Bilingualism and aging: Electrophysiological and behavioural measures of interlingual priming

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ABSTRACT

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The literature regarding the representation of a bilingual's two languages is inconsistent. Some studies suggest selective bilingual language access (i.e., preferential access to one language), while others find non-selective bilingual language access (i.e., both languages are initially accessed simultaneously). In addition, little is known about such representations in the older bilingual speaker. In monolinguals, an age-related slowing in semantic activation may result from an inhibition deficit, which may limit the ability of older adults to ignore irrelevant information. Consequently, they may rely more heavily on compensatory strategies (e.g., context). This implies that bilingual older adults may rely more heavily on language context than young adults. We examined bilingual language selectivity and processing using both event-related brain potentials (the N400) and response time measures in highly proficient bilingual young (18-35 years of age) and older (65-80 years of age) adults. Participants were presented with triplets of words consisting of a language context cue, an interlingual homograph (IH, i.e., a word with identical orthography but different meanings in two languages, e.g., COIN meaning 'corner' in French and 'money' in English), and a target, in a semantic priming paradigm. Language consistency between the cue and target were varied to investigate the effect of language context on the reading of an IH. Results from 10 young and 10 older participants suggest age-related differences in bilingual language processing.

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It is estimated that half of the world's population is bilingual (Fabbro, 1999), yet there is a limited amount of research that investigates language processing in these individuals. Furthermore, as a result of general improvements in life conditions, public health interventions and technological advances, the average life expectancy rate has increased by 20 to 25 years in the latter half of the 20th century, from 41 years in the early 1950s to 62 years in 1990 (Bourée, 2003; "Population Ageing", 1998; "Trends in Ageing", 2003). In 1998 there were an estimated 355 million people over the age of 60 living in developing countries and it is projected that there will be 1000 million by the year 2020 ("Population Ageing", 1998). Taken together these facts indicate that there is a large proportion of elderly, bilingual individuals living in our society and this number is continuing to increase. Statistics estimate that with respect to French and English (i.e., not including any other languages), in 2001, 13.4% of Canadian individuals over the age of 65 were bilingual, an increase of 0.6% since 1996 (Canadian Heritage, 2004). Language is our primary form of communication and thus supports social functioning and well-being, which is of increased importance in the aging population since social isolation and loneliness are important contributors to declines in physical and mental health (Hall & Havens, 2001; Ryan & Butler, 1996). This increases the importance of research in the area of language and bilingualism in the aging population, an area that, until now, has received very little attention.

The purpose of the present study is to examine bilingual language processing in young and older adults in order to identify age-related differences in the processing of a native language (L1) and a second language (L2), using both behavioural and electrophysiological measures. More specifically, this thesis examines age-related differences in the use of language context in the processing of lexically ambiguous words.

An overview of the relevant literature will begin with an explanation of semantic priming followed by a review of two prominent theories in the bilingualism literature. An introduction to event-related brain potentials and their use in semantic priming paradigms will follow. Interlingual homographs used in the study of lexical ambiguity in bilinguals, aging and the inhibition deficit hypothesis, as well as studies of lexical ambiguity in aging will then be considered. This section will conclude with a discussion of the present study.

Semantic priming

Studies investigating bilingual language access have often used semantic priming paradigms with variations in the types of primes and targets employed. Semantic priming refers to the facilitation of the processing of a word (the target) when it has been preceded by a related word (the prime) rather than an unrelated word. For example, the word 'cat' is more easily processed when preceded by the word 'dog' than when preceded by the word 'table'. Behavioural semantic priming effects are robust and are reflected in faster response times (RT) and greater accuracy for semantically related prime-target pairs than for semantically unrelated or neutral prime-target pairs (e.g., Neely, 1977, 1991). These semantic priming effects have been extended to bilinguals with French and English as an L1 (Favreau & Segalowitz, 1983).

Two of the common explanations that account for semantic priming effects include automatic spreading of activation and expectancy (Neely, 1991). According to automatic spreading of activation, semantically related nodes are strongly linked and therefore the activation of one node (e.g., the prime) rapidly spreads to semantically related nodes (e.g., the target). This spread of activation accounts for the facilitation (i.e., faster RT and greater accuracy) observed when a prime and a target are strongly related and decreases as the degree of relatedness between the prime and the target decreases. Furthermore, as the name implies, the automatic spreading of activation occurs without an individual's awareness and is fast acting. The expectancy-based mechanism, on the other hand, is slow acting and requires the individual's intention or awareness. This explains semantic priming effects in terms of an expectancy set that is generated by the individual, from the prime, comprised of potential related target words which are recognized more rapidly than words not contained in the expectancy set. Automatic spread of activation operates at short stimulus onset asynchronies (SOAs; e.g., 200 ms), whereas the expectancy based mechanism functions at longer SOAs (e.g., greater than 500 ms).

Language access in bilingualism

Presently, the available literature provides inconsistent results regarding whether a bilingual's two languages are accessed simultaneously or whether there is preferential access to one language over the other. Some studies provide evidence that a bilingual's access to language is non-selective (Beauvillain & Grainger, 1987; de Bruijn, Dijkstra, Chwilla & Schriefers, 2001) such that both languages are accessed concurrently. Conversely, other research provides evidence that a bilingual's two languages are processed separately (Keatley, Spinks & de Gelder, 1994; Kroll & Stewart, 1994) with greater and more rapid activation of a native language.

Two of the prominent theories regarding the organization of a bilingual individual's lexical memory representations are the revised hierarchical model (RHM; Kroll & Stewart, 1994) and the bilingual interactive activation model (BIA; Dijkstra & van Heuven, 2002). The RHM supports separate processing of a bilingual's two languages and describes bilingual memory in terms of lexical and conceptual links between an L1 and an L2. It proposes that there are both lexical (i.e., word form) and conceptual (i.e., concepts) links in each language, but the strength of these links is greater in L1 (see Figure 1). More specifically, Kroll and Stewart postulate that there are links between words in L1 and L2, which are stored in separate lexical memory systems, and there is a common conceptual memory system that is shared by both languages. The strength of the links between words in L1 and L2, and between words and concepts in L2, depends on L2 fluency as well as the relative dominance of L1 to L2. In Figure 1, L1 is represented as being larger because it is assumed that individuals know more words in their L1 than in their L2 and lexical associations are represented as being stronger from L2 to L1 than from L1 to L2 because this is the direction in which an individual initially acquires new L2 words. Accordingly, access to words and concepts occurs more easily and quickly in L1 than in L2. However, the strength of conceptual links in L2 differs with respect to fluency and the relative dominance of L1 to L2 such that as fluency increases, and relative L1 dominance decreases, the strength of L2 conceptual links also increase. Furthermore, the model proposes that lexical connections are stronger from L2 to L1 than from L1 to L2, thus allowing for more rapid translation from L2 to L1 than vice versa.

