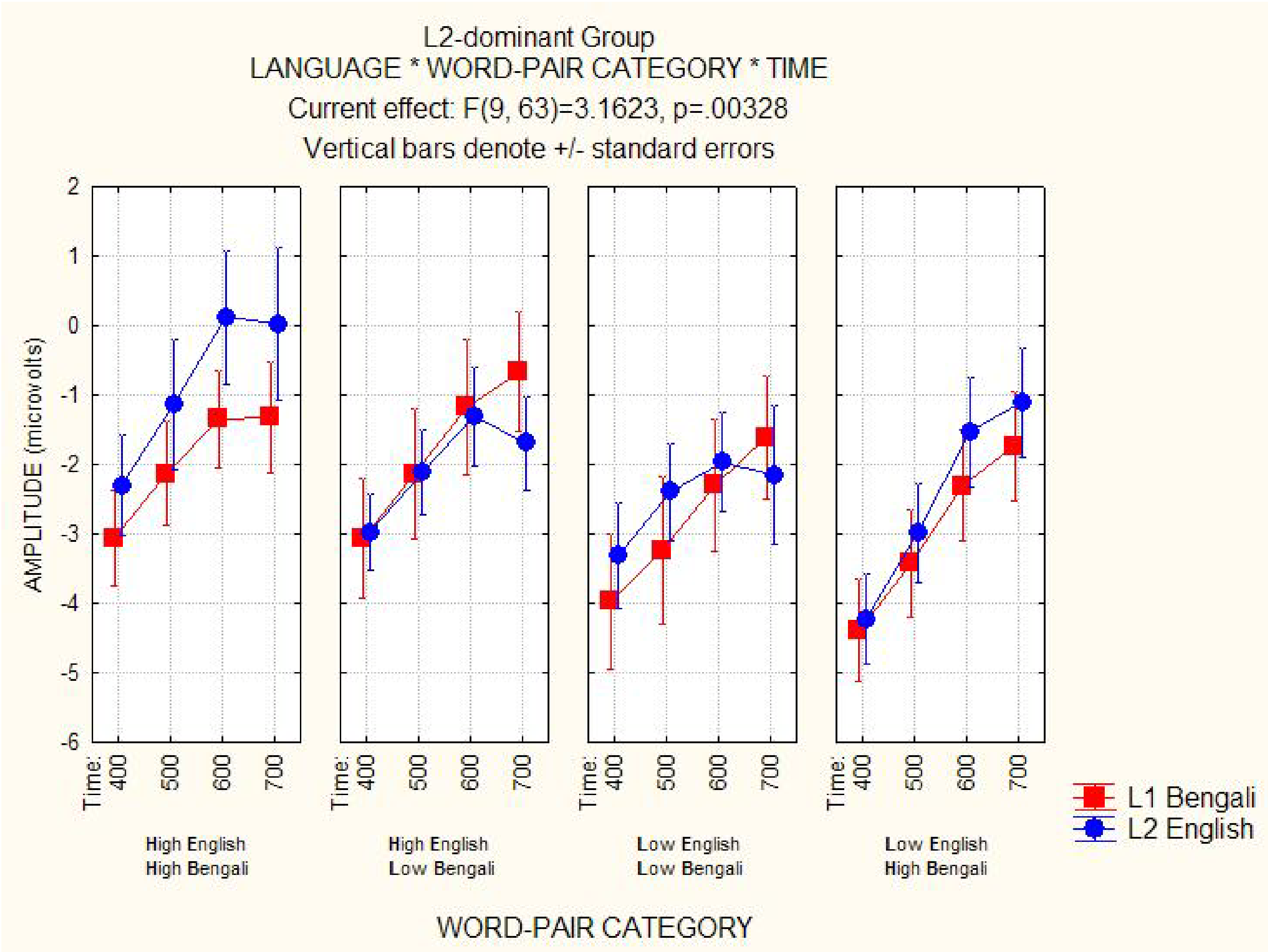

Figure 24. ERP responses to English and Bengali from 400-800 ms for the L2-dominant group for each of the four Word-pair Categories showing responses to Bengali are more negative relative to English in the HighEnglish-HighBengali category

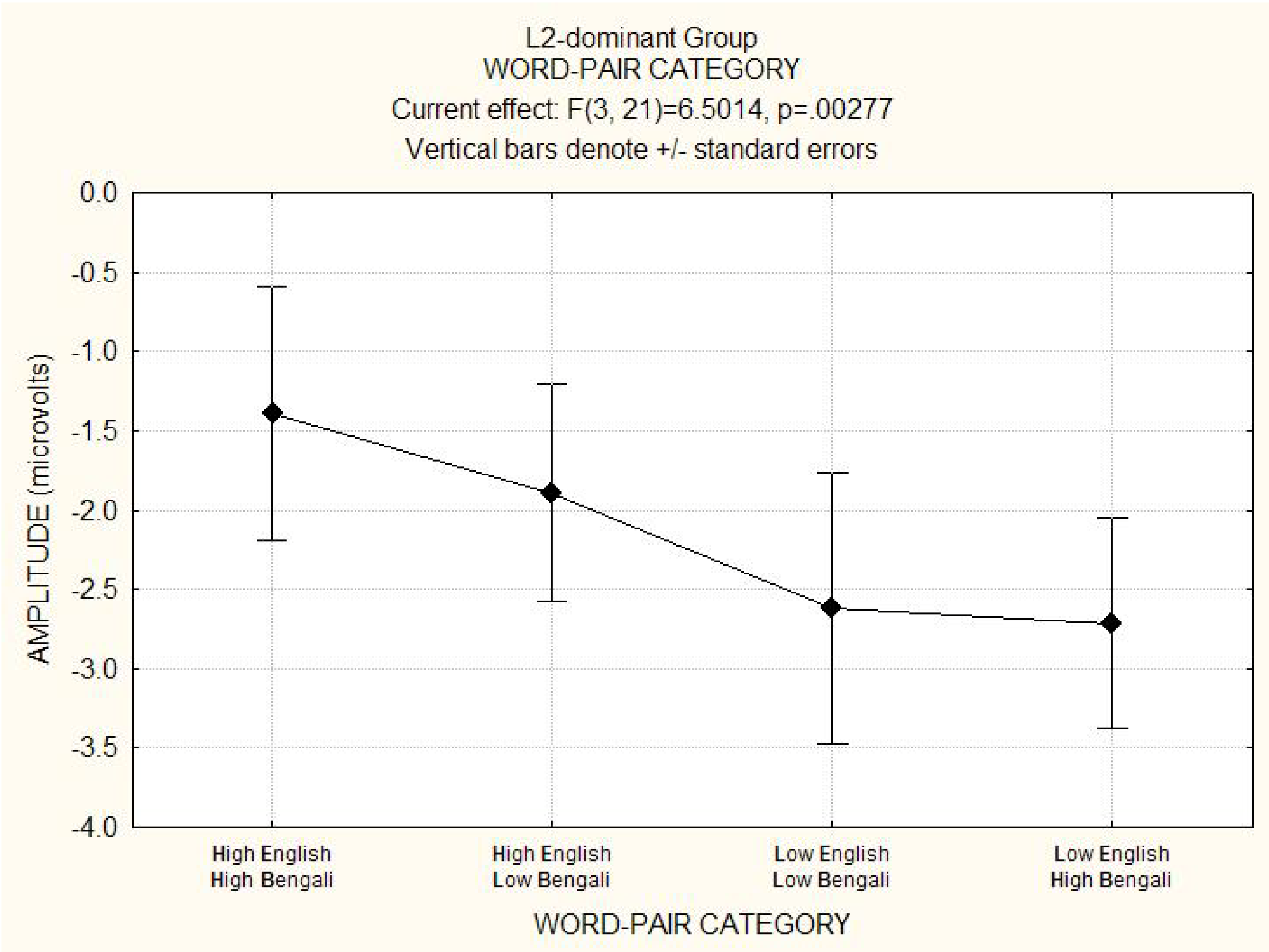

Figure 25: ERP responses for the four Word-pair Categories across both Bengali and English for the L2-dominant group between 400 and 800 ms

In summary, the L2-dominant group maintained similar patterns to what we observed in the earlier time frame. Both English and Bengali words elicited the least negative ERP amplitudes for the HH category and the most negative ERP amplitudes for the LeHb category. In this later time frame, the L2-dominant group, appears to maintain greater ERP amplitudes for High familiarity English words compared to low familiarity ones, as they did in the earlier 160-440 ms timeframe. In addition, we also observed that Bengali elicited greater amplitudes than English only for the HH category. This pattern was similar to our behavioral results for word-pair category and language, which will be addressed in the discussion.

4.2.1.2.2.2 Late Word-pair Category Effects for the L1-dominant group in ERP data

There were no effects of Word-pair Category in the L1-dominant group ($p = .38$) . However, we did obtain a significant LANGUAGE X TIME [$F(1, 8) = 11.20$; $p = .01$; $\eta_p^2 = .583$] interaction along with a main effect of Language [$F(3, 24) = 6.50$; $p = .03$; $\eta_p^2 = .329$]. A follow up Tukey confirmed that for the L1-dominant group, English elicited greater negativities than Bengali from 400-700 ($p < .01$) ms across all Word-categories. Therefore, both in the early as well as in the latter time frames, the L1-dominant group did not show any effect of word-pair categories on their L1 and L2.

4.2.2 Group and Language effects in the ERP data for incongruent words

Recall that besides the four word-pair categories we had for the RT data, we built in a control condition for the ERP experiment consisting of words that were also incongruent to the picture, presented half the time in Bengali and the other half in English. The purpose of this condition was to examine whether participants obtained a typical "N400" response, i.e., the large posterior negativity around 400 ms following a word that is incongruent to a picture or a preceding context. Both groups (L2-dominant and L1-dominant) showed this increased posterior negativity to the incongruent items in both languages (L1 and L2) as shown in Figure 26.

A GROUP (L2-dominant, L1-dominant) X LANGUAGE (L1, L2) X CONGRUENCY (Congruent, Incongruent) X SITE (Cz, Pz_34, Pz_38) X TIME (200-300, 301-400, 401-500, 501-600, 601-700) ANOVA was performed to examine the statistical significance of the semantic effects of English and Bengali on the ERP responses for the two groups. Results yielded a main effect of Congruency [$F(1,15) = 24.49$; $p < .01$; $\eta_p^2 = .620$] (see Figure 16) and a significant interaction of GROUP X LANGUAGE X CONGRUENCY [$F(1,15) = 11.68$; $p < .01$; $\eta_p^2 = .438$]. The L2-dominant group generated a large negativity to the incongruent words in English, but not to those in Bengali.1. Also, this negativity to the English mismatches in the L2-dominant group was larger than that to either English and Bengali mismatches for the L1-dominant group (see Figure 27).

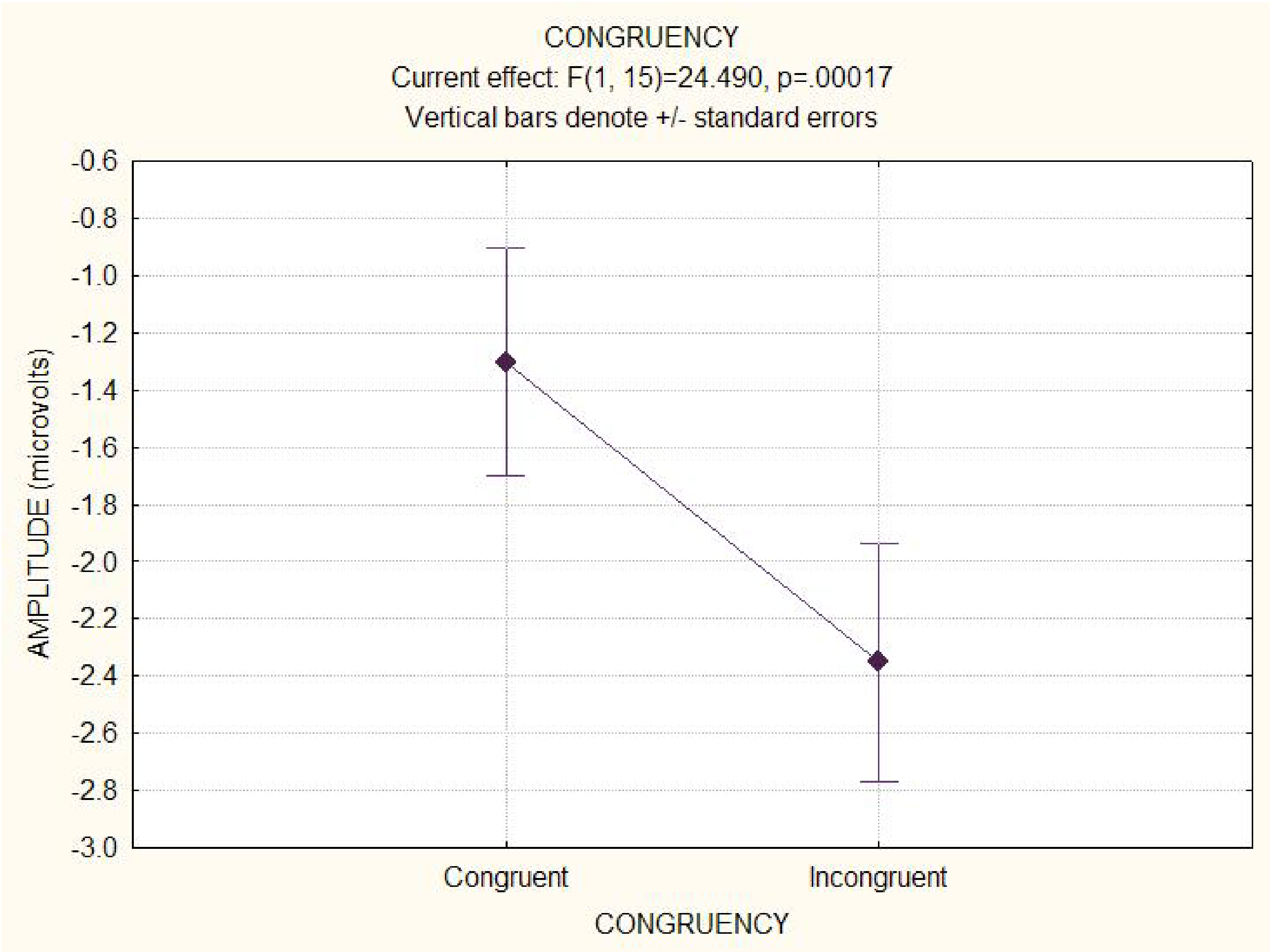

Figure 26. ERP amplitudes (200 to 700 ms) for Congruency showing greater negativity for incongruent words as compared to congruent words