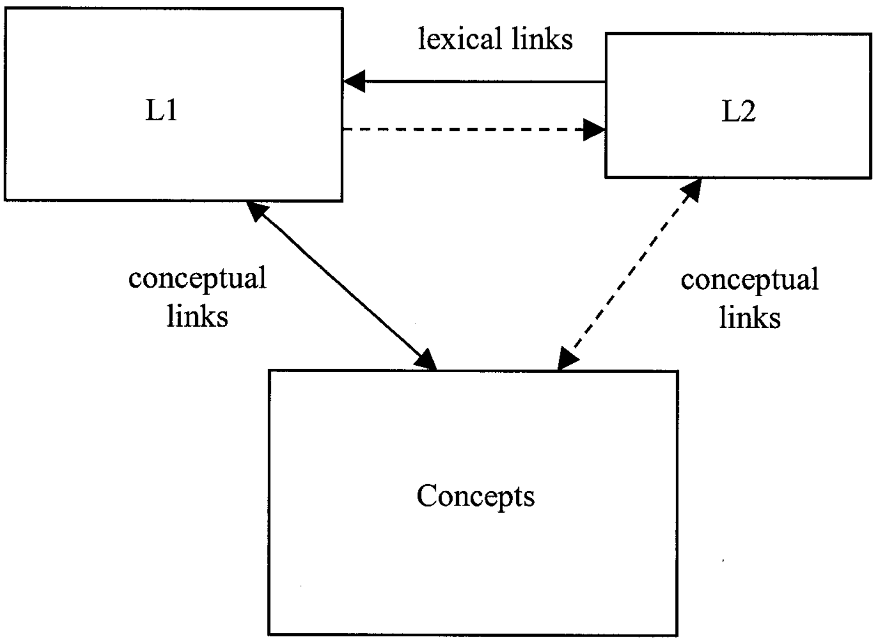

Figure 1. Kroll and Stewart's (1994) revised hierarchical model.

Kroll and Stewart found support for their model from translation and picture naming tasks where they found that fluent, although unbalanced bilinguals, were in fact faster at translating from their L2 to their L1 as would be expected if they were accessing lexical-level language connections in their L2.

Several experiments conducted by Keatley, Spinks and de Gelder (1994) found support for the RHM. They found, in two experiments, that a word in one language was capable of priming a target word in the other language provided that the prime was in the participant's L1 and the target word was in their L2. In their third experiment, using translation equivalents, Keatley et al. found priming in both L1 to L2 and L2 to L1 directions. However, the priming was asymmetrical such that there was greater priming when the prime was in the participant's L1 and the target was in their L2 (L1 to L2 condition). This was taken as evidence in support of the hypothesis that L1 representations have stronger and richer representations both within and across the separate language memory systems, which is in agreement with the revised hierarchical model.

The BIA model (Dijkstra & van Heuven, 2002), on the other hand, describes the recognition of orthographic representations in two languages in terms of an interactive language system (see Figure 2) rather than a separate system for each language. More specifically, the model proposes that there is a single, integrated, system containing separate language nodes. According to this model, when a string of letters is presented to the system, the particular features of each letter causes excitation, at the letter level, in letters that contain the corresponding features, and inhibits letters that do not. The activated letters then cause excitation of words, in both of the bilingual's two lexicons,