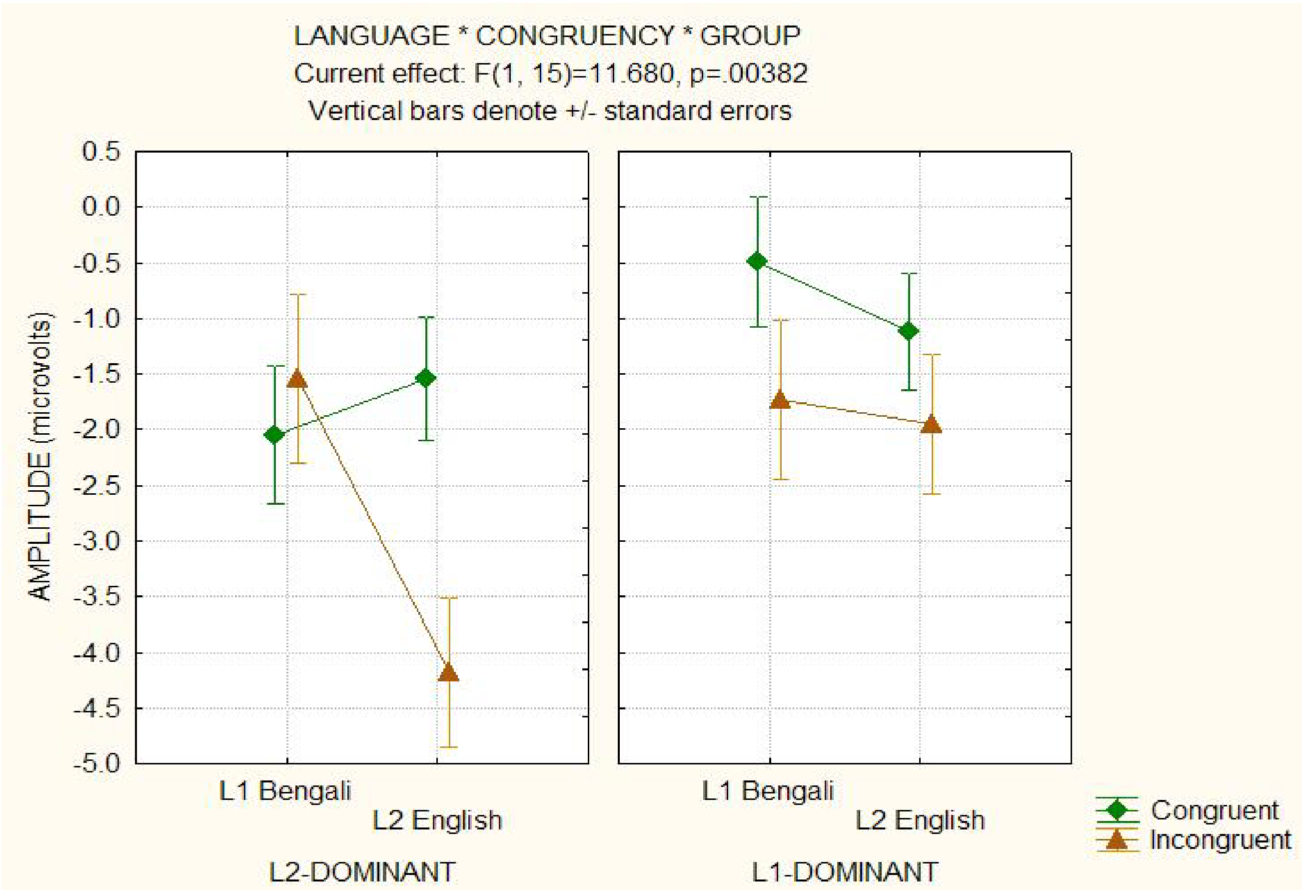

Figure 27. ERP responses for the two languages (L1 Bengali and L2 English) and groups (L2-dominant and L1-dominant) showing that the English-dominant group has a larger negativity for the English incongruent relative to the English congruent words

In summary, the L2-dominant group showed a greater negativity to the incongruent words compared to that for the related words in English. The L1-dominant group, by contrast, showed greater negativities to the incongruent words in both languages, although these were smaller in amplitude than those elicited by the L2-dominant group in English.

4.2.3 Summary: ERP Results

The electrophysiological portion of the experiment entailed voltage recording from 64 scalp sites as the participants heard the auditory targets 150 seconds following the onset of the picture on screen. They were instructed to covertly name the picture and listen to the following auditory word. This auditory word was most often the name of the picture, half the time in L1 Bengali and the other half in L2 English, but sometimes the auditory word did not semantically match the picture.

The ERP data revealed differences for the two groups for the two languages. First, in terms of the incongruent items, the L2-dominant group showed a very large negativity to the English but not to the Bengali incongruent words. The L1-dominant group showed large negativities both for English and Bengali incongruent targets. The negativities however, were smaller than those generated by the L2-dominant group to the English incongruent targets.

As for the congruent items (in English and Bengali), we examined the data in two different time frames. In the earlier time frame (160-440 ms, divided into 40 ms time bins) we found that the L1- and L2-dominant groups showed different patterns for L1 and L2 respectively. The L1-dominant group generated larger negativities for L2 than for L1 words. The L2-dominant group showed a different pattern. The word-pair categories affected the ERP data differently than the behavioral data in this early time frame. The L2-dominant group showed larger negativities for both Bengali and English for words in the Low familiarity English category relative to those in the High familiarity English category. Specifically, the largest differences were between the HH, HeLb category and the LeHb categories, the latter generating the largest negative responses. No significant effect was obtained for the LL category specifically. The L1-dominant group did show differences in negativity related to word-pair category; but overall they showed larger negativities to English than to Bengali.

The later time frame (400-800 ms, divided into larger 100 ms time bins) generated very similar results to the earlier time frame. Here too, the two groups behaved differently, with the L1-dominant group showing significantly larger negativities to English than to Bengali words. Again the L2-dominant group showed more negative responses to the English Low familiarity than the High familiarity words. This difference was greatest for the LeHb category compared to the HH category. In addition, for this time frame, the L2-dominant participants showed larger negativities to Bengali compared to English in the HH category, which was a pattern also observed in the RT data. The L2-dominant group also showed longer RTs to the Bengali words compared to the English words in the HH word-pair category. The RTs occurred around 958 ms (mean) with a standard deviation of 321 ms. The late ERP effects, occurring between 400-800 ms, could very well be the preceding brain responses to these RT data. Finally, as in the earlier time frame, the L1-dominant group did not show a word-pair category effect.

Again, as with the RT data, the L2-dominant group showed language behavior that indicated an interaction of the two languages in a way that affected L1 differently than L2. While the L1-dominant group showed an overall pattern of L1 better than L2, the L2-dominant group showed language patterns beyond L2 being better than L1.

Name	Age	Gen	LOR	AoA	AoI	HEHB_r	LELB_r	HELB_r	LEHB_r	Overall_r	HEHB_e	LELB_e	HELB_e	LEHB_e	Overall_e	L1 rate	L2 rate	L1 fl	L2 fl	L1 U	L2 U
B01	28	F	5.0	0	23	74.28	23.05	57.91	71.88	56.78	-1.6088	-1.0950	-1.4013	-2.2161	-1.5803	4	7	15.67	27.33	20.56	78.89
B02	29	F	3.5	3	24	-59.09	-150.28	-127.62	-234.72	-142.93						6	6	18.33	18.00	21.67	75.56
B03	29	M	3.5	3	26	-59.90	-54.76	-92.20	-112.34	-79.80						7	6	19.67	19.00	35.56	62.22
B05	24	M	1.0	4	24	-132.43	-54.60	-49.74	-104.60	-85.34						7	7	18.00	14.00	52.22	47.78
B06	29	M	1.0	4	28	-57.47	-55.99	-73.98	-187.06	-93.62						5	6	18.33	18.67	24.44	75.56
B07	31	F	4.5	3	27	69.33	40.97	-64.57	-91.48	-11.44	0.6525	0.9291	-1.1395	0.1014	0.1359	5	7	17.33	20.33	0.00	100.00
B08	30	F	5.5	4	25	74.25	-54.59	96.15	-37.57	19.56	0.1004	0.0868	-0.3161	-3.1309	-0.8150	4	6	15.67	24.67	4.44	90.56
B11	25	F	1.5	3	24	163.27	-54.02	-21.76	-5.87	20.40	0.1061	0.2502	5.1279	5.0205	2.6262	7	7	14.33	17.67	28.89	68.89
B12	24	F	5.5	3	18	18.23	64.28	35.79	-112.13	1.54	-0.9920	-1.2910	-1.9323	0.2165	-0.9997	6	7	18.67	19.67	14.44	84.44
B13	37	F	0.0	4	34	-137.66	-98.29	-144.80	-166.12	-136.72	0.6474	-0.4178	0.7727	0.7569	0.4398	6	6	18.67	17.67	44.44	53.33
B14	26	F	2.5	3	6	31.26	-47.87	-45.67	-13.91	-19.05						5	6	24.00	24.00	32.22	57.78
B15	36	F	0.0	5		-14.46	-9.43	-56.30	-20.36	-25.14						5	6	28.00	23.33	41.11	38.89
B16	24	F	0.0	4		-117.56	-77.52	-102.27	-58.76	-89.03						7	5	25.00	14.67	53.33	37.78
B19	33	M	15.0	4	4	-115.07	13.40	-129.14	-104.44	-83.81	0.5187	0.5371	-1.0890	2.3579	0.5811	7	7	21.33	27.00	15.89	83.89
B20	28	F	9.0	2.5	17	49.38	-66.59	-4.45	-86.58	-27.06	-0.3962	-0.3556	-0.4524	-1.7316	-0.7340	7	7	17.33	20.33	21.11	76.67
B21	33	F	22.0	3.5	11	-0.61	52.13	35.01	-5.36	20.30	-0.6351	-0.3519	-0.4112	-0.2585	-0.4142	3	7	10.00	18.67	15.56	84.44
B22	33	F	21.0	4	8	42.42	107.98	-2.07	-55.88	23.12	0.3019	0.6794	-0.9471	0.5333	0.1419	3	7	9.33	13.33	2.22	97.78
B23	48	M	29.0	3	19	-55.29	-14.48	-115.22	-32.43	-54.36	0.9176	-0.0108	1.2604	-1.4154	0.1880	5	7	20.33	20.33	36.67	58.89
B24	62	M	37.0	2	24	-133.72	-28.68	-45.14	-32.69	-60.06	0.7087	0.3022	0.7545	-0.7081	0.2643	7	7	23.67	21.00	7.22	92.78
B25	32	M	6.0	3	26	59.16	-16.75	-18.62	20.00	10.95	-2.1954	0.0846	1.0272	-0.4608	-0.3861	7	7	27.67	29.00	17.22	72.78
B26	57	M	13.0	2	46	45.55	-256.67	-51.51	-84.92	-86.88	-0.0761	-0.1072	3.2612	0.1726	0.8126	5	7	16.67	16.33	49.44	50.56
B27	32	F	8.0	1	1	128.16	72.94	126.72	-54.88	68.23	-1.3727	-0.0718	-1.0445	-1.0441	-0.8833	7	7	15.33	18.67	8.00	91.78
B28	29	M	6.0	8	22	-45.60	-42.04	44.93	58.38	3.92	-0.4008	0.3372	-0.4632	1.4826	0.2389	7	7	15.00	19.00	35.56	64.44

Table 4. Data from individual participants used in the correlation and regression analyses

Gen = gender**,** LOR = Length of Residence**, AoA** = Age of Acquisition**, AoI** = Age of Immersion**, HEHB_r/LELB_r/HELB_r/LELB_r =** ReactionTimes differences between Bengali and English for 4 word-categories**, Overall_r =** Overall Bengali Reaction Time – Overall English Reaction Time, **HEHB_e/LELB_e/HELB_e/LELB_e** = Voltages differences between Bengali and English for 4 word-categories, **Overall_e** = Overall voltage in Bengali – Overall Voltage in English, **L1 rate** = Self-rating for L1, **L2 rate** = Self-rating for L2, **L1 fl** = Category fluency scores for L1, **L2 fl** = Category fluency scores for L2, **L1 U** = L1-use, **L2 U** = L2-use

4.3 Relationship between and within Reported and Measured Language Attributes

This section includes analyses exploring the relationship between the variables involved in this study. Table 4 (see above) summarizes values for a set of variables we included for all the participants in the study except B04 whose data we discarded from any analysis because he missed responses on more than 50% of the trials. No other participant missed more than 25% of the trials. We conducted two different analyses. The first analysis was carried out in order to determine the relationship between certain predictor variables selected from the Language Background Questionnaire (LBQ) as well as the Category Fluency (CF) Task and the overall RT difference between the first and second languages. This was carried out for a larger set of participants who undertook the reaction time experiment and the subset of participants who carried out the electrophysiological experiment. We also examined the relationship between the overall voltage response and overall RT to L1 and L2 with the LBQ reports and CF data from the smaller set of participants from whom we collected both RT and ERP data.

4.3.1 Correlations

We conducted correlations to examine how the variables affected each other. We correlated the overall RT difference (L1-L2) between L1 and L2 with age of L2 acquisition (AoA), age of L2 immersion (AoI) and length of L2 residence (LOR). Only AoI correlated significantly with L1-L2 RT ($r = -0.449$, $p = 0.04$) as shown in Figure 28. In addition we correlated the CF scores in L1 and L2 with L1 and L2 ratings and use. L1 CF scores showed a positive correlation ($r = .446$, $p = .03$) with L1 rating (see Figure 29), but no other correlations were significant. On examining the subcomponents of self-ratings, we found a positive correlation between L1 CF scores and L1 self-rating for speaking ($r = .50$, $p = .02$), but not for understanding or reading.