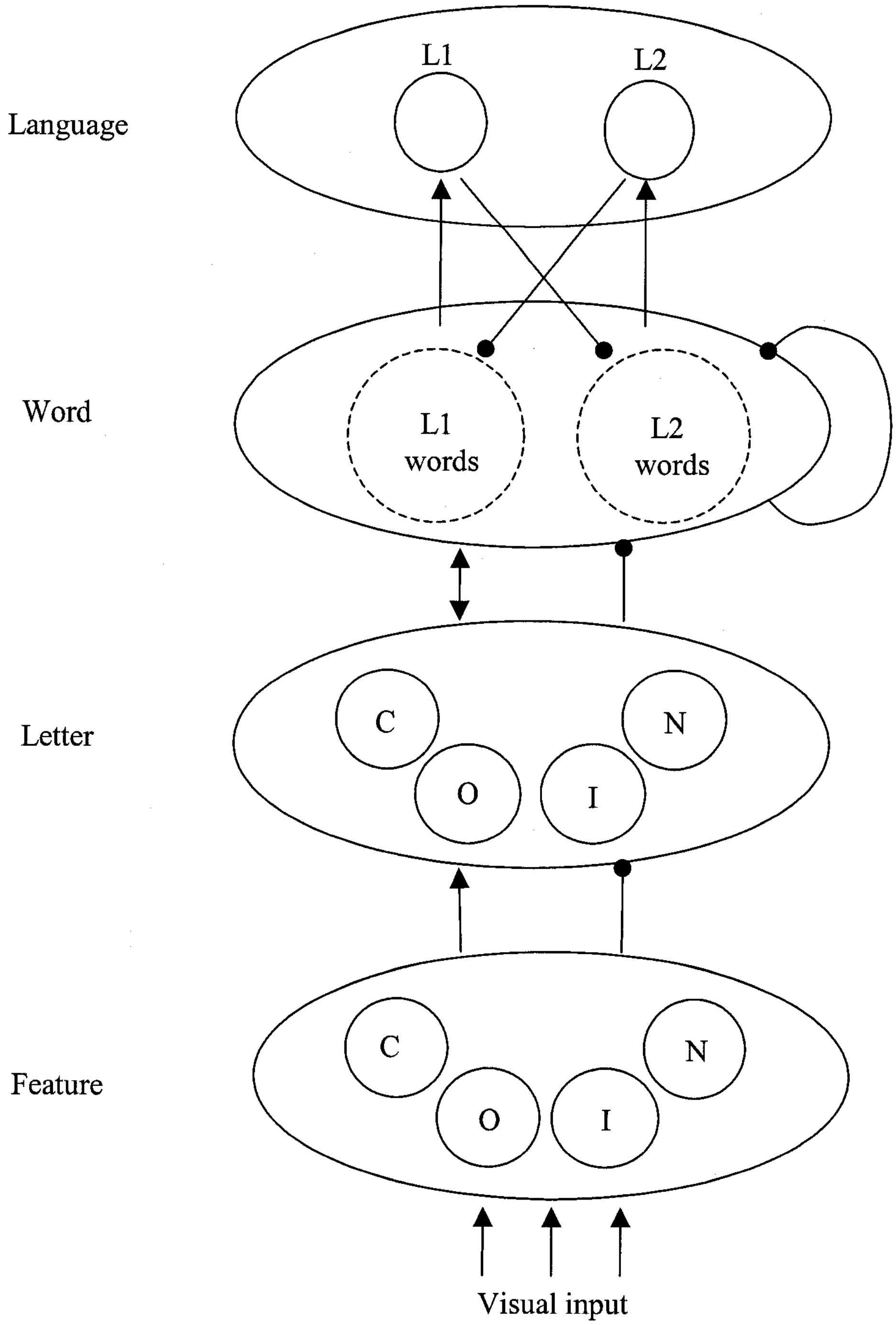

Figure 2. The Bilingual Interactive Activation (BIA) model for bilingual word recognition (adapted from Dijkstra & van Heuven, 2002). Arrow heads represent excitatory connections and black filled circles represent inhibitory connections.

that contain the activated letters in the correct position and all other words are inhibited. At the level of the word, all words cause inhibition of other words regardless of language. Activated word nodes from each language then cause excitation in the corresponding language node and activated language nodes send inhibitory feedback to word nodes in the other language, thus the language nodes receive activation from word nodes in their corresponding language and inhibit word nodes in the other language. The activity in each lexicon is therefore represented by activation in the language nodes. This model was first proposed in 1998 and has since been modified, now called the BIA+ model. The BIA+ model considers the interaction between the word identification system and higher order systems, however, Dijkstra and van Heuven conclude that more evidence about IH representations is needed in order to apply them in this model, therefore we will adhere to the original BIA model.

Further support for a language non-selective account of bilingual lexical access comes from bilingual Stroop experiments. Stroop interference refers to the increase in RT observed when individuals are asked to name the colour of the print of incongruent colour words (e.g., the word 'red' printed in blue ink) relative to their RT for naming colours (Stroop, 1935). In a bilingual Stroop paradigm the individual is presented with colour words in one language printed in incongruent colours and asked to name the colour of the print in their other language. Using such a paradigm Preston and Lambert (1969) found comparable interlingual and intralingual Stroop interference providing evidence that the activation of one language system does not, in fact, inhibit the other language system and that activation of the unattended language is occurring automatically. In a similar bilingual Stroop experiment Tzelgov, Henik, and Leiser

(1990) manipulated the expectancy of the language of the written word by having a disproportionate number of items in each language (i.e., 80% in one language and 20% in the other) and found that interlingual interference persisted. Zied et al. (2004) also found equivalent intra- and inter-lingual interference effects for balanced bilinguals using a bilingual version of the Stroop task.

Event-related brain potentials and semantic priming

Semantic priming can also be measured electrophysiologically using ERPs which are extracted from the electroencephalogram (EEG), an ongoing measure of electrical brain activity. ERPs are associated with specific cognitive processes, thus reflecting the activity of a particular population of neurons in response to a stimulus. The N400 component is a negative deflection of the brain wave approximately 400 ms post-stimulus (Kutas & Van Petten, 1994), although its latency varies, as does its amplitude, which are believed to reflect the timing and strength of the underlying psychological processes (Rugg & Coles, 1995). The negativity of the N400 increases as the mismatch between a current stimulus and an expected stimulus increases and is a valuable tool for studying language since it allows for an on-line measure of cognitive processing (see Kutas & Federmeier, 2000). The N400 priming effect refers to the greater negativity observed when a target is unrelated to the prime and is inversely related to the degree of association between the prime and target.

The studies described above used RT to measure L1 and L2 word recognition. More recently, however, it has been suggested that RT may not be ideal for measuring the underlying processes involved in bilingual word recognition (Kotz, 2001). Kotz found different RT and ERP priming effects suggesting that these two measures are sensitive to, or measure, different underlying processes involved in semantic priming. Since event-related brain potentials (ERPs) are capable of measuring on-line cognitive processes as they unfold and, due to their high temporal resolution, on the order of milliseconds, the argument is that they permit a more accurate assessment of bilingual word recognition than RTs alone.

Using both RT and ERP measures Kotz (2001) investigated L1 and L2 semantic priming in early fluent bilinguals (i.e., all participants had started to acquire their L2 before the age of four). It was found that semantic priming occurred in both L1 and L2, and furthermore, the results demonstrated that RT and ERP measures may monitor different cognitive processes. With regard to behavioural semantic priming effects, only associative priming (e.g., HOT - DOG) was found, whereas the N400 was sensitive to both associative and categorical priming (e.g., CAT - DOG). The similar priming observed L1 and L2 does not provide support for the revised hierarchical model (Kroll & Stewart, 1994) and suggests a more balanced representation of the two lexicons in the bilingual brain.

Interlingual homographs

Although within-language and cross-language semantic priming studies provide insight into the possible similarities or differences in a bilingual's access to memory representations in each of their languages they provide little information with regard to whether a bilingual exhibits selective or non-selective language access in a lexically ambiguous situation. A greater comprehension of bilingual language representation in the brain is crucial for the successful understanding of communication in the young bilingual, as well as the changes which occur as a result of healthy aging. Further research into bilingual language representation will also inform researchers about neural pathologies which may lead to communication breakdowns.

A convenient way to explore language selectivity is through the use of interlingual homographs (IHs; e.g., words with identical orthography in two languages, but with distinct semantic features, e.g., COIN meaning 'money' in English and 'corner' in French). Using IHs in a semantic priming paradigm allows one to establish whether individuals show preferential access to one meaning of the lexically ambiguous word (e.g., preferential access to the L1 meaning, as would be predicted by the revised hierarchical model (Kroll & Stewart, 1994)), or whether there is simultaneous activation of both meanings, suggesting a language non-selective account of bilingual memory. This is accomplished by pairing an IH with a target word related to each meaning of the IH and measuring differences in observed semantic priming effects when the target is in an individual's L1 versus when it is in their L2. More specifically, if only one meaning of the IH is accessed semantic priming should only occur in response to that meaning. Furthermore, using IHs one can also investigate how context influences individuals in lexically ambiguous situations.