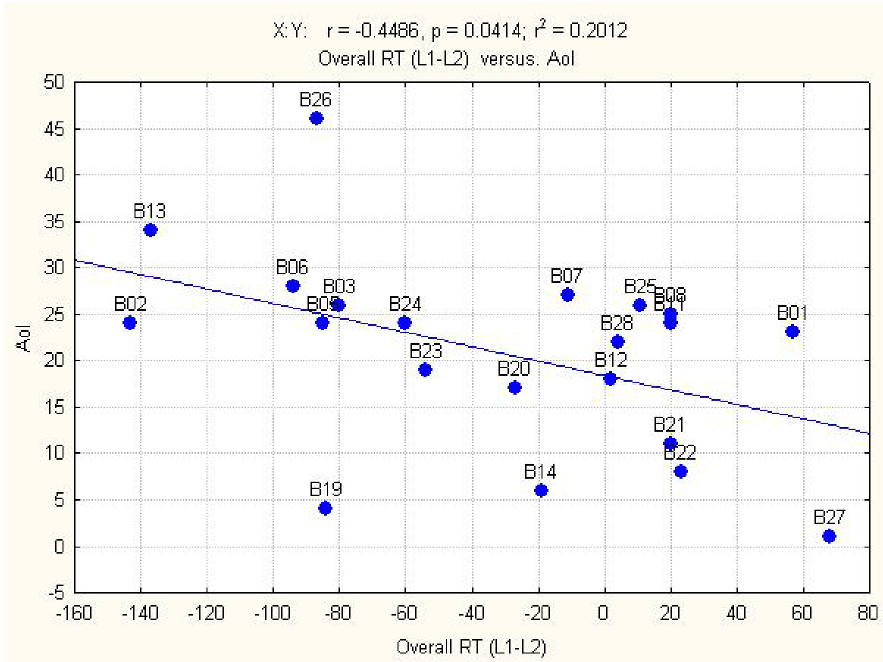

Figure 28. Age of Immersion for L2 (AoI) plotted against subtraction of L1-L2 for RT showing a moderate correlation was found between the two factors

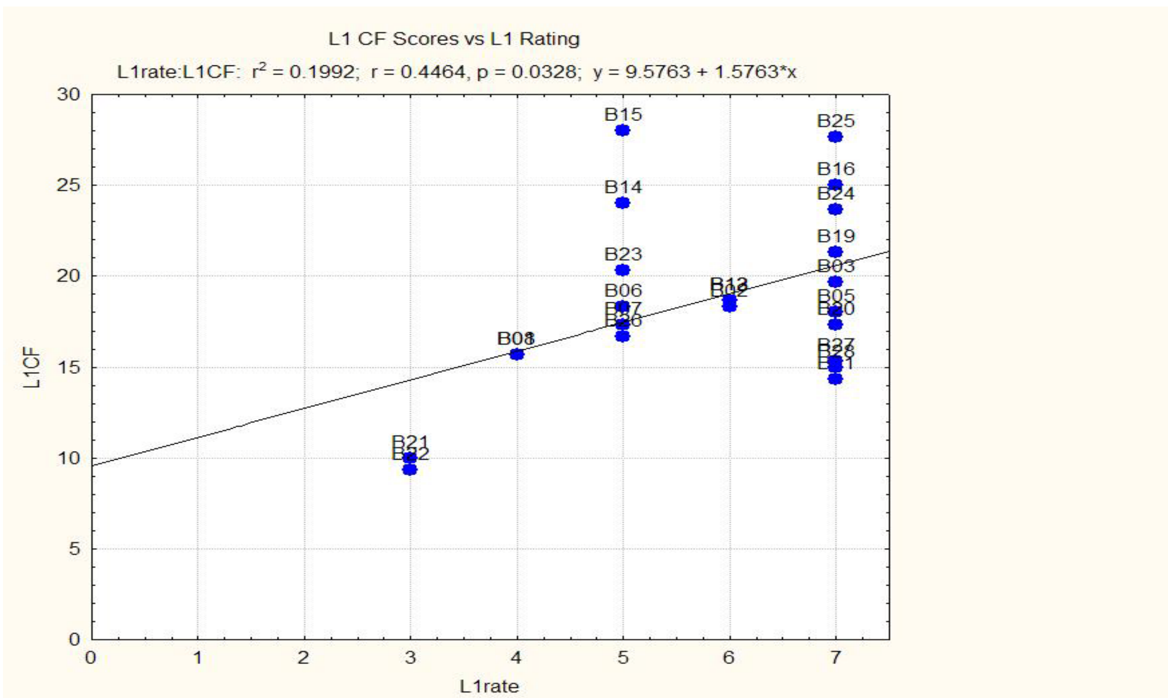

Figure 29: Category Fluency scores for L1 vs. L1 self-rating for 23 participants showing a significant positive correlation

Next we examined whether there was a relationship between the voltage values and the RT values for the participants who provided both types of data. In order to do this, we first performed a correlation analysis with all 17 participants who participated both in the behavioral and electrophysiological experiments. The relationship between the voltage responses to L1 compared to L2 and the reaction times to L1 compared to L2 were examined. . A moderate correlation approaching significance was obtained ($r = -0.434$, $p = 0.08$). Figure 30 shows a scatterplot with one clear outlier (B11) who demonstrated a positivity (indicating better L1 than L2 performance) but a large difference in reaction time in the direction of L1 being poorer than L2. After removing this participant, B11, then, as shown in Figure 31, a strong negative correlation between the two measures was obtained ($r = -0.791$, $p = 0.0003$). B11 was not excluded from any other analyses from this study for the following reasons. Firstly, the number of participants in the group analyses was limited and removing an additional participant would decrease confidence in those results. Results without B11 strengthened the present patterns reported but did not alter any of them. Also, since the groups were selected based on RT and CF data and B11 was not an outlier in these data distributions, we did not have any reason to remove this individual from those analyses. By the same reasoning, no other analyses in this section involved both ERP and RT data, so, here too we did not have any reason to remove B11 from any of these analyses.

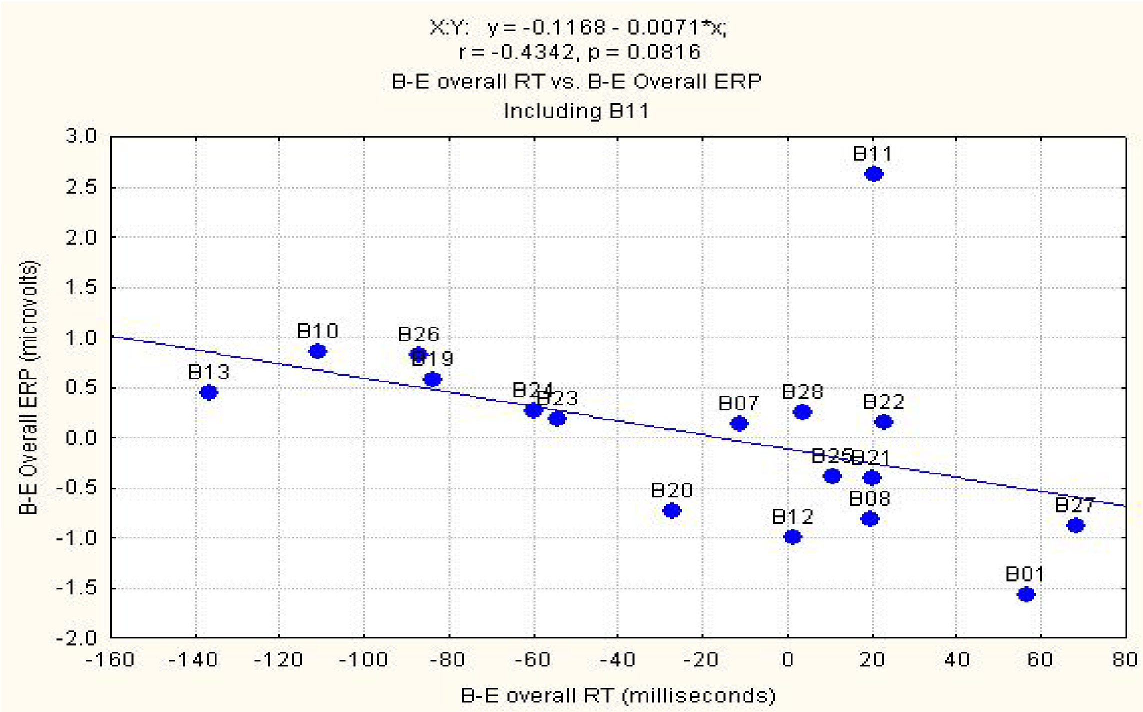

Figure 30. Subtraction ERP responses to English from Bengali words plotted responses against subtraction of RT responses to English and Bengali for each participant . Clearly, B11 is an outlier in this correlation.

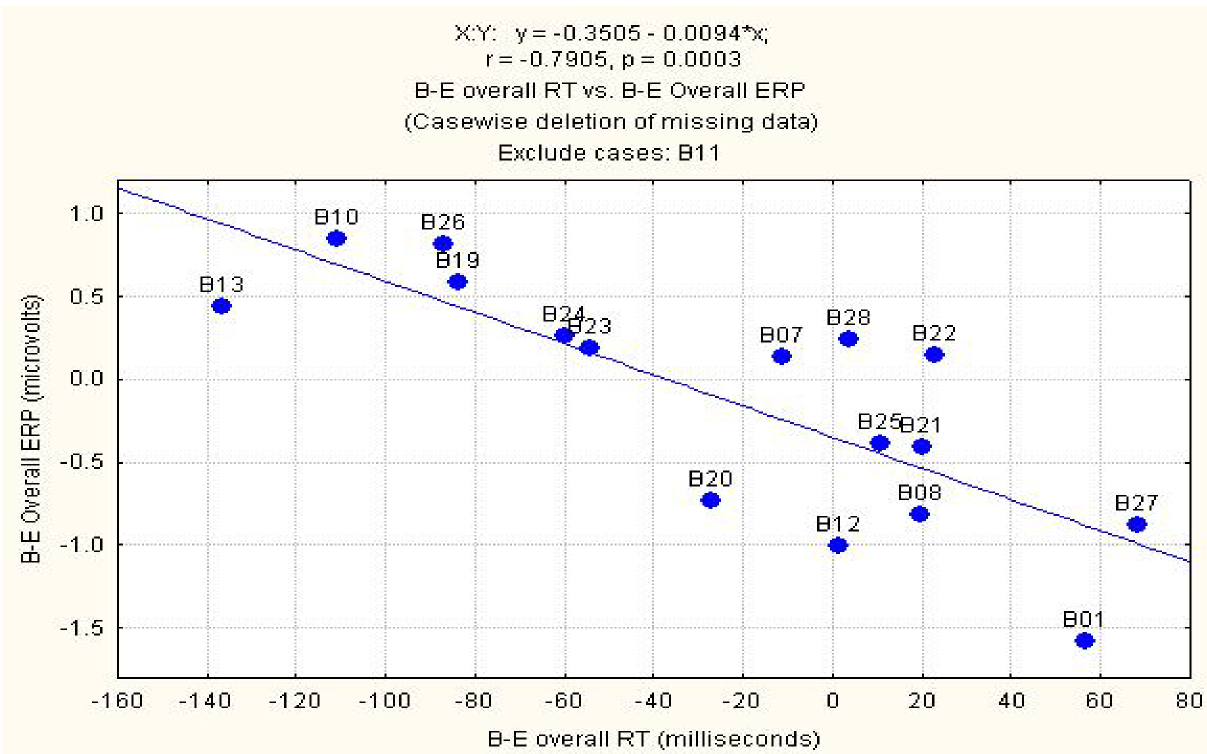

Figure 31. Subtraction ERP responses to English from Bengali words plotted responses against subtraction of RT responses to English and Bengali for each participant except B11.

4.3.2 Regression with RT data

We conducted a multiple regression with the list of dependent and predictor variables for 23 of the 27 participants who provided RT data in the priming experiment. Four participants were removed from this analysis due to missing data. Due to our low N, we were able to use only a few predictor variables. The first step towards consolidating our variables was to discard the ones that are represented by an overall variable. For example, we collapsed the CF measures for animal, food and clothing into one overall measure for CF in each language. Next we performed intercorrelations between independent variables to determine those that were highly correlated. Language-use included L1, L2 and Lx use. Lx was calculated as 100 - (L1 + L2) as 3/23 participants reported using more than just two languages. Since use of the languages was represented as percentages and the three percentages add up to 100, the language-use variables could not operate independently. Therefore the predictor variables for overall use were examined in three different (L1 and L2 use, L1 and L3 use and L2 and L3 use) regressions. The variables selected for use in this regression are summarized in Table 5.

Predictor Variables	*Dependent Variables*
L1 overall self-rating	
L2 overall self-rating	
L1overall use	
L2overall use	Overall L1-L2 RT
Lx overall use	
L1 overall CF 1 minute	
L2 overall CF 1 minute	

Table 5. Variables used in the first regression analysis

The result of this regression led to significant contributions of L2 self-rating, L1 CF score and L1 and Lx use (Table 6). We also correlated Lx use with L1 and L2 use. Results indicated that use of a third (or more) language (Lx) negatively correlated with L2 use (r = -0.536, p = .01) but did not show any significant relationship with L1-use (see Figure 32). It is important to understand, however, that since L1, L2 and Lx use are represented as percentages of total language-use, a moderate correlation such as this cannot be reliably interpreted. On inspecting the individual data, it appeared that 15/23 participants reported using (speaking, listening or both) Hindi, in very small amounts (ranging between 0.22-20%). Two of these Hindi-users also reported being exposed to Kannada, Spanish and French as well.

Dependent Variable	**Predictor Variable**	β (Standardized Regression Coefficient)	**B** (Unstandardized Regression Coefficient)	**t**	**P**	**% variance explained**
Overall	L2 overall self-rating	0.38	38.00	2.04	0.06	4.41
L1-L2	L1 1 minute CF	-0.90	-11.12	-2.98	0.01	11.66
RT	L1 overall use	-3.15	-11.46	-3.56	<.01	2.75
(milliseconds)	Lx overall use	0.85	10.28	3.39	<.01	23.21

Table 6. Summary of L1-L2 RT regression statistics showing β, p and percent of variance accounted for by the predictor variables

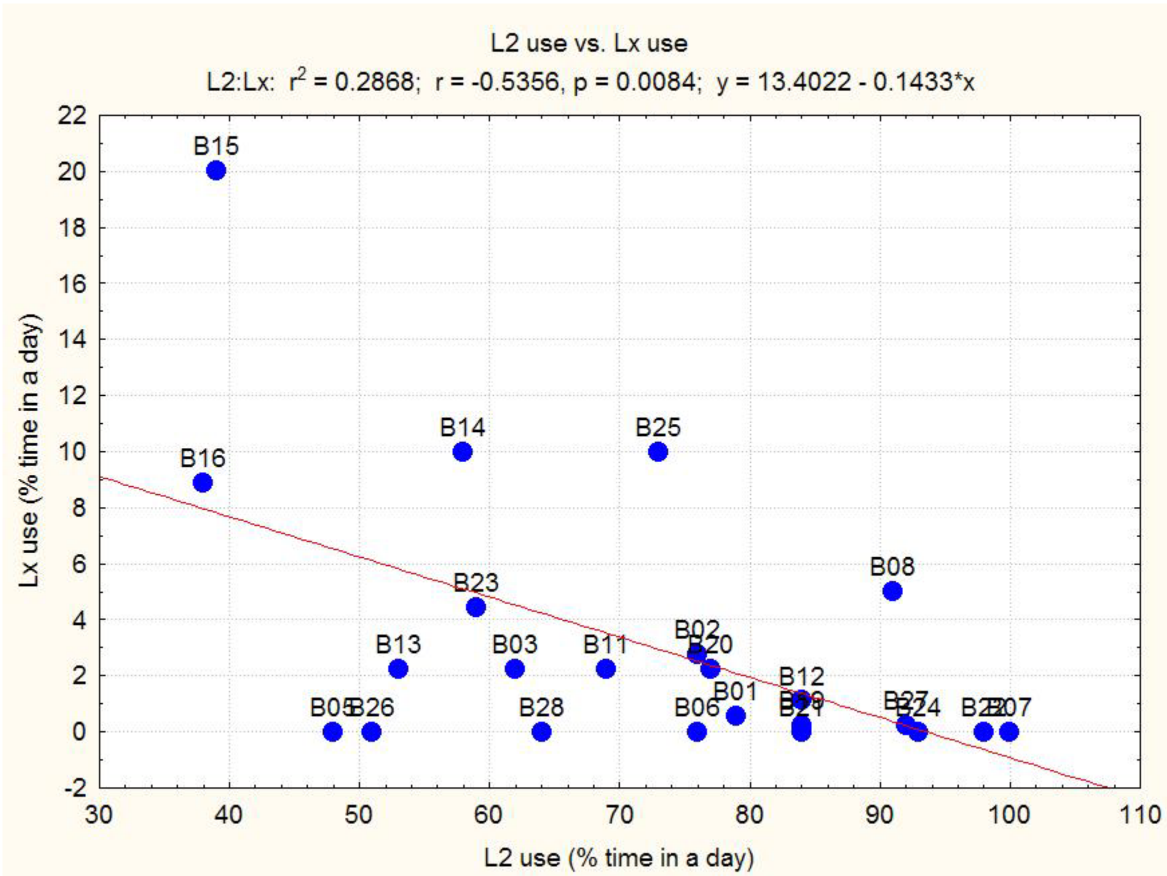

Figure 32: Correlation demonstrating a negative relationship between L2 use and Lx use

4.3.3 Regression with ERP data

In a second analysis, we wanted to examine how the seven predictor variables used in the previous analysis affected the voltage responses to L1 and L2. To do this, first we subtracted the voltage responses to L2 targets from those to L1 targets across different word-categories to create dependent variables from 16 participants with all the reported, behavioral and ERP data. The subtractions were performed for the average amplitude between 200 to 300 ms post stimulus onset, which was the time frame of the earlier peak in the ERP data (see Figures 10a and b). These ERP variables included L1-L2 voltage subtractions for all the word-categories (overall), as well as HeHb, LeLb, HeLb and LeHb categories. However, no variables appeared to contribute significantly to any of these five dependent variables.

Next, we examined these variables in a multiple regression with the voltages as the predictor variables along with the predictor variables in the first regression analysis, but this time with the overall L1-L2 voltage response and with 16 participants. We gradually titrated out predictors, which showed no significant relationship to the dependent variable through repeated multiple regressions. Results indicated that only the voltages responses, amongst all the predictor variables, (that is L1 and L2 overall self-ratings, L1 and L2 CF scores and L1, L2 and Lx use) negatively predicted the overall L1-L2 RT ($\beta = -62.91$, $t = -4.159$, $p = .001$, % variance explained = 57.91). So, the participants with faster Bengali RTs (compared to English) also showed less voltage negativity for Bengali compared to English words. The reason the other variables that appeared to significantly predict overall L1-L2 RT earlier did not emerge significant in this analysis was probably the lower N in this analysis compared to the previous one.

4.3.4 Summary: Measured attributes

In sum, we found that L1-use and L1 proficiency as characterized by L1 Category Fluency negatively predict L1 and L2 reaction time differences. L2-self-rating also showed a trend towards being a significant predictor for L1-L2 RTs. In addition, third language-use emerged as a significant predictor of L1-L2 performance as well. Both L2-self-rating and Lx use showed a positive relationship with the dependent variable. ERP responses were also found to significantly predict reaction times to L2 and L1.

V. DISCUSSION

The focus of this study was to investigate how L1 lexicon is affected in individuals who have been predominantly using L2 as their primary language. Specifically, we asked whether L1 lexicon suffers due to 1) a reduction of L1 trace strength from decreased L1-use or 2) interference from L2. It was also possible that both models play a role. In addition, we were interested in examining how variables concerning language-use relate to measures of performance in the experiment. We employed a cross-modal and cross-language priming paradigm (based on Jescheniak et al., 2002) using lexical items with similar and different familiarity-ratings across the two languages to answer our first research question. Both reaction time (RT) and electrophysiological (ERP) measures were examined. Additionally, our participants completed an extensive language background questionnaire and performed Category Fluency Tasks in both L1 and L2 to address the second question.

To test the influence of the L1-strength and L2 interference models, we examined how the L2-dominant participants performed in each language across the four word-categories. Semantic concepts were classified into these different word-categories based on the familiarity of their lexical names in the two languages. The RT data suggested that L2 interference rather than L1-strength model better accounts for L1 inaccessibility because the L2-dominant participants demonstrated slower access of Bengali compared to English words only in the High-English-High Bengali category, as well as slower access to English words in the High Bengali-Low English category compared to those in the High English-High Bengali category. The failure to find slower L1 compared to L2 lexical retrieval across all categories, regardless of L2 familiarity, indicated that L2 influenced L1 lexical retrieval. The ERP measures revealed more effortful access for low familiarity English words and their translation equivalents in Bengali, regardless of their Bengali familiarity-ratings. This was reflected by the larger negativities to the low familiarity English words and Bengali translation equivalents of these compared to amplitudes to the high familiarity English words in the L2-dominant group. Despite the difference between the two measures in how the word-categories affected the language performance in the L2-dominant group, it appears that for both measures, L2 word familiarity had substantial influence on L1 performance. In addition, the incongruent auditory words to pictures elicited larger negativities in English than in Bengali for the L2-dominant group. This suggests that L2 interference into L1, rather than reduction of L1-strength, is what affects the nature of L1 attrition in this group of L2-dominant individuals.

Results for the second question, regarding the relationship between reported measures of language-use [i.e., self-ratings on language skills, amount of language-use, age of acquisition (AoA), age of immersion (AoI) for L2 and length of residence in the L2 environment (LOR)] and performance reflected by the ERP and RT measures, as well as the category fluency task, suggested different levels of contributions from each factor. As expected, findings confirmed that L2 self-rating, L1-use and L1 category fluency performance significantly predicted poorer performance in Bengali than English. Of additional interest was our finding that the use of a third (or more) language(s) contributed negatively to L1 performance. Only AoI, and not AoA or LOR, showed significant correlations with RT in Bengali relative to English.

This chapter has three sections dedicated to the interpretation of the results obtained from our experiment and a final section on future directions for this research. In the first section, we discuss in greater detail how the two groups were different from each other. In the following two sections, we examine how our data can be interpreted within the context of the research questions we asked and the existing literature. We also evaluate how this project has contributed to the understanding of L1 attrition.

5.1. Difference between L1-dominant and L2-dominant groups

Existing studies of L1 attrition have usually contrasted groups who do not overlap in their language profiles: consisting of bilinguals, who are very proficient with their L2 residing in an L2 environment for 10 or more years and who have little or no contact with their L1, contrasted with monolinguals, residing in the native L1-speaking country and ideally have never visited the L2-speaking country. However, we wanted to examine the process of L1 attrition in a more realistic bilingual setting, where potential L1 attriters in an L2 environment were in contact with their L1, but not nearly as much as they would have been had they been living in an L1 environment. Moreover, it was not possible to test monolingual Bengali L1 speakers; as such speakers are rare in an urban setting in both India and the U.S. Therefore we chose to contrast our L2-dominant individuals, who used more L2, with a group of L1 dominant participants, who used L1 more and remained within an L1 environment for the most part as compared to the L2-dominant group. The process of becoming and maintaining a proficient multilingual is highly dynamic and this process operates within a continuum of language gain and decline. Therefore, creating different groups of proficient multilinguals, is arbitrary in some sense. Likewise, in this study, although two groups were created based on two performance based measures (RT to target words in the experimental tasks and a category fluency task in both languages), they are to a certain extent arbitrary as distinct groups and, as has been seen, their performance is better represented as a cline. Nevertheless, as groups, the L2- and L1-dominant participants did show distinct behaviors in their L1 and L2.

5.1.1 Differences in language proficiency and use

The L1-dominant group reported having spent more comparable amounts of time with L1 and L2 than did the L2-dominant group (especially in speaking and hearing) in their daily lives, but performed comparably in the Category Fluency Task for both languages (mean CF in English: 19.15

and Bengali: 19.81), indicating that they were competent in their L2 as well. The L2-dominant group, by contrast, reported that they used L2 much more than L1 on a daily basis and performed significantly better in the Category Fluency task for L2 English than for L1 Bengali (mean CF in English: 21.12 and Bengali: 15.83). Hence, the Bengali-English speakers in both L2-dominant and L1-dominant groups were proficient L2 users, as reflected by their similar CF scores in L2. Additionally, the L1-dominant group presented with expected CF scores (Gollan et al. 2002; Portocarrero et al. 2007, Rupela, 2010) and ratings (< 5 out of 7) in L2 across groups) for bilinguals in either group.

It is evident from these scores and ratings that the L1-dominant group was performing comparably in their languages, while there was a gap in the use and performance of the two languages in the L2-dominant group. It is then reasonable to propose, that the better performance of L2 relative to L1 in the L2-dominant group (who were assumed to have been L1-dominant at a previous time in their life) was not a reflection of merely improved L2-skills expected in the course of L2-acquisition. Rather, the L2-dominant group's performance in L1 and L2 reflects easier access to L2 lexical items and that this facilitated access to L2 may be responsible for their interference with L1 lexical items.

5.1.2 Differences in RT and ERP measures in the congruent words

As a group, the L1-dominant participants performed faster in their L1 than in their L2 across all four experimental word-categories as reflected by their RTs in the two languages. That is, whether the respective familiarities of words across the languages were the same or different did not affect how this group performed in L1 and L2. However, recall that 11 out of 16 participants in this group were significantly faster in RTs in L1 than in L2 as reflected by individual t-tests. Nine of these sixteen participants who were tested on the ERP experimental paradigm also showed similar overall patterns to the larger group for the RT data; i.e., compared to the L2 groups these participants demonstrated that they accessed their L1 Bengali more easily than their L2. In contrast, the L2-dominant participants were affected differently in the two languages by the four word-categories, as reflected both by their RT, as well as ERP data. Specifically, L2 word familiarity influenced L1 measures. Therefore, while it is possible neither group was entirely homogenous in its constituency, they did show significantly different performances in their L1 and L2.

5.1.3 Differences in ERP measures for the incongruent words

The L2-dominant group showed a larger negative ERP response to incongruent words presented in the context of pictures in English, compared to that in Bengali. The L1-dominant group also elicited negativities to the incongruent words in both English and Bengali. However, the response to English was significantly smaller than that elicited by the L2-dominant group. The responses to Bengali unrelated words did not differ between the two groups (see Figure 27). A larger negative ERP response relative to a smaller one, in this experimental paradigm, reflects more difficulty in accessing lexical items by the participant. This suggests that the L2-dominant group was more sensitive to the incongruent words in English than was the L1-dominant group. It is possible that this is because the L2-dominant group is largely operating in English and is heightened in its sensitivity in English relative to Bengali.

Another interesting difference between the two groups was that while the L1-dominant group showed the expected pattern of larger negativities to the unrelated words in both languages, the L2-dominant group did not. The L2-dominant group showed larger negativities for the incongruent words than the related words in English but not for these words in Bengali. Specifically, the negativity to the related words was in the direction of being larger than to the unrelated words. It is possible that the L2-dominant group is operating largely in English throughout the experiment, which leads to the unexpected pattern found for the Bengali words. Since the experimental conditions were not presented in blocks presenting just one language, the participants could not adopt different strategies for different conditions. When the L2-dominant group encountered a congruent word in Bengali, the expectation of hearing it in English led to a tendency towards a greater negativity for Bengali as less expected words have been reported to produce larger negativities even when they are semantically congruent (Lau, Phillips & Poeppel, 2008). For the incongruent words, the expectation of an English congruent word led to a large negativity to a incongruent-word in English. The failure to find increased negativity to the unrelated Bengali words relative to related Bengali words could have two possible explanations. First, the individual may have chosen not to complete the access process after recognizing that it was not a match with the picture in case of the incongruent Bengali word. The task of syllable-judgment did not require complete access of the semantic representations. Studies of lexical access of phonological information have found that listeners will stop attempting to access lexical representations if the form is phonotactically unacceptable in their language, (e.g. Praamstra, Meyer & Levelt, 1994); here, unacceptable in the 'expected language'.

The L1-dominant group, on the other hand, may not have been as biased by Bengali as the L2-dominant group was by English. This could have led to large negativities to the English as well as Bengali incongruent words compared to related words in the L1-dominant group. In addition, since the incongruent and the -related words were not to the same pictures (recall that the incongruent words were a fifth set of words used to balance the syllabic differences across the languages), it is possible that some other factor, such as word length contributed to this unexpected finding. The important point here is that the L2-dominant group differed from the L1-dominant group in the incongruent condition for the two languages. The data reliably support that the L2-dominant group was indeed more sensitive to English than to Bengali semantic anomalies compared to the L1-dominant group.