In two studies conducted by Beauvillain and Grainger (1987) self-reportedly French/English bilingual participants were presented with pairs of letter strings. In the first experiment L1 English-speaking participants were informed that the first letter string in each pair was a French word and they were asked to decide whether or not the second letter string was an English word. In approximately one-fifth of trials the first letter string (i.e., the prime) was an IH and the researchers assumed that telling participants that the first letter string was a French word would bias their reading of the IH towards the French meaning. Results showed that, despite this manipulation, the IH primed a target word in English, as well as in French, indicating that initially both meanings of the IH were accessed. The stimulus onset asynchrony (SOA) was also manipulated such that the prime word remained on the screen for either 100 or 700 ms. It was found that, for English targets, priming effects were only observed in the 100 ms SOA condition demonstrating that initially there is language non-selective access to IHs. However, at long SOAs there is language selection suggesting that with enough time individuals inhibit the inappropriate meaning of the IH, and only the appropriate meaning remains activated. In a second experiment, Beauvillain and Grainger manipulated the reading of the prime (i.e., there were conditions where the IH prime was biased towards its reading in either of the participant's languages). It was found that, using an SOA of 150 ms, there was non-selective access to both meanings of the IH regardless of whether the bias was towards the participants L1 or L2, demonstrating that the previously observed non-selective access was language-independent.

De Groot, Delmaar, and Lupker (2000) found further evidence of language non-selective access using IHs. They conducted three experiments in which task-demands allowed them to manipulate the activation of bilingual memory systems. In the first experiment, they used a translation recognition task which necessarily requires the participant to activate both of their lexicons. In this task participants were presented with word pairs, one word in each language, and asked if the words were translation equivalents of each other. If both of the lexicons are in fact activated then the introduction of an IH should, theoretically, increase RT and/or error rate. For example, if the IH 'glad', meaning 'slippery' in Dutch, is paired with the English translation (i.e., 'slippery') then the English meaning of 'glad' should interfere with correctly responding that the two are translation equivalents. Both RT and error rate indicated that both meanings of the IH were activated and that activation of the 'inappropriate' meaning caused interference in responding (i.e., slower RT and increased number of errors). Furthermore a position effect was found, such that the interference caused by an IH was smaller when the IH appeared in the second position, that is, when it was preceded by a non-homographic first word, suggesting that the non-homographic first word biased the reading of the IH towards the target language. In the second and third experiments de Groot et al. used a lexical decision task (LDT) and participants were asked to categorize letter strings as words or non-words. The results confirmed those from experiment 1, showing that bilingual lexical access is initially non-selective.

De Bruijn, Dijkstra, Chwilla and Schriefers (2001) also found evidence of non-selective language access using a language context cue designed to bias the reading of an IH towards one reading. The purpose of their experiment was to determine the extent to which a surrounding language context modulates access to one semantic representation of an IH over the other. Participants were native speakers of Dutch who were fluent in English. The critical stimuli were 104 word triplets comprised of a language context cue, an IH prime, and a target. The context cues were high frequency Dutch or English non-homographic words and were designed to bias the reading of the IHs towards the language of the context cue. The IH served as the prime and was followed by a target word that was either related or unrelated to the English (L2) meaning of the IH. The context cue and the IH were presented to the participant simultaneously, immediately followed by the target word, and both RT and ERPs were recorded. The results were consistent with those of Beauvillain and Grainger (1987) in that both meanings of the IH were accessed. Regardless of the biasing context provided by the language cue, both RT and ERP measures demonstrated facilitation of the processing of a target word that was related to the IH, that is, an incompatible language cue was not sufficient to suppress the activation of the meaning of an IH in the non-target language. De Bruijn et al. interpret their results as support for the BIA model. According to the BIA model IHs are represented twice within the system, once in each of the lexicons, and the resting level of activation for each representation depends on the frequency of occurrence of the IH in the corresponding language.

The BIA model has also been supported by studies investigating the effects of context on the processing of spoken homophones (Li & Yip, 1998) as well as the role of phonology on the recognition of IHs (Dijkstra, Grainger & van Heuven, 1999).

It is apparent from this review that the question of whether bilingual language access is selective or non-selective requires further investigation, as does the question of how context affects access to the bilingual's lexicon(s). Furthermore, it is noteworthy that all of the studies discussed were limited to young adults.

Aging and the inhibition deficit hypothesis

The available aging literature suggests that there are age-related declines in both sensory and cognitive functions that cause increased difficulty in language comprehension in the older adult (Wingfield & Stine-Morrow, 2000). Despite the interaction between sensory and cognitive declines in aging the present investigation focuses on age-related declines in cognitive processing, in particular on age-related slowing in semantic activation or processing.

Hasher and Zacks (1988) propose that this age-related slowing in semantic activation or processing is the result of an inhibition deficit present in older adults. More specifically, the inhibition deficit hypothesis (IDH; Hasher & Zacks) proposes that the inefficiency of inhibitory mechanisms in older adults allows more irrelevant information to enter working memory (i.e., a limited-capacity cognitive system that temporarily retains recent information and allows for its manipulation (Craik & Jennings, 1992)) and receive more sustained activation than it otherwise would. Ultimately, this inhibition deficit would lead to impaired functioning in the older adult if there were no compensatory strategy available for them to reduce the amount of irrelevant information entering working memory. Hasher and Zacks propose that the compensatory strategies that permit these individuals to preserve functioning include reliance on: (1) information that is easily accessed from memory and (2) information that is in the surrounding environment. Information in the surrounding environment includes contextual information, thus the model suggests that the older adult will rely on context to a greater extent than young adults, when confronted with competing information. Evidence to support the IDH comes from studies showing that older adults make greater use of context in semantic priming tasks (Cohen & Faulkner, 1983), and show increased semantic priming than young adults (Paul, 1996; Shaw, 1991).

Shaw (1991) provided evidence of increased automatic semantic priming in older adults using a modified flanker paradigm. Participants were presented with a target word belonging to one of two semantic categories (metal or furniture) and had to identify the category to which the target belonged. The target word was presented between two identical distractor or 'flanker' words that could be: neutral (i.e., a non-metal, nonfurniture word); the same word where the target and flanker were the same word; the same category (i.e., the target and flanker were different words from the same category) or; a different word (i.e., the target and flanker were words from different categories). The results provided support for the IDH (Hasher & Zacks, 1988) since older adults showed a greater flanker effect (i.e., longer RT for targets when the flanker was from a different category than when it was from the same category) suggesting that the older adults were less able to inhibit the irrelevant semantic information than the young adults.