In the preceding sections we presented evidence to support the argument that this study addressed aspects of L1 attrition and not merely L2-dominance over time. In summary, the two groups showed different patterns of access for Bengali versus English words for both congruent and -unrelated words. This indicates that differences in performance by the L2- and the L1-dominant groups are not driven by L2 alone. Rather, differences in language behavior between the groups and L1-effects in the L2-dominant group are the result of interactions between their L2 and L1, in a way that cannot be explained by either L1 or L2 performance alone. They can best be attributed to differences in amount of use of L2 relative to L1, since both groups showed good proficiency in L2.

5.2 L1-strength or L2 interference?

The primary question we addressed was which contributes to L1 attrition more: reduced L1-strength or L2 interference? Since the L2-dominant participants' responses were influenced more by the relationship between L2 and L1 than L1 properties alone, we conclude that L2 interference contributes more to attrition than L1-strength. In the following sections, we discuss our data, first for the congruent words, then for the incongruent words, across the two languages, Bengali and English.

5.2.1 Congruent words

Our RT data were most consistent with the second hypothesis, favoring L2 interference, as the L2-dominant participants demonstrated longer RTs to L1 than L2 overall with a reversal of this pattern only in the LeHb category. Specifically, these L2-dominant participants generated 1) longer RTs to Bengali relative to English words when both were of high familiarity and had high familiarity translations in the other language and, 2) longer RTs to low familiarity English words than to high familiarity English, both have high familiarity Bengali translations. However, no RT differences between Bengali words with different familiarity levels or their English translations of different familiarity levels. This indicated that familiarity with English words affected the L2-dominant participants' responses more than familiarity with Bengali words.

By contrast, the ERP data showed a more complicated pattern suggesting that higher L2 familiarity actually facilitated access of both these L2 words and their L1 translations. Specifically, for the L2-dominant group, we obtained larger ERP negativities, indicating more difficult access, to low familiarity English words and Bengali words with low familiarity English translations, compared to high familiarity English words and Bengali words with high familiarity English translations for the earlier ERP time frame (160-440 ms).

The later ERP time frame (400-800 ms) showed a pattern similar to the behavioral RT data that indicated that L2, but not L1, lexical factors influenced access. Specifically, high familiarity English words were easiest to access and low familiarity English words and their Bengali translations were the most difficult to access. This interpretation is based on the observation that the L2-dominant participants showed larger negativities to Bengali than to English words that were from the high familiarity category for both languages and the most negative amplitude were for English words with low familiarity-ratings and their Bengali translation equivalents. The familiarity-ratings of the translated Bengali words had no effect on amplitude of the ERPs in this later time-frame as well. Additionally, the ERP data to the incongruent words for the L2-dominant group suggests that L2 lexical factors most strongly influence access because only English words showed larger ERP negativities to incongruent words compared to related words. Bengali congruent and -unrelated words showed no difference for the L2-dominant group.

Our interpretations are based on ERP research showing that an increase in the negative amplitude at the posterior superior sites (from 200 – 600 ms) to words in lexical tasks indicates an increase in difficulty in accessing words (Shafer et al., 2004; Jescheniak et al., 2002). This increased negativity is the N400 component found in many lexical access studies (Brown & Hagoort, 1993; Anderson & Holcolmb, 1995; Deacon, Hewitt, Yang & Nagata, 2000). Thus, increased negativities to the words with low familiarity-ratings in English, in this study, suggest greater difficulty in accessing low familiarity words in English and their translation equivalents in Bengali, regardless of their ratings in Bengali.

These findings, although not entirely consistent with our original predictions, indicate that L2 interference plays a greater role than L1-strength in influencing L1 lexical access for the following reasons: first, in our L2-dominant group, word familiarity categories affected Bengali and English words differently and second, L1 accessibility (for both RT and ERP data) was modulated by L2 and not L1 familiarity-ratings. This pattern was expected. L2, the stronger and more activated language, was predicted to show larger word-pair category effects than L1, use of which was reduced as a whole. These patterns of L2 modulation of the RT and ERP effects were not obtained in the L1-dominant group. Their RT and ERP data showed better performance in L1 than in L2 across all word-categories.

The mechanisms operating in attrition may also be related to the type of participants tested. In her recent paper on perspectives on first language attrition, Köpke (2007) suggests that the nature of interaction between L1 and L2 depends largely on how much L1 is accessed by an individual. She describes two possible situations that could lead to L1 attrition in bilingual individuals. The first is one in which immigrants are not in contact with their L1 at all, possibly giving rise to a dormant, low active state of L1 with high activation thresholds. The other possibility is that of a group of immigrants who are in contact with L1 (but much less so than if they were in an L1 environment) and encounter much more interference from L2 than those who live in an L1 dominated bilingual environment. A similar set of classifications is also made by Green (1998) in his Inhibition Control model, where he describes three states of activation for languages. The first state is selected (when it is accessed and being used). The second state is active. In this state the language is not currently being accessed but it is a frequently used language and could be accessed at any time. The third state is dormant. In this state, the language is hardly activated or used over a long period of time. Under this model, the active language often interferes with the selected language for an individual (i.e., if they are different from each other). The strength and frequency of interference by this active language is modulated by the level of activity it experiences. Since our L2-dominant participants were not completely isolated from L1, but were using L1 less than L2 and less than our L1-dominant participants were, it was not unexpected that they showed interference patterns. In the future, it will be important to explore more extreme cases of L1 attrition, such as those of individuals who are in almost no contact with L1.

Probing into the interference patterns obtained in this study a bit further, it is necessary to evaluate our findings within the context of existing literature on L1 lexical attrition. Since there have been no other experiments directly comparing L1-strength and L2 interference, we will begin with studies supporting L2 interference as a possible mechanism for L1 attrition. Ammerlaan (1996) and Gürel (2004) also attributed their L1 attrition results, in part, to L2 interference. Recall that in Ammerlaan's (1996) experiment, he tested Dutch-English emigrants in Australia on their lexical skills in Dutch. His experiment was focused on understanding how phonological and morphological systems (similarities and dissimilarities) of the two languages contributed to L1 attrition. He reported that his participants had least difficulty with phonologically similar words across the languages (especially the cognates amongst these) and relatively more difficulty with morphologically or phonologically distinct words. Most difficult, however, were words that were phonologically similar but morphologically different in the two languages. This suggests that phonological similarity at the lexical level across one's L1 and L2 may help preserve L1 lexical access through the period when L2 gains dominance over L1. Conversely, it is possible that phonological similarity can induce interference across the languages as well, especially if the meanings across such words differ in the two languages involved (i.e., they are false cognates).

The current study is different from Ammerlaan's study for two reasons: 1) Bengali and English are phonologically different languages (i.e., they do not share many cognates and have mutually exclusive phonemic segments) and hence the phonological similarity advantage was not available to the speakers and 2) words across the languages were not selected to test morphological dissimilarity. Given these differences, it still appears that our findings are not in conflict with Ammerlaan's data. He predicted some amount of difficulty in recall of lexical items for words that are phonologically dissimilar but morphologically not so.

Gürel (2004) tested a set of three pronouns in Turkish for Turkish-English bilinguals in North America using three receptive tasks. Her data showed that her participants had more difficulties with the pronoun that had an English competitor than with the two others, which had no competitors in English. Although she attributed her findings to both raised activation thresholds in L1 and interference from L2, she had no empirical evidence to decide between these two possibilities. Our behavioral data showed a pattern that was similar. Specifically, high familiarity Bengali words showed slower RTs when they had high-familiarity English compared to low familiarity English competitors.

Few studies examining lexicon in particular have focused on the role of L1-use alone (Altenberg, 1991; de Bot, Gommans & Rossing, 1991). The term ‘language-use’ has been described rather loosely in the literature, mostly as a sociolinguistic variable measured on the basis of participants’ reports of their L1-use. Although we employed “L1-use” in a similar fashion in the Language Background Questionnaires we administered, an additional aspect of “L1-use” was explored in the current study. We proposed that this decreased L1-use (and perhaps increased L2 use) could lead to an overall decrease in L1 accessibility, evident in the data from the L2-dominant participants. The expected pattern, if indeed decreased use of L1 was what underlay L1 attrition, was an overall difficulty with L1 words across all four word-categories, regardless of their familiarity-ratings. However, as explained in the previous paragraphs, we did not see this pattern in either our RT or ERP data. In addition, L2-use and self-rating but not L1-use (see section 5.2) emerged as significant predictors of RT differences between L1 and L2 for all participants (both L1- and L2-dominant groups), supporting an interference model.

5.2.2 Relationship between lexical access, RT and ERP measures

Having discussed how our findings fit into our hypotheses for our first question, we need to turn our attention to an important issue, reported earlier, i.e., the discrepancies between the RT and ERP data patterns. Obtaining more than one data set from the same experiment enables us to examine our hypotheses from multiple angles. While converging findings facilitate confidence in the data, conflicting findings aid us in obtaining a deeper understanding of the mechanisms being tested. Below, we discuss possible reasons for the differences in the two datasets, collected at different points of time in a one and one half hour long session with different complex tasks and examine whether the findings can be reconciled.

Research involving RT and ERP data from the same task often report disparity in findings between the two data types, indicating that they index different aspects of lexical processing (e.g., Brown & Hagoort, 1993; Chwilla & Kolk & Mulder 2000; Kerkohfs, Dijkstra, Chwilla, & de Bruijn, 2006). Our ERP measures indexed processing beginning between 160 and 800 ms post-stimulus onset, whereas the behavioral response to phonological decision occurred between 693 to 1405 ms after stimulus onset. The early time-frame is likely to be more influences by phonological and lexical factors, whereas the later time frame by is related to the decision process for the behavioral response.

First we will discuss the effects for the congruent words, as there were significant findings for language and word-categories for both RT and ERP data. Both similarities as well as discrepancies between these data types were observed. The L2-dominant group showed data suggesting easier access to L2 than L1 and the L1-dominant group showed the opposite pattern. Also, the word familiarity levels (reflected by the word-categories) did not influence RT or the ERP measures for the L1-dominant group. Specifically, the L1-dominant group overall demonstrated easier (less negative ERP amplitudes) and faster (RTs) access to L1 relative to L2, regardless of the four word-categories.

For the L2-dominant group, word familiarity for the L1 and L2 words did affect the RT and ERP measures, but not identically for the two types of data. RTs for the L2 dominant group were significantly faster for L2 than L1 words with high familiarity. This pattern was reversed for the words from the Low English-High Bengali category, although it did not reach significance. In contrast, the ERP data form the earlier time-interval showed a different pattern suggesting that only English word familiarity mattered. Specifically, the ERP data suggested more difficulty in accessing the low familiarity English words and their Bengali translations, compared to high familiarity English words and their Bengali translations, regardless of Bengali word familiarity. The later time frame in the ERP data, however, showed a similar pattern to the RT data. In this case, the ERP data showed more difficulty accessing high familiarity Bengali words than high familiarity English translations. The later ERP responses are likely to reflect the decision processes that result in the behavioral response. Thus, it is reassuring that these two data sets show similar patterns.

Both the RT and ERP data index L1 changes driven by L2 rather than L1 properties. The word-pair category that demonstrated the worst L2 performance for the L2-dominant group in the RT data is one in which low familiarity English words have high familiarity Bengali translations and hence were expected to hardly interfere with the Bengali words. In addition, the two categories which showed poorer lexical access in the same group, as reflected by the early time frame in the ERP data, are those which have low L2 familiarity. Low familiarity English words are expected to be used relatively less, leading to even less frequent access of the L1 translation equivalents.

Our data support the claim that different language processes are indexed at different points in the ERP and RT responses. The behavioral response required a decision (pressing buttons to indicate a decision about the syllabicity of the words). There earlier time-frame of the ERP responses are likely to have preceded the decision processes. Hence, even though both types of data, RT and ERPs, index language processing, they are tapping into different points in the process. We elaborate on the nature of these differences in the next few paragraphs.

The nature of ERPs elicited during lexical processing and its functional underpinnings have been greatly debated in the literature (Praamstra, Meyer & Levelt, 1994; Deacon, Hewett, Yang & Nagata, 2000; Jescheniak et al., 2002; Kiefer, 2002, Pylkkänen & Marantz, 2003, Lau, Phillips & Poeppel, 2008). Specifically whether ERPs to words in priming paradigm (such as the one used here) reflect lexical retrieval (as in production), access (as in word recognition) or contextual integration (as in how the prime- picture affects the target auditory-word) has not been resolved. Furthermore, the nature of contextual integration reflected by such ERPs, (i.e., N400s) is also not clear. There are two views regarding the underlying process of contextual integration in lexical paradigms utilizing ERPs. One proposition is that a greater negativity to a contextually unexpected or incongruent word[1] relative to its congruent or expected cohort is driven by the amount of overlap between separate automatic activations of the prime and target. The other view is that this greater negavitiy to the incongruent word is driven by a post-lexical congruency comparison between the prime and the target of some sort. Whether N400s generated in lexical priming paradigms are mediated by the former or latter process is still ambiguous. In the next few paragraphs we explore how the results of this study relate to the current understanding of lexically modulated ERPs.

It is likely that the electrophysiological measure at the earlier time-frame is reflecting phonological and semantic aspects of lexical access of a more automatic nature, but not integration of information allowing for a decision. Specifically, the early N400 response probably indicates a more automatic level of priming that is less influenced by the task. Additionally, we can explore the notion of spreading activation (Collins & Loftus, 1975; Dell, 1986; Roelofs, 1992. Jescheniak et al. 2002) during lexical access over the lifespan of a bilingual individual as we unpack what the ERP data may reflect in this study. It is possible that the more often a concept is used in English, the more it gets activated in Bengali, even if it is only via a spread of activation and this accounts for easier access of the low familiarity Bengali words with high familiarity English translations. Indeed a vast literature on bilingual lexical access speaks to activation of both languages during lexical access (Kroll & Stewert, 1994).