Paul (1996) also found greater semantic priming effect in older adults relative to younger adults. Younger and older participants were presented with sentences (e.g., It hung from the beam) that were followed by a high salient (e.g., support), low salient (e.g., above) or unrelated (e.g., quack) target word, and were asked to name the target word as quickly as possible. Results demonstrated facilitation (i.e., faster RT for related versus unrelated targets) for both the young and older groups when the target was highly salient. When the target was a low salient word, however, both groups showed facilitation at short SOAs, whereas, at longer SOAs facilitation only persisted in the older group. This was interpreted as support for the IDH (Hasher & Zacks, 1988) since older adults demonstrated sustained activation of irrelevant information relative to young adults. That is, both groups showed facilitation to low salient words at short SOAs, suggesting initial activation of this low-salient information, however the young group appeared to inhibit this information over time, whereas in the older adults it remains activated.

Cohen and Faulkner (1983) found evidence of contextual facilitation in older participants, relative to young participants, when context was provided by a sentence. Participants were visually presented with sentences in a LDT such that the terminal word could be of high or low predictability and half of the sentences ended with a non-word. As a 'no context' control condition, participants were presented with a series of Xs, mimicking a sentence, followed by a single word. The same words that were used as final words in the sentences comprising the 'context' condition were used for the control condition, e.g.,

THE DOG CAME RUNNING AND WAGGING ITS
TAIL -context condition
XXX XXXX XXXXXXX XXX XXXXXXX XXX
TAIL -no context condition

Their results showed similar contextual facilitation (i.e., faster RT for terminal words in the context condition than for the same words in the no context condition) for both the young and the older groups for high predictability terminal words. When the terminal words were of low predictability the older participants showed significantly greater contextual facilitation than young adults demonstrating that the older adults were using the context to a greater extent than the young adults.

Support for the IDH (Hasher & Zacks, 1988) has also been obtained using ERP measures of the use of sentence context in older adults. Cameli and Phillips (2000) presented younger and older participants with sentences that varied in the degree of relatedness of the terminal word to the sentence context such that the terminal word was the best completion (e.g., The paint turned out to be the wrong *colour*), a word semantically related to the best completion (e.g., The paint turned out to be the wrong *shade*) or a word semantically unrelated to the best completion (e.g., The paint turned out to be the wrong *consistency*). Participants were also presented with word pairs, in a semantic priming paradigm, derived from the terminal words of the sentences such that words that were the best completion of the sentence were preceded by the word most highly related to it, and both the semantically related and unrelated terminal words were preceded by the best completion sentence ending (e.g., colour – shade and colour – consistency, respectively). Their results demonstrated similar N400 amplitudes for all types of sentence terminal words for the older adults whereas the young adults showed an amplitude gradient such that the N400 was largest for semantically unrelated sentence endings, smaller for semantically related sentence endings and smallest for the best completion ending, as would be expected if they were making use of the sentence context. This N400 amplitude gradient was shown in both the young and the older participants for the word pairs, although for the older group the amplitude difference was only significant between targets in the unrelated and best completion conditions. These results were taken as evidence for the IDH (Hasher & Zacks) since older adults failed to benefit from a preceding sentence context, demonstrating that they were activating irrelevant semantic information rather than inhibiting it. This interpretation stems from the fact that differences between the sentence terminal words were subtle, supporting the possibility that all words were primed by the sentence context in older adults whereas less likely sentence endings were inhibited in the young group.

Federmeier and Kutas (2005) found that older adults were not able to make use of the context provided by a preceding sentence. In their investigation young and older adults were presented with sentences such that the terminal word was of high or low predictability, however, for both the conditions the terminal words were the same and it was the sentence context that differed (e.g., No one at the reunion recognized Dan because he had grown a *beard* (high predictability) vs. At the children's park next to the beach she saw a man with a *beard* (low predictability)). Their results demonstrated similar mean N400 amplitude responses for the young and older groups when the terminal word was of low predictability whereas when the terminal words were of high predictability the young adults showed greater facilitation (smaller N400 amplitudes) than the older adults. Since both groups showed similar responses to low predictability terminal words but not high predictability words the authors interpret the results as demonstrating an inability of older adults to use the constraints of a sentence context.

Lexical ambiguity and aging

Several studies have investigated lexical ambiguity in aging using monolingual homographs (i.e., words with identical orthography but multiple meanings with in a single language (e.g., 'bank', which can mean a financial institution or the edge of a river)).

Using a naming paradigm Hopkins, Kellas and Paul (1995) investigated word meaning activation in response to monolingual homographs (subsequently referred to as homographs) in young and older adults. Participants were presented with sentences that were followed by a target word and they were asked to name the target word as quickly as possibly. Each of the sentences terminated with a homograph and for each homograph there were two corresponding sentence contexts, one that biased the reading of the homograph towards the more frequent reading (dominant; e.g., She received the *letter*) and one that biased it towards the less frequent reading (subordinate; e.g., The boy learned a new *letter*). Furthermore, the target words could be related and of high saliency (e.g., note/alphabet) or low saliency (e.g., address/school) or unrelated to each of the readings of the homograph. Hopkins et al. hypothesized that if older adults were not as efficient as young adults in using a sentence context in order to activate the contextually appropriate meaning of the homograph then their working memory would become overloaded and they would only show facilitation for high saliency targets. Results showed that both young and older adults showed facilitation for contextually appropriate targets relative to unrelated controls. Furthermore, these results were found for both high and low saliency targets for both age groups. Hopkins et al. interpret these results as providing support for a spared language-processing system with aging. In terms of the IDH (Hasher & Zacks, 1988) inhibition serves two functions: 1-to prevent irrelevant information from entering working memory and; 2-to reduce the activation of irrelevant information in working memory. Hopkins et al. remark that their experiment only examined the first function of inhibition and, although their results suggest that there is no inhibition deficit evident in aging, further research investigating the second function of inhibition is needed to establish the validity of the IDH (Hasher & Zacks).

In two experiments Paul (1996) further examined age-related differences in the processing of lexically ambiguous words. In the first experiment, described earlier, young and older adults were presented with sentences terminating with a homograph (e.g., It hung from the *beam*) followed by high salient (e.g., support), low salient (e.g., above) and unrelated target words in a naming paradigm similar to that used by Hopkins et al. (1995). The interstimulus interval (ISI; i.e., the time interval between the last word of the sentence and the presentation of the target) was also manipulated in order to investigate age-related differences in the time course of activation of irrelevant information. It was hypothesized that if aging is accompanied by an inhibition deficit then both younger and older adults will show initial facilitation of high and low salient targets, whereas, at longer ISIs the younger adults will inhibit the low salient information and only show facilitation for the high salient targets. The older adults, on the other hand, will show an inability to inhibit the previously activated low salient information (i.e., the second function of inhibition), and will thus continue to show facilitation of both high and low salient target words at long ISIs. Paul's results confirmed this hypothesis providing support for an inhibition deficit in older adults, causing them to experience sustained activation of irrelevant information.

In his second experiment Paul (1996) presented younger and older adults with sentences containing a homograph early in the sentence. Following the homograph half of the sentences ended with a context biasing the reading of the homograph towards the dominant reading (e.g., The *bark* frightened away the prowler) and the other half ended with information biasing the reading towards the subordinate reading (e.g., The *bark* felt rough against his skin). The sentences were then followed by target words that were related to the dominant reading (e.g., growl) or the subordinate reading (e.g., tree) of the homograph or were unrelated to the homograph. Results showed facilitation for contextually appropriate targets, regardless of meaning dominance, but not for inappropriate targets, for both age groups. This demonstrated the successful use of context in a lexically ambiguous situation in older adults, contrary to what had been concluded from the results of his first experiment, and thus not in support of the IDH (Hasher & Zacks, 1988).

The present study

The literature reviewed here raises questions with regard to how a bilingual's two languages are represented in memory as well as how contextual factors may be used differentially by young and older adults to process lexically ambiguous words. To our knowledge research has yet to investigate age-related differences in the use of language context in the resolution of lexical ambiguity in bilingual situations. Using a semantic priming LDT the present study assesses the effects of aging, context, and language on interlingual priming. Two groups of participants, young and older, were presented with triplets of letter strings and asked to decide whether all three were real words in French or English or whether there was at least a single non-word present. Critical triplets consisted of a language context cue (i.e., a high frequency French or English word); a prime (a French/English IH in two-thirds of cases) and; a semantically related or unrelated target word. In addition, the design was such that both the effects of an L1 context on an L2 target and the effects of an L2 context on an L1 target were examined.

The electrophysiological measure we used is the N400 component of the ERP. Using French/English IH in a semantic priming paradigm it is possible to determine which of the two meanings of the IH is activated, and whether this is affected by a preceding context. Recall that N400 amplitude difference is inversely related to the degree of semantic relatedness between a prime-target word pair. Following this logic, if only one meaning of an IH is activated then a large N400 would be expected in response to a target word related to the other language meaning. However, if both meanings are simultaneously activated then there should be no difference in the N400 amplitude resulting from a target word related to either meaning. For example, if the word COIN (meaning 'money' in English and 'corner' in French) precedes the word MONEY a small N400 would be expected if COIN is processed in English or in English and French simultaneously, whereas a large N400 is expected if it is processed solely in French since there is no semantic relationship between COIN ('corner') and MONEY.

Furthermore, we measured RT and accuracy to determine whether there were differences in behavioural priming effects observed for IHs. Depending on which meaning of an IH is accessed one would expect to see differential semantic priming effects similar to those described for the N400. Specifically, if only one language meaning of the IH is activated then semantic priming should only be observed in conditions where the target word is related to that meaning, conversely, if both meanings are simultaneously activated then there should be similar semantic priming for target words related to either meaning of the IH.

Following the IDH (Hasher & Zacks, 1988) it is hypothesized that the older adults will make greater use of the language contextual cue and will show a greater priming effect, to the extent that the target is consistent with the language cue, than the young group, where previous research has found no evidence of context effects in young adults (de Bruijn et al., 2001). A second hypothesis is that, in accordance with the revised hierarchical model (Kroll& Stewart, 1994), participants will show poorer performance in their L2 relative to their L1, demonstrated by slower RTs and increased error rate, due to stronger conceptual links in their L1 leading to easier and faster access to the meaning of the words in their L1.

Method

Participants

Thirteen French/English bilingual young adults were tested but 3 were excluded based on their results from an animacy judgement task which indicated that they were not equally proficient in their L1 and L2. The final sample was comprised of 10 individuals (6 males and 4 females), between the ages of 19 and 35, recruited from a participation pool, as well as posted advertisements, at Concordia University, Montréal, Québec, Canada. The sample of older adults consisted of 10 individuals (4 males and 6 females) between the ages of 65 and 81 recruited from databases within the Cognitive Psychophysiology and the Psychology Aging Research Laboratories at Concordia University. Participants recruited from the participation pool received course credit for their participation; all other participants were paid $10 CDN per hour of participation.

All participants were screened using a self-report health and language questionnaire (see Appendix A) that was administered in a telephone interview prior to testing. Inclusion criteria for all participants included comparable proficiency in French and English measured using self-report as well as an animacy judgement task, self-reported good health, and no prior history of heart disease, alcohol abuse, heavy tobacco usage, head injury, medical illness, or chronic use of medication which might affect cognitive functioning. Since the neural mechanisms underlying language processing in bilinguals is yet to be fully understood (Abutalebi, Cappa, & Perani, 2001) participants did not have knowledge of any languages other than French and English in order to reduce any possible confounds that may have been introduced by including multilinguals. Six young and four older participants had English as their L1, while four young and six older participants had French as their L1. The animacy judgment task provided an objective measure of the individual's level of bilingualism, and all participants learned their L2 before the age of 16. Due to the linguistic nature of this study, all participants were right handed with the exception of one young participant. In order to justify inclusion of this participant, grand average waveforms were computed both including and excluding this participant and no obvious differences were observed. Participants were matched for years of education ($t(18) = 0.92, p > .05$), scores on the Montréal Cognitive Assessment (MoCA; $t(18) = 0.15, p > .05$), and level of proficiency in their L1 ($t(18) = .12, p > .05$) and their L2 ($t(18) = .11, p > .05$). Table 1 shows means and standard deviations for age, years of education, MoCA scores and the coefficient of variability (CV) for L1 and L2 where similar values of the CV in L1 and L2 represent similar levels of proficiency in each language.

Materials and Apparatus

Testing consisted of: an animacy judgment task to assess relative L1 and L2 proficiency; the Montréal Cognitive Assessment (MoCA; Nasreddine, et al., 2005) to assess overall cognitive functioning; the experimental lexical decision/semantic priming task; and an Interlingual Homograph Checklist.