1. Incongruency in lexical paradigms using ERPs can phonological, semantic, or here, language, i.e. any pattern that breaks the expectancy set up for the upcoming stimulus,

Therefore, over time, the less familiar a word is in English, the lower the chances of it being activated in English and hence in Bengali. The functional significance of the ERP indexes of lexical processing, (i.e. the N400) has been investigated at length. Although both post lexical-semantic integration processes and automatic lexical access processes have been attributed to these ERP components, our data from the early time-frame are more consistent with the suggestion of automatic lexical activation processes (Deacon, Hewett, Yang & Nagata, 2000; Kiefer, 2002, Pylkkänen & Marantz, 2003, Lau, Phillips &Poeppel , 2008). Lexical processes and its spreading activation together can explain our findings as follows. When our participants encountered an auditory word, it was more easily accessed if it was one with high rather than low familiarity in English, regardless of whether the actual word was in English or its translated equivalent in Bengali. Although this explanation deviates from the original predictions, it does not counter the notion that it is L2 access patterns that interfere with L1 access over time.

In contrast to the ERP data, the behavioral data may be indexing how the interface between the picture and auditory word contributed to the syllable task, as it is recorded at a much later time (approximately 900 ms post) with respect to the auditory stimulus. RT has been associated with both automatic lexical access as well as post lexical integration processes (Chwilla, Kolk & Mulder, 2000). However, it is likely that at this later time-frame associated with an attention demanding lexical task, RT in this experiment may reflect a post-lexical integration process between the already activated words. At the onset of the picture on the screen, lexical items in English were expected to be at an advantage for the L2-dominant participants for all but the LowEnglish-HighBengali category. Most of this advantage could be attributed to the fact that L2-dominant participants have been operating in an English environment long enough to become English dominant. Therefore, when English words are activated at the picture onset, the activation Bengali auditory targets would lead to a mismatch, resulting in slower RTs for these items for this group.

The “English” advantage was available for the high familiarity English words, as these English words gained strength over time spent in L2 environment (high familiarity English words with high or low familiarity translation equivalents in Bengali) or they had a prior advantage over Bengali (high familiarity English words with low familiarity translation equivalents in Bengali) as well. The advantage could also be available to English words in the low familiarity category, (in the same way it was available for the high familiarity English words with high familiarity Bengali translation equivalents) through extended periods of L2 immersion. Hence for these three categories, if the pictures led to a high probability of activating English words, it was expected that Bengali auditory targets would elicit slower RTs. The only case where this pattern was not expected was that of the low familiarity English words with high familiarity Bengali translation equivalents. In this condition, the pairing of low familiarity English with high familiarity Bengali was expected to lead to the higher (or at best equal due to L2 immersion in these participants) probability of activating a Bengali word from a picture as compared to an English. Thus Bengali auditory targets in this category was not expected to encounter as frequent a mismatch with the words accessed from the preceding pictures as did the other categories and then, would not be expected to elicit longer RTs than English targets. The pattern in the RT data showed a trend supporting these predictions.

What was interesting was that in the later time-frame the ERP data resembled the RT data quite closely for the L2-dominant participants across languages and word-categories. This could suggest that the ERP data were reflecting the behavioral process in the later time-frame attributed to post lexical access integration processes (Pylkannen & Marantz, 2003, Lau, Poeppel & Phillips, 2008), especially since the task was a phonological one.

RT and ERP responses to the incongruent words showed differences as well. The major difference between the two types of data for this condition was the absence of an interaction between group and semantic unrelatedness in the behavioral data. Semantic unrelatedness led to slower RTs and larger ERPs for both groups. In contrast, the ERP data showed a robust group, congruency and language interaction. As discussed in section 5.1, the ERP data also showed that the L2-dominant group was more sensitive to semantic anomalies (unrelatedness) in English than in Bengali compared to the L1-dominant group. It appears, then, that RT was not sensitive enough to capture the group differences for the incongruent words in the two languages.

In summary, the early ERP responses probably reflect more of the automatic lexical access process to the auditory words. The differences in the amplitudes of these responses are driven by the the differences in difficulty of access across words in the four word-pair categories. The button-press response, in contrast, indexes the time taken to perform the syllabification task and make a controlled judgment about it. Our results indicate that these processes of syllabification and decision are influenced by lexical access of the visual and auditory information, since lexical factors affect the button press times as well.

5.3 Relationship between reported and measured attributes

An interesting focus of this study was to examine the relationship between the language attributes reported by the participants in the language background questionnaire (LBQ) and their performance on the experimental tasks. Both L1 and L2-dominant groups of participants were included in this analysis. While preliminary correlations showed that neither Length of Residence (LOR) in the L2 environment nor Age of L2 acquisition (AoA) had any relationship with participant RTs, Age of L2 immersion (AoI) showed a moderate correlation with the difference between L1 and L2 RT. The earlier the AoI, the greater the difference between L1 and L2 RT, in the direction of L1 being longer. A lack of relationship between LOR and experiment performance was anticipated, since LOR has not always emerged as a powerful predictor of L1 attrition research (de Bot et al., 1991). The small spread of AoA amongst the participants was what was likely to have been responsible for its non-significant relationship with experimental measures. Further analyses revealed that the RT differences between L1 and L2 (Bengali-RT-English-RT) were most strongly predicted by L1-use and L2 overall self-rating. In addition, higher scores in the L1 category fluency (CF) task predicted shorter RTs in L1. It was reassuring to find the expected patterns that less use of L1 and higher self-rating of L2 predicts one's reaction time in L1 to be longer, while L1 category fluency predicted shorter L1 RTs. L1 CF scores also showed moderately positive correlations with L1 self-ratings. These measures of association confirm that indeed, proficiency and use of English and Bengali contributed towards the participants' performance in these languages.

An additional finding that helps us understand the relationship between the ERP responses and the RT data was the strong negative correlation between RT and ERP amplitudes. Specifically, the difference between L1 and L2 (that is L1-L2) for RT was more positive when the early ERP response (collapsed across all the word-categories) was more negative, that is, smaller numbers for L1-L2 for RTs corresponded to more negative amplitudes for L1-L2 ERPs. Also, the ERP data successfully predicted the behavioral response RT data, indicating a positive brain-behavior relationship. An unanticipated finding with these data however, was the manner in which the presence of a third language affected the RTs in the participants. We found that the amount of use in a third (or additional) language significantly predicted how the participants performed in their L1. That is, additional language-use was associated with to slower RTs in L1 Bengali.

It is important to understand the influences of a third language in our data, for a number of reasons. First, there is now a body of research that focuses particularly on polyglots who use more than two languages. It has been shown that trilinguals are indeed different from bilinguals in that they have more possible permutations of dynamic relations between their languages (Goral, 2001). Second, although it is relevant to begin understanding multilingualism based on information on bilinguals (just as monolingual individuals have served as model for understanding basic language processing), it is crucial to realize that a large proportions of bilinguals in the world probably know a third language. In fact, Bengali speakers from India are very likely to know a third language (most often Hindi) because they lived in a multilingual urban society. There is more than sufficient exposure to a different Indian language in such an environment for Bengali-English speaking individuals to be able to at least comprehend this language. A large proportion of this exposure is experienced via media. Bengalis in India spend a large portion of their free time listening to media in Hindi and may continue to do so when they immigrate to a different language environment.

Studies of lexical access in trilinguals, such as the one by Goral (2001), show that the relative strengths of connections between multilinguals' languages depend on how proficient they are in each of these languages. Goral (2001) carried out a cross-language priming study for Hebrew (L1)-English-Arabic trilinguals in order to systematically explore the interconnections between the lexicons between these languages. Despite priming effects between Hebrew and English (the more proficient non-native language), she did not find any priming effects between Hebrew and Arabic. She attributed these differences to relative proficiency in English and Arabic. Proficiency in this study was measured using self-rating, RT to lexical decision task (LDT) and error rates from the LDT. Goral showed that the participants in her study were slower and made more errors with a larger range of variability in both RT and error rates in Arabic than in English. She suggested that the lack of a priming relationship between Hebrew and Arabic was perhaps due to an overall low proficiency and a greater variability of proficiency in Arabic in her participant group. In addition, her data also indicated more inhibitory priming (priming reflecting interference rather than facilitation from the prime into the target) for Arabic than for English from Hebrew. This was, again, explained as being the result of lower proficiency in Arabic. Priming effects between the two non-native languages (English and Arabic) were modulated by the relative proficiencies of the two languages. That is, when the target language was more proficient than the prime language, facilitation priming effects were observed. Conversely, when the target language was less proficient than the prime language, inhibition priming was observed.

Other studies (Abunuwara, 1992; de Groot and Hoeks, 1995; Dijkstra and van Hell, 2003) have also reported relationships between L1 and L3 in the context of relative proficiency differences between L2 and L3. There appears to be some level of controversy about the nature of connections between L2 and L3, however. A few studies (e.g., Abunuwara, 1992; de Groot and Hoeks, 1995) report that as L3 (often a weaker language) operates through the stronger L1 (like L2 does) there may be no connections required between L2 and L3. Others (Ecke, 1999; Goral, 2001) suggest that indeed there is some dependency between L2 and L3. All these connections between languages are probably related to their relative proficiencies and possibly the amount of use as well as the structural closeness between the three languages.

In the context of the existing information about how L1, L2 and L3 are related, it is not completely unexpected that we find L3 influences on L1 and L2 skills. Data reported from studies in the previous paragraph were explained from an acquisitional point of view, that is, L1 was always the strongest language and influences of L1 were expected and found on the non-native languages. In the current study, from our regressional analyses we find that time spent using a third language probably takes away from time spent using a first language, since we find RTs for Bengali increase (for both L1 and L2-dominant participants) as amount of usage reported for the third/other language increases. As multilingual speakers grow more proficient in all their languages, L1 no longer being dominant, L3 effects on L1 can also be expected. Although we need to explore this finding further, one or both of the following may have contributed to our data patterns: 1) effects of the “other” language on the first language may be more prominent for the L2-dominant than the L1-dominant participants because L2-dominant participants are spending less time with their L1 already rather than the L1-dominant participants, 2) the L1-dominant participants currently living in India spent more time using L3 (when it was Hindi) as more of it was available in the environment.

To explore the use of a third language further, we correlated third language-use with L1- and L2-use as reported in the questionnaires, although we found no significant correlation between Lx and L1 (as predicted), we did find a significant negative correlation between Lx and L2. This did not confirm our predictions about how the Lx may have affected L1-use, rather, it appeared as if time spent using Lx was part of time spent using L2, although a moderate correlation such as the one we obtained may not render conclusive results or reliable interpretations.

Taken together, our participants largely behaved as we expected, consistent with our hypotheses, given their reported language ratings and histories. Although neither AoA nor LOR was related to their RT performances, AoI appeared to have a strong correlation with RT differences between L1 and L2. Other factors found to significantly predict this RT measure included L2 rating and L1-use as well as L1 category fluency. This demonstrates that socio-linguistic behaviors that develop over the life span of individuals, indeed, contribute significantly to their language performances. Thus, if individuals feel strongly about maintaining language skills in a particular language, even if it has been mastered to an adult standard earlier, continuing to use it frequently will be a prudent strategy.

5.4 Impact and clinical implications

Research on attrition and its mechanisms suggests that language, even a first language, is not resilient to decline or inaccessibility. Therefore, it is important to understand that if we are not using our first language regularly and are immersed in a second language environment, the latter gains strength in a way that interferes with later first language-use. Language skills are thus dynamic in nature and need to be maintained, possibly actively, if we wish to have access to them over the lifespan.

Although our L2-dominant participants were adults who arrived in the U.S. after mastering an L1, learning and maintaining languages are even more important for young children. If younger children are not given an L1 environment that can compete with their L2 immersion, L1 attrition can be expected over time. Thus bilingual education in languages that are available in the U.S. and private education in L1 are reliable techniques to prevent L1 attrition over time.

Not limited to the U.S. or India, in general, bilingual education does not only help a child maintain their L1, it also motivates the adults who teach in such schools and the parents whose children attend the classes, engage in L1 practices. This in turn creates more multilingual communities and raises the status of a first language of the immigrants in their L2-dominated environment. This increased multilingualism in a community of immigrants will then provide support for children in learning and maintaining the LI.

There are a few issues that surface in this project that can impact evaluation and treatment of clinical populations, especially bilingual aphasia in long-term immigrants. In terms of evaluation, it is important to understand the history of language-use in patients. If a patient performs better in one language than another, this can be due to natural inaccessibility of the unpracticed language over time, aphasia or both. Given that parallel language recovery in bilingual aphasia is so prevalent

(Paradis, 1977; Fabbro, 2001), information regarding language-use for all the languages both before and after the clinical event is important to have. In terms of the nature of language interactions in such patients, there is evidence that shows that persons with aphasia often mix their two (or more) languages to a greater degree than typical language-users **(**Muñoz, Marquardt & Copeland, 1999; Chengappa, Daniel & Bhat, 2004). Recently, Bhat (2010) reported that while the frequency of such mixing may be higher in these patients, especially with a monolingual interlocutor, they try to correct themselves and mix languages grammatically. While language mixing can be attributed to lack of cognitive control in individuals with aphasia, again, it can also stem from long-standing interactions of the languages they use and how those change over time, (especially after aphasia, when patients may be confined to a more monolingual home environment). In case bilingual communication is possible, in a bilingual community, patients and therapists may benefit from encouraging language mixing to enhance communication, rather than constraining patients to use just one language (Bhat, 2010). Lastly, the ERP data demonstrated that English words with high familiarity and Bengali words that have high familiarity English translations both showed relatively easy access compared to low familiarity words. This could suggest that highly familiar concepts in English facilitated access of the Bengali translations, even though the concepts are considered low familiarity by Bengali raters. If such spread of activation works in individuals with aphasia, it is worthwhile to investigate whether transfer of therapy from the trained language to the untrained language is possible for them (Goral, Levy, Obler & Cohen, 2006; Kiran & Roberts, 2010; Miertsch, Meisel & Isel 2009)

5.5 Future Directions

The current study has extended our knowledge of L1 attrition by addressing an existing controversy in the literature. Results indicated that L2 interference plays a greater role than L1-strength towards L1 attrition. In the following paragraphs we explore both the limitations of this study as well as the possible directions we can take this research in order to understand the mechanisms of L1 attrition in more detail.

One limitation of this study was the variability in L1 and L2 experience in conjunction with the relatively small groups of participants. We need to test larger numbers of participants and possibly more homogenous groups with greater difference between their L1 and L2 experience and proficiencies. Of course, the ideal way to understand L1 attrition would be to test participants longitudinally over a number of years in order to document their performance in L1 and L2 over this time frame. As a follow up to the current study it would be useful to test a group who is totally isolated from L1. Also, since language-use was reported as percentages of total language-use, it was difficult to interpret independent contributions of each language towards RT performance.