Animacy judgment task. This task required the participant to judge, as quickly and accurately as possible, whether a noun was a living or nonliving object. It produced an objective measure of an individual's language proficiency (Segalowitz & Frenkiel-Fishman, 2005). As used here, it consisted of 144 nouns in French and 144 nouns in English, divided into four blocks; two in French and two in English. Within each language one block was presented in the visual modality and consisted of 64 nouns,

Table 1

Demographic and Neuropsychological Data for Young and Older Participants

	Young (n = 10)	Old (n = 10)
	M (SD)	*M (SD)*
Age	25.8 (5.45)	73.0 (5.56)
Education	14.7 (1.77)	14.8 (2.74)
MoCA	27.7 (1.83)	26.5 (1.70)
Response time for animacy judgement (L1)	836.78 (220.37)	924.96 (178.65)
Response time for animacy judgement (L2)	888.20 (260.42)	987.34 (215.89)
Coefficient of Variability (L1)	.26 (.099)	.19 (.092)
Coefficient of Variability (L2)	.28 (.098)	.21 (.088)

preceded by 8 practice trials, and the second block, also consisting of 64 nouns and preceded by 8 practice trials, was presented in the auditory modality. Data were collected in the two modalities in anticipation of potential analyses comparing the task in each modality and examining the efficacy of this task as a measure of L2 proficiency in the visual versus the auditory modality. These data are not presented here. The stimuli were presented using Inquisit version 1.32 presentation software (Millisecond Software, 2000) on a Compaq Deskpro computer with an Intel Pentium II processor and Microsoft Windows 98 operating system. Visual stimuli were presented in the center of a 16 inch monitor, in yellow 20 point Arial font on a black background, and auditory stimuli were pre-recorded in a male bilingual voice and presented using external Yamaha YST-M8 speakers at a volume comfortable for the participant. A response-stimulus interval of 0ms was used, i.e., there was no interval between the participant's response and the onset of the following stimulus. Participants responded using a green key on the keyboard to categorize the noun as an animate object and a red key to categorize the noun as an inanimate object. The nouns differed between the visual and auditory versions of the task and there were no translation equivalents between the French and English versions. The task was designed such that the different blocks were balanced in terms of the number of animate and inanimate nouns as well as the number of same/different responses relative to the previous trial (N. Segalowitz, personal communication, November 9, 2004).

Montréal Cognitive Assessment (MoCA). The MoCA is a 10-minute cognitive screening test designed to detect mild cognitive impairment in older adults (Nesreddine et al., 2005). It tests several cognitive domains including visuospatial/executive control, naming ability, memory, attention, language, abstraction, and orientation. It is scored on a

30 point scale, where a score equal to or greater than 26 is considered within the normal range. It has been shown to have very good to excellent sensitivity and specificity.

Lexical decision/semantic priming task. The stimuli used in the lexical decision/semantic priming task consisted of 900 triplets of letter strings presented in a lexical decision task, where participants were asked to decide whether all three of the letter strings were real French or English words or whether there was at least one letter string that was not a real word.

Three hundred of the triplets were filler triplets, 90% of which contained a single nonword, appearing an equal number of times in each of the three positions within the triplet, and 10% contained two nonwords appearing an equal number of times in each combination of two positions within the triplet. The nonwords were all phonologically legal and were derived from both French and English words by substituting one letter using pseudoword version 1.5beta5 (Van Heuven, 2000).

The 600 experimental triplets were comprised exclusively of real words. The first word was a high frequency French or English word, which served as a language context cue. The second word was a prime, which could be an IH (400 trials) or an exclusively French or English word (200 trials). The third word was a target word which was exclusively French or English. There were two independent variables, Consistency and Relatedness, which were manipulated in order to generate 6 conditions in each of the participants' L1 and L2, for a total of 12 conditions. Each condition was comprised of 50 trials. The Consistency variable refers to the consistency between the language of the three words comprising the triplet and had three levels: exclusive, where all three words were exclusively in one language (i.e., there was no IH in the triplet); consistent, where the prime was an IH and the language cue and target were in the same language, and inconsistent, where the prime was an IH and the language cue and target were not in the same language. The relatedness variable refers to the relatedness between the prime (the second word) and the target (the third word) and had two levels: related, where the two words were semantically related and; unrelated, where the two words were not semantically related. Table 2 defines each of the 12 conditions and includes sample stimuli. It should be noted that, throughout the thesis, L1 and L2 refer to the language of the target word.

There were a total of 100 IH used, which were divided into four groups of 25 matched on frequency of occurrence (Baudot, 1992; Kučera & Francis, 1967) concreteness, imageability and familiarity (MRC Psycholinguistic Database, http://www.psy.uwa.edu.au/mrcdatabase/mrc2.html). In the case of French words, the English translation was used to obtain the concreteness, imageability, and familiarity norms. Appendices B and C show the list of IH and their corresponding norms in French and English. Due to the nature of the stimuli, in some cases it was not possible to match the groups on all four variables so priority was given to frequency since the accuracy of the concreteness, imageability and familiarity norms for the French words is questionable as a result of the translation to English. Using a Latin square design, the four groups were then combined to create eight groups of 50 IH such that each IH appeared 4 times, twice in an English context and twice in French context. The 100 exclusively French and exclusively English primes were also matched on the same word norms with the IH primes.

Table 2

Experimental Conditions and Sample Stimuli (assuming L1 is English)

Condition	Language Cue	Prime	Target
L1 exclusive	**L1**	**L1**	**L1**
1- related	shoe	flower	garden
2- unrelated	shoe	flower	pillow
L1 consistent	**L1**	**IH**	**L1**
3- related	shoe	coin	money
4- unrelated	shoe	coin	house
L1 inconsistent	**L2**	**IH**	**L1**
5- related	soulier	coin	money
6- unrelated	soulier	coin	house
L2 exclusive	**L2**	**L2**	**L2**
7- related	soulier	fleur	jardin
8- unrelated	soulier	fleur	oreiller
L2 consistent	**L2**	**IH**	**L2**
9- related	soulier	coin	ruelle
10- unrelated	soulier	coin	maison
L2 inconsistent	**L1**	**IH**	**L2**
11- related	shoe	coin	ruelle
12- unrelated	shoe	coin	maison

The exclusive language context cues were 100 French and 100 English high frequency words that were matched between languages using a similar procedure as that used for the IH. Target words were also exclusively French or English words and were also matched across conditions using the same procedure as was used for the language cues and targets. Furthermore, targets and primes were matched within conditions and target words appeared only once throughout the course of the experiment to eliminate the possibility of repetition priming for the targets.