A second limitation was that this study was designed to examine lexical access from individual pictures, which takes lexical access out of natural language context. A more ecologically valid way to study lexical access, such as in codeswitching in conversation, would be a useful follow-up to this study. In addition, as it is well established now that codeswitching is a tool used in sophisticated bilingual conversation between two bilingual interlocutors, an important aspect to investigate in L1 attrition would be the nature of codeswitching in attriting bilinguals as compared to proficient non-attriting individuals. It would be interesting to investigate whether the attriting individuals show a tendency to codeswitch due to difficulty in L1 lexical access or for other reasons. A more naturalistic experiment would address both needs. A sentence-level stimulus set, or perhaps even discourse data, would permit us to simulate natural language situations, enabling us to test lexical access in such a context and codeswitching in attriting bilingual individuals.

Currently, the existing models in L1 attrition are limited to psycholinguistic models that are disconnected from theories of bilingualism. It is important to examine L1 attrition as part of the development and maintenance of bilingualism or multilingualism and incorporate these findings into a more comprehensive set of models that address the dynamic nature of bilingualism over the lifespan. We need to understand the neurolinguistic processes, such as activation and inhibition of traces, that underlie this dynamic nature of multilingualism, both over a small isolated frames of time (e.g., as bilingual individuals are engaged in conversation), as well as over extended periods of language-use. Coupling behavioral and neurophysiological methods in studying language enriches our understanding of brain-language relationships, helping us answer such questions better.

High English-Low Bengali		Low English-High Bengali		High English-High Bengali		Low English-Low Bengali		Comgruency /Fillers	
English	**Bengali**	**English**	**Bengali**	**English**	**Bengali**	**English**	**Bengali**	**English**	**Bengali**
airplane	*biman*	bucket	*balti*	book	*boi*	arrow	*teer*	apple	ak
baby	*shishu*	candle	*mombati*	bowl	*bati*	axe	*katari*	banana	bagh
barn	*golabari*	cauliflower	*phoolkopi*	boy	*chhele*	barrel	*pipa*	basket	bang
blanket	*kombol*	chilli	*lonka*	bread	*pauruti*	beetle	*gubre-poka*	bicycle	bash
boat	*nouko*	cloth	*kapor*	car	*gari*	butler	*khanshama*	bottle	bhoot
brain	*mostisko*	cockroach	*arshola*	chicken	*murgi*	cactus	*nagphoni*	butterfly	bhor
bubble	*boodbood*	coin	*poisha*	cucumber	*shosha*	camel	*uut*	caterpillar	chhooch
candy	*lojense*	crow	*kak*	dog	*kukur*	canon	*kaman*	cigar	deep
carrot	*gajor*	fish	*machh*	ear-ring	*kaner-dul*	cockatoo	*kakatua*	cigarette	dhoop
drum	*dhol*	ginger	*aada*	egg	*deem*	crab	*kakra*	deer	dosh
envelope	*kham*	gourd	*lau*	feet	*paa*	crane	*bok*	donkey	gachh
eye	*chokh*	heart	*ridoy*	girl	*meye*	crocodile	*kumeer*	elephant	geet
file	*ukha*	lamp	*hariken*	god	*bhogoban*	fig	*dumur*	football	ghash
finger	*angool*	mango	*aam*	hair	*chool*	fishing-net	*jal*	gorilla	glash
flower	*phool*	market	*baajaar*	hands	*hat*	flute	*bashi*	grasshopper	gof
glasses	*choshma*	notebook	*khata*	oil	*tel*	hippopotamus	*jolohosti*	guitar	hash
grapes	*angoor*	okra	*dharosh*	paper	*kagoj*	hot-air-balloon	*phanoosh*	hammer	jol
key	*chabi*	ponytail	*jhuti*	plate	*thala*	intestine	*naribhoori*	helicopter	khat
knife	*chhuri*	radish	*mulo*	potato	*aloo*	ostrich	*uut-pakhi*	kangaroo	khor
lock	*tala*	road	*rasta*	rain	*bristhti*	parrot	*tiya-pakhi*	ladder	kol
onion	*peyaj*	sari	*shari*	rice	*bhat*	pelican	*sharosh*	leopard	laj
orange	*komla-lebu*	schoolteacher	*mastarmoshai*	shirt	*jama*	porcupine	*shojaru*	monkey	lok
picture	*chhobi*	swan	*rajhash*	shop	*dokan*	porter	*kooli*	mountain	mosh
scarf	*roomal*	temple	*mondir*	sky	*akash*	rhinocerous	*gondar*	mushroom	nak
shoe	*juto*	utensils	*bashon*	spoon	*chamoch*	saw	*korat*	pencil	neem

High English-Low Bengali		Low English-High Bengali		High English-High Bengali		Low English-Low Bengali		Congruency /Fillers	
English	**Bengali**	**English**	**Bengali**	**English**	**Bengali**	**English**	**Bengali**	**English**	**Bengali**
socks	*moja*	wok	*korai*	teeth	*dat*	snail	*shamukh*	penguin	noy
squirrel	*kathbirali*			watch	*ghori*	spade	*kodal*	piano	paach
train	*relgari*					spider-web	*makorshar-jal*	pineapple	rong
umbrella	*chhata*					tortoise	*kochchhop*	pumpkin	shaat
						trumpet	*bheri*	refridgerator	shap
						tusk	*hatir-dat*	rooster	shing
						vine	*lota*	sandwich	tak
						wrestler	*kustigeer*	snowman	tash
								strawberry	teen
								suitcase	thot
								telephone	tool
								toaster	
								zebra	

Appendix II

Background Questionnaire

Please fill out the requested information to the best of your knowledge. Feel free to add any information you feel might be relevant using the back of the page if necessary.

The following questions regard general biographical information

Date:			**e-mail address:**	

Address:	

Telephone Numbers	Home		Work	

Date of Birth:				Gender:	

Birthplace		
	Town/City:	State/Country:

Years of education after high school		**Degrees Earned:**	

What is/are your first/native language/s?:	

What languages do you speak now?		
German		

What languages do you read in now?		
German		

What languages do you write in now?	English	French
German		

What language(s), if any, did you speak/understand as a child (before going to school) that you lost? Please report by what age you no longer were able to use that language.			
1. Language/Age		2. Language/Age	
2. Language/Age		4. Language/Age	
5. Language/Age		6. Language/Age	

List any languages you have been exposed to somewhat regularly but did not learn:			
Language		How often you heard it	
Language		How often you heard it	

Language		How often you heard it	
Language		How often you heard it	
Language		How often you heard it	

Do you like learning foreign languages?	

Do you feel you have particular difficulty learning foreign languages?	

Do you feel you have particular talent for learning foreign languages?	

Do you have a known history of difficulty with speech, language, reading, or learning in general? Is so please explain.

Which is your dominant hand (e.g., Which hand would you use to throw a ball, answer the phone, stir a pot?)

Please list the countries you have lived in, when you lived there and languages spoken

Country	Time there (gross estimates are fine)				What Language/s was/were spoken at home? (Please list)
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		
	From age		to age		

Please fill out the form as best you can for any that apply

Person	Birth Place	Person's Dominant Language	Please list other languages spoken in order of dominance. Begin with the most progressing to the least dominant	What language/s did this person use with you and to what extent? (Please indicate: always, sometimes, on occasion, rarely, or never)
Parent 1				
Parent 2				
Parent 3				
Sibling 1				
Sibling 2				
Sibling 3				
Gradparent1a				
Grandparent 1b				
Grandparent 2a				
Grandparent 2b				
Other (please specify)				
Other (please specify)				

***The following questions regard the languages you know. Please fill out a different form for each of the languages you speak. Indicate the language of focus in the box below. (This form was filled out each language that the participant has been exposed to).**

Language:	

Age began learning this language:	
Age began reading this language:	
Age began writing this language:	
Was this the language of primary school instruction?	
Please list the grades this language was the language of **<u>primary instruction</u>**. Include preschool through University and Graduate School where applicable.	
Please list year/months/grades of formal study if this language was studied as a subject at school and not the language of primary instruction.	
Do you feel you are proficient in this language? And if so, for how long?	

Please circle all that apply	Write Answer in this Column
Do you actively try to improve your skills in this language? Yes or No?	
How often do you work at improving your skills? Daily, weekly, monthly, other (Please Specify)?	
How do you improve your skills? Taling, reading, Watching TV/Movies, Self teaching via workbooks, CD Roms, etc. please specify?	

Please mark you answer here

How did you learn this language?	
a. at school where it was the primary language of instruction	
b. at school as a subject I elected to study . Please list Hrs./Week and number of years/months or semesters	
c. at home. This language was used __________ % of the time	
d. at an extracurricular course. Please list Hrs./Week and number of years/months	
e. in a country where spoken	
f. through relatives. Please state with **whom**, **how often**, and **how** :	

g. exposure in neighborhood. Please state with **whom**, **how often**, and **how** :	
h. via exposure to television. Please list Hrs./Week and number of years/months	
i. via exposure to radio. Please list Hrs./Week and number of years/months	
j. via exposure to books, newspapers. Please list Hrs./Week and number of years/months	
k. at religious services. Please list Hrs./Week and number of years/months	
l. In classroom devoted to all areas (e.g. conversation, grammar, translation etc., equally)	
m. In a conversation oriented classroom	
n. In a grammar oriented classroom	
o. In a translation oriented classroom	
p. Self-study (please specify):	
q. Other (please specify):	

Hours

***Please fill in the following grid to give an idea of where you are and what you do through the day. This will help give an idea of when, where, and in what way you use your languages.**

On a typical **week day** how many hours …	# of Hrs.	On a typical **weekend day** how many hours …	# of Hrs.
Are you at home		Are you at home	
Are you at work		Are you at work	
Do you watch TV		Do you watch TV	
Do you read		Do you read	
Do you write (emails, reports, etc.)		Do you write (emails, reports, etc.)	
Radio/Music		Radio/Music	
Other (please specify)		Other (please specify)	
Other (please specify)		Other (please specify)	

Percentages

***Please use the first three letters of each of your languages (for example: Spa = Spanish; Man = Mandarin) to fill in the approximate percentage of the time you use that language during the day for any of the area listed that apply.**

<u>For Example:</u> Sofia speaks English, Italian and French. At home she uses mostly English and then Italian. She does not typically use French at home. When she speaks with her husband she uses both Italian and English. When she speaks with her son she uses mostly English. When she speaks to her mother, who lives with her, she uses Italian with an occasional English vocabulary words or phrases.

Below is how Sofia filled out her chart:

A. % time spoken at home… (This row should add to 100%)	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	Fre			Ita				Eng			

***The next set of boxes regards <u>SPEAKING</u> in your various languages in different contexts (e.g., home, work, free time). Please remember to use all the languages you know. The boxes should add up to 100%.**

A. % time spoken at **<u>home</u>**… (This row should add to 100%)	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

B. % time spoken at **<u>school…</u>** (This row should add to 100%)	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

C. % time spoken at **<u>work…</u>** (This row should add to 100%)	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

D. % time spoken in **<u>free time</u>**…This row should add to 100%)	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

***The next set of boxes regards <u>LISTENING</u> in your various languages in different contexts (e.g., home, work). This means that you, yourself, are not physically speak the language but only hear it instead. Some examples may be attending religious services in a particular language or listing to music in a particular language. This could even be the case in conversation whereby one person regularly speaks one language while the other regularly answers in another (e.g., A mother generally speaking Spanish to her daughter, but her daughter generally answering in English).**

***Please remember to include all the languages you know when filling out these charts. All the rows should add up to 100%**

A. % time only listening to these languages at **home…**	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

B. % time only listening to these languages at **School…**	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

C. % time only listening to these languages at **work…**	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
D1. % time only listening to these languages in **overall free time…**										
D2. List % time across specific activities if possible										
D2a.tv/movies/video										
D2b. Religious Service										
D2c. Radio/Music										
D2d. Other (please specify)										
D2e. Other (please specify)										
D2f. Other (please specify)										
D2g. Other (please specify)										
D2h. Other (please specify)										
D2i. Other (please specify)										

***The following section regards <u>READING</u> in your various languages. Keep in mind that reading may include any print form such as newspapers, magazines, books, trade journals, email, web sites. etc.**
***Please remember to include all the languages you know when filling out these charts. All the rows should add up to 100%**

A. % time reading your languages at **<u>home/free time</u>**	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

B. % time reading your languages at **<u>work</u>**	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

C. % time reading your languages at **<u>school</u>**	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

D. % time reading your languages in **<u>other</u>** situations (please specify)	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

E. % time reading your languages in **other** situations (please specify)	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

Abilities

***Please write the initials for all of your languages in each row in the applicable column.**

Can you use this language:	Yes	Probably	Barely	No
a. To buy train tickets				
b. To read road signs				
c. To explain your job				
d. To make small talk				
e. To read the newspaper				

f. To discuss the news				
g. To discuss literature				
h. To read a classic novel				
i. To argue an opinion				
k.To perform your job				
l. For bachelor’s level study				
m. For master’s level study				
n. For doctoral level study				

Section 4: Ratings

***Please rate each of your language skills as best you can. Place an "X" in only number for each skill**

1. Language:

(please fill in the language you are rating here)

Overall Skill:						
1	2	3	4	5	6	7
limited knowledge						

Speaking Skills						
1	2	3	4	5	6	7
limited knowledge						

Listening Comprehension Skills						
1	2	3	4	5	6	7
limited knowledge						

Reading Skills						
1	2	3	4	5	6	7
limited knowledge						

Writing Skills						
1	2	3	4	5	6	7
limited knowledge						

VI. REFERENCES

Abunuwara, E. (1992). The structure of the trilingual lexicon. *European Journal of Cognitive Psychology, 4,* 311-322.

Albert, M. L., & Obler, L.K. (1978). *The Bilingual Brain: Neuropsychological and Neurolinguistic Aspects of Bilingualism*. New York: Academic Press.

Altenberg, E. P. (1991). Assessing first language vulnerability to attrition. In: H.W. Seliger & R.M. Vago, (Eds.), *First language attrition* (pp. 189-206). Cambridge: Cambridge University Press.

Ammerlaan, T. (1996). *You get a bit wobbly? Exploring bilingual lexical retrieval processes in the context of first language attrition*. Unpublished Doctoral Dissertation. Nijmegen: Katholieke Universiteit.

Anderson, J. E., & Holcomb, P. J. (1995). Auditory and visual semantic priming using different stimulus onset asynchronies: An event-related brain potential study. *Psychophysiology*, *32,* 177-190.

Ben Rafael, M (2001). *Contact de langues: le français parlé des francophones israéliens*. Unpublished Doctoral Dissertation. University of Tel Aviv.

Bentin, S., Kutas, M., & Hillyard, S. (1995). Semantic processing and memory for attended and unattended words in dichotic listening: Behavioral and electrophysiological evidence. *Journal of Experimental Psychology. Human Perception and Performance, 21,* 54-67.

Bhat, S. (2010). Effects of conversational contexts on language mixing in Kannada-English bilingual aphasics. Paper presented at *International Symposium of Bilingual Aphasia*, Mysore India.

Birdsong, D. (2004). Second language acquisition and ultimate attainment. In A. Davies & C. Elder (Eds.), *The Handbook of Applied Lingustics* (pp. 82-105). Oxford, UK: Blackwell.

Boyd, S. (1993). Attrition or expansion? Changes in the lexicon of Finnish and American adult bilinguals in Sweden. In K. Hyltenstam, & A. Viberg (Eds.), *Progression & regression in language* (pp. 386-411). New York: Cambridge University Press.

Brown, C. M., & Hagoort, P. (1993). The processing nature of the N400: Evidence from masked priming. *Journal of Cognitive Neuroscience, 5,* 34-44.

Chengappa, S., Daniel, K. E., & Bhat, S. (2004). Language mixing and switching in Malayalam-English bilingual aphasics. *Asia Pacific Disability Rehabilitation Journal, 15(2),* 68-76.

Chwilla, D.J., Kolk, H.H.J., & Mulder, G. (2000). Mediated priming in the lexical decision task: Evidence from Event-Related Potentials and Reaction Time. *Journal of Memory and Language, 42* (3), 314-341.

Collins, A. M., & Loftus, E. F. (1975). A spreading activation theory of semantic processing. *Psychological Review, 82*, 407-428.

Cook, V. J. (1997) Monolingual bias in second language acquisition research?, *Revista Canaria de Estudios Ingleses*, 34, 35-50.

De Bot, K., & Weltens, B. (1991). Recapitulation, regression and language loss. In H. W. Seliger, & R. M. Vago (Eds.), *First language attrition: Structural and theoretical perspective* (pp. 31-51). Cambridge: Cambridge University Press.

De Bot, K., Gommans, P., & Rossing, P. (1991). LI loss in an L2 environment: Dutch immigrants in France. In H. W. Seliger, & R. M. Vago (Eds.), *First language attrition: Structural and theoretical perspectives*. Cambridge: Cambridge University Press.

De Groot, A. M. B., & Hoeks, C. J. (1995). The development of bilingual memory: Evidence from word translation by trilinguals. *Language Learning, 45*, 683-724.

Deacon, D., Hewitt, S., Yang, C., & Nagata, M. (2000). Event-related potential indices of semantic priming using masked and unmasked words: evidence that the N400 does not reflect a post-lexical process. *Cognitive brain research, 9*, 137-146.

Delorme, A. & Makeig, S. 2004.EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics. *Journal of Neuroscience Methods, 134,* 9-21.

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review,* 93, 283–321.

Dell, G. S. (1990). Effects of frequency and vocabulary type on phonological speech errors. *Language and cognitive processes, 5,* 313 – 349.

Dijkstra, T., & van Hell, J. G. (2003). Testing the language mode hypothesis using trilinguals. *International Journal of Bilingual Education and Bilingualism, 6,* 2-16.

Dijkstra, T., & van Heuven, W. J. B. (1998). The BIAmodel and bilingual word recognition. In J. Grainger & A. Jacobs (eds.), *Localist connectionist approaches to human cognition*. New Jersey: LEA.

Ebbinghaus, (1885). ber das Ged chtnis. Untersuchungen zur experimentellen Psychologie. In Friederici, A. D., & Jacobsen, T. (1999). Processing of grammatical gender during language comprehension. *Journal of Psycholinguistic Research*, 28(5), 467–484.

Ecke, P. (1999). Lexical retrieval in a third language: Evidence from errors and tip of the tongue states. Paper presented at the International Conference on Third Language Acquisition and Trilingualism, Innsbruck, Austria.

Frenck-Mestre, C. (1993). Use of orthographic redundancies and word identification latency in bilinguals. *Journal of Psycholinguistic Research,* 22, 397-410

Goral, M. (2001). Lexical access and proficiency of trilingual speakers. Unpublished doctoral dissertation, The Graduate Center, City University of New York, New York, NY.

Goral, M. (2004). First language decline in healthy aging. *Journal of Neurolinguistics*. *17,* 31-52.

Goral, M., Levy E. S., Obler L. K., & Cohen E. (2006). Cross-language lexical connections in the mental lexicon: Evidence from a case of trilingual aphasia. *Brain and language, 98(2),* 235-247.

Goral, M., Libben, G., Obler, L. K., Jarema, G., & Ohayon, K. (2008). Lexical attrition in younger and older bilingual adults. *Clinical Linguistics & Phonetics*, *22,* 509-22.

Green, D. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism and Cognition*, *1*, 67-81.

Grodzinsky, Y. (2002). Neurolinguistics and neuroimaging: Forward to the future, or is it back? *Psychological Science*, *13(4),* 388–393.

Gürel, A. (2004). Selectivity in L2 induced L1 attrition: A psycholinguistic account.

Journal of Neurolinguistics. 17, 53-78

Holcomb, P. J., & Anderson, J. E. (1993). Cross-modal semantic priming: A time-course analysis using event-related brain potentials. *Language and Cognitive Processes, 8,* 379-411.

Holcomb, P. J., & Neville, H. J. (1990). Semantic priming in visual and auditory lexical decision: A between modality comparison. *Language and Cognitive Processes, 5,* 281-312.

Hutz, M (2003). Is there a natural process of decay? A longitudinal study of language attrition. In: M.S. Schmid, B. K pke, M. Keijser & L. Weilemar, (Eds.), *First language attrition: The next phase*. Proceedings of the international conference on first language attrition: interdisciplinary perspectives on methodological issues, John Benjamins, Amsterdam.

Jasper, K. & Kroon, S. (1992). From the typewriter of A.L.: A case study of language Loss. In: W. Fase, K. Jasper & S. Kroon, (Eds.), *Maintenance and loss of minority languages*, (pp. 137-147). Amsterdam: John Benjamins,

Jasper, K. & Kroon, S. (1989). Social determinants of language loss. *Review of Applied Linguistics (I.T.L.) 83/84*, 75-98.

Jescheniak, J. D., Schriefers, H., Garrett, M. F., & Friederici, A. (2002). Exploring the activation of semantic and phonological codes during speech planning with Event-Related Brain Potentials. *Journal of Cognitive Neuroscience, 14,* 951-964.

Jescheniak, J., D. & Levelt, W. (1994). Word frequency effects in speech production: Retrieval of Syntactic Information and of Phonological Form. *Journal of Experimental Psychology: Learning, Memory and Cognition, 20,* 824-843.

Kerkhofs, R., Dijkstra, A., Chwilla, D. & De Bruijn, E. (2006). Testing a model for bilingual semantic priming with interlingual homographs: RT and ERP effects. *Brain Research, 1068,* 170-183.

Kiefer, M. (2002). The N400 is modulated by unconsciously perceived masked words: Further evidence for a spreading activation account of N400 priming effects. *Cognitive Brain Research, 13,* 27-39.

Kiran, S. & Roberts, P. (2010). Semantic feature analysis treatment in Spanish–English and French–English bilingual aphasia. *Aphasiology*, *24(2)*, 231 – 261

Köpke, B. (1999). *L'attrition de la première langue chez le bilingue tardif: Implications por l'ètude psycholinguistique du bilinguisme*. Unpublished Doctoral Dissertation, Toulouse: Universite de Toulouse-Le Mirail.

Köpke, B. (2001). Quels changements linguistiques dans l'attrition de la L1 chez le bilingue tardif? *TRANEL*, *34/35*, 355-368.

Köpke, B. (2004). Neurolinguistic aspects of attrition. *Journal of Neurolinguistics*, *17*, 3-30.

Köpke, B. (2007). Language attrition at the crossroads of brain, mind and society. In B. Köpke, M. S. Schmid, M. Keijzer & S. Dostert (eds.), *Language Attrition*, (pp. 9–37).

Kroll, J. F. & Stewart, E. (1994). Category interference in translation and picture naming: Evidence of asymmetric connections between bilingual memory representations. *Journal of Memory and Language, 33*, 149-174.

Kroll, J. F., & Tokowicz, N. (2001). The development of conceptual representation for words in a second language. In J. L. Nicol (Ed.), *One Mind, two languages: Bilingual language processing* (pp. 49-71). Cambridge, MA: Blackwell Publishers.

Kutas, M. and Hillyard, S. A. Reading Senseless Sentences: Brain Potentials Reflect Semantic Incongruity. *Science*, *207*,203-205.

Kutas, M., & Hillyard, S., A. (1983). Event-related brain potentials to grammatical errors and semantic anomalies. *Memory and Cognition, 11*, 539-550.

Lachman, R., & Mister-Lachman, J. (1976). Dominance lexicale chez de bilingue. *Bulletin de*

Psycologie, 15, 281-288.

Lau, E.F., Poeppel, D., & Phillips, C. (2008). A cortical network for semantics: (de)constructing the N400. *Nature Reviews Neuroscience, 9,* 920-933.

Levelt, W. J. M ., Roelof S, A., & M eyer , A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22,* 1–75.

Levy, B., J. & Anderson, M., C. (2002). Inhibitory processes and the control of memory retrieval. *Trends in Cognitive Sciences, 6,* 299-302.

Loftus, E. F. (1980). *Memory: Surprising new insights into how we remember and why we forget*. Massachusetts: Addison-Wesley Publishing Co.

Mägiste, E. (1979). The competing language systems of the multilingual: A developmental study of Decoding and Encoding Processes. *Journal of Verbal Learning and Verbal Behavior, 18(1),* 79-89.

Major, R.C. (1992). Losing English as a first language. *The Modern Language Journal*. *76*, 190-208.

Mayer, M. 1969. *Frog, where are you?* New York: Dial Press

Miertsch, B., Meisel, J. M., & Isel, F. (2009). Non-treated languages in aphasia-therapy of polyglots benefit from improvement in the treated language. *Journal of Neurolinguistics*, *22*, 135-150.

Muñoz, M. L., Marquardt, T. P., & Copeland, G. (1999). A comparison of the codeswitching patterns of aphasic and nurologically normal bilingual speakers of English and Spanish. *Brain and Language, 66*, 249-274.

Newman, R., S. & German D., J. (2002). Effects of lexical factors on lexical access among typical language-learning children and children with word-finding difficulties. *Language and Speech*, *45*, 285-317.

Oldfield, R., C. & Wingfield, A. (1965). Response latencies in naming objects. The *Quarterly Journal of Experimental Psychology*, *17*, 273-281.

Olshtain, E., & Barzilay, M. (1991). Lexical retrieval difficulties in adult language attrition. In H. W. Seliger, & R. M. Vago (Eds.), *First language attrition* (pp. 139-150). Cambridge: Cambridge University Press.

Paradis, M. (1989). Bilingual and polyglot aphasia. In F. Boller, & J. Grafman (Eds.), *Handbook of neuropsychology*, (Vol. 2) (pp. 117–140). Amsterdam: Elsevier.

Paradis, (2001). An integrated neurolinguistic theory of bilingualism (1976-2000). *LACUS Forum* 2*7*, 5-15.

Paradis, M. (2004). *A neurolinguistic theory of bilingualism.* Amsterdam : John Benjamins.

Paradis M. (2007). L1 attrition features predicted by a neurolinguistic theory of bilingualism. In B. Köpke, M. S. Schmid, M. Keijzer & S. Dostert (eds.), *Language Attrition*, (pp. 9–37).

Pelc. L. (2001). Lexical, morphological and morphosyntactic attrition in Greek-English bilinguals. Unpublished doctoral dissertation, The Graduate Center, City University of New York, New York, NY.

Praamstra, P., & Stegeman, D. F. (1993). Phonological effects on the auditory N400. *Cognitive Brain Research, 1,* 73-86.

Praamstra, P., Meyer, A. S., & Levelt, W. J. M. (1994). Neurophysiological manifestations of phonological processing: Latency variation of a negative ERP component timelocked to phonological mismatch. *Journal of Cognitive Neuroscience, 6*, 204-219.

Pylkkänen, L., & Marantz, A. (2003). Tracking the time course of word recognition with MEG. *Trends in Cognitive Sciences*, *7,* 187-189.

Radeau, M., Besson, M., Fonteneau, E., & Castro, S. L. (1998). Semantic, repetition and rime priming between spoken words: Behavioral and electrophysiological evidence. *Biological Psychology*, *48,* 183-204.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition, 42,* 107-142.

Rugg, M. D. (1984). Event-related potentials in phonological matching tasks. *Brain and Language*, *23*, 225-240.

Rupela,V. (2010). Verbal fluencies in Telegu-English bilingual persons with dementia. Paper presented at *International Symposium of Bilingual Aphasia*, Mysore India.

Scherag, A., Demuth, L., Rosler, F., Neville, H., & Roder, B. (2004). The effects of late acquisition of L2 and the consequences of immigration on L1 for semantic and morpho-syntactic language aspects. *Cognition*. *93*, B97-B108.

Seliger H.W. & Vago. R.M..(1991). *First language attrition*, Cambridge University Press, Cambridge.

Shafer, V.L., Schwartz, R.G.,, &, Kessler, K.L (2004). ERP Indices of Phonological and Lexical Processing in Children with SLI. *Proceedings of the 28th Annual Boston University.* Conference on Language Development, Somerville, MA: Cascadilla Press, pp. 522-531.

Signorelli, T. (2007). *Working memory in simultaneous interpreters.* Unpublished Doctoral Dissertation, The Graduate Center, City University of New York, New York.

Snodgrass, J, G., & Vanderwart, M. (1980). *Journal of Experimental Psychology: Human Learning and Memory. 6(2),* 174-215.

Underwood, B.J (1957). Interference and forgetting. *Psychological Review 64*, 49-60.