Due to the repetition of the IH in different language conditions, the stimuli were divided into two equal parts, such that participants only saw the same IH twice per testing session in order to reduce the possibility of repetition priming for the IHs. The different conditions were intermixed with the stipulation that the same response regarding whether the triplet was made up of all real words or whether there was a nonword present, did not occur more than three consecutive times. The stimuli were presented on a Compaq Deskpro computer with an Intel Pentium II processor and Microsoft Windows 98 operating system in lowercase yellow 24 point Arial font on a black background using STIM version 2.0 presentation software (Neuroscan, El Paso, TX, USA). Participants responded using a keypad with left/right keys and the ‘correct’ response key was counterbalanced across subjects. The language cue and the prime were presented simultaneously for 1000ms, on either side of the center of the monitor, immediately followed by the target, which remained on the screen until the participant responded. Three younger and two older participants were initially tested with the target word presented at the center of the monitor but, due to the large amount of artefact introduced by the horizontal eye movements required to return fixation from the location of the second letter string to the center, the target was presented between 0.007 and 0.020 degrees of visual angle to the right of center for subsequent participants. Following the presentation of each triplet, there was a subject-controlled pause which was comprised of a blue rectangle presented at the center of the monitor and lasted until the participant pressed any key on the keypad indicating their readiness to continue.

Interlingual homograph checklist. The Interlingual Homograph Checklist was administered at the end of the experiment and consisted of a written list of all the IH use in the experiment embedded within a list of exclusively French and English words. The participant was asked to indicate whether each word was exclusive to one language or whether it had meaning in both languages (see Appendix D). This checklist was used as a qualitative measure of the participants' recognition of the dual meaning of the IHs. These data were not analysed statistically since their validity is questionable. Participants were not asked to identify each of the two definitions thus, it is uncertain whether this is an accurate measure of their recognition of the IHs.

Procedure

Most participants were tested on two separate occasions, lasting approximately two hours each, within seven days of each other. However, two participants completed both testing sessions on one day with a break in between, due to time constraints, and for one there was a two week interval between testing sessions due to personal circumstances experienced by the participant.

Participants were seated in a comfortable chair and informed consent (see Appendix E) was obtained at the beginning of the first testing session. Participants were encouraged to ask any questions or express any concerns regarding the testing procedure before testing began.

On the first testing day, the participant completed the MoCA to ensure they were not suffering from any cognitive impairments prior to completing the remainder of the tasks. Following this, they performed the animacy judgment task in either the visual or auditory modality, in counterbalanced order, followed by either part 1 or part 2 of the lexical decision/semantic priming task, also in counterbalanced order, for which EEG recording took place.

On the second testing day participants began with the animacy judgment task in the other modality followed by the lexical decision/semantic priming task. Following this they completed the Interlingual Homograph Checklist and were given a debriefing sheet (see Appendix F). Any questions or concerns they had were addressed and they were compensated for their time.

Animacy judgment task. For this task participants were asked to categorize nouns as being animate or inanimate objects as quickly and accurately as possible. The *SD* of their response time (RT) for correct trials was then divided by their mean RT for correct trials to obtain the coefficient of variability (CV), a measure of variability in responding that is independent of response latency (Segalowitz & Segalowitz, 1993) in L1 and L2 for the visual and auditory tasks separately. In the present report, only the visual CV was used to evaluate L1 versus L2 proficiency since stimuli for the experimental semantic priming task were presented only in the visual modality. Table 1 shows the mean CV and the RT and *SD* for the animacy judgement task in L1 and L2 for the younger and older participants. Once the CV was obtained in L1 and L2 for each participant, a comparison of the two values allowed for an objective evaluation of relative language proficiency. Participants with a difference between their L1 and L2 CVs of less than ± .10 were considered balanced bilinguals and were included in the study; as stated previously, three young participants were excluded based on these criteria.

EEG recording. A commercially available nylon EEG cap containing tin electrodes (Electro-Cap International, Inc., Eaton, OH, USA) was used. The EEG was recorded continuously from six midline sites (FPz, Fz, FCz, Cz, CPz, Pz) and 23 lateral sites (prefrontal: FP1, FP2; frontal: F3, F7, F4, F8; frontocentral: FC3, FC4; frontotemporal: FT7, FT8; central: C3, C4; centroparietal: CP3, CP4; temporal: T5, T4, T6; temporoparietal: TP7, TP8; parietal: P3, P4; occipital: O1, O2) and was time locked to the presentation of the first two letter strings and to the target letter string. A cephalic (forehead) location was used as a ground. All sites were referenced on-line to the left ear and re-referenced off-line, using Scan4.3 computer software (Neuroscan, El Paso, TX, USA), to a linked ear reference. Horizontal electro-oculogram (EOG) was recorded from electrodes placed at the outer canthi of both eyes and vertical EOG was recorded from electrodes placed above and below the left eye. The EEG was amplified using Neuroscan Synamps (Neuroscan, El Paso, TX, USA) and was recorded at a sampling rate of 100Hz in a DC to 30Hz bandwidth with electrical impedances below 5 kΩ. Vertical EOG artefacts were corrected off-line using a spatial filter particular to each participant (Neuroscan Edit4.3). Trials with horizontal EOG artefact exceeding peak amplitudes of ±50 μV were excluded from averaging. In order to retain an acceptable number of trials, horizontal EOG rejection criteria were raised to ±75 μV for four participants. Furthermore, trials containing EEG activity exceeding ±100 μV were also rejected, and only correct trials (i.e., trials for which the participant correctly responded that all three words in the triplet were real words) were included in averages. The electrophysiological time epoch was 1100ms per trial, 100ms prior to the onset of the target word and 1000ms following its presentation. All averages were baseline corrected relative to the 100ms pre-stimulus interval. Amplitude for correct trials was averaged, based on the 12 conditions reflecting the different languages and different levels of Relatedness and Consistency, over eight 50ms time intervals (300-350, 350-400, 400-450, 450-500, 500-550, 550-600, 600-650 and 650-700 ms post-stimulus). This 300-700 ms post-stimulus time window was chosen because preliminary analyses revealed delayed N400 latencies in the older adults suggesting that a longer window was necessary in order to include the entire duration N400 effect in the analyses.

Results

First, the behavioural analyses will be presented, followed by the electrophysiological results. Since our interest was in examining age differences within L1 and L2 processing, separate analyses were conducted for each language on all data. All analyses were conducted using SPSS version 11.5 statistical software (SPSS Inc., Chicago, IL, USA) and the alpha level was set at .05 for all statistical tests.

For all analyses the Huynh and Feldt (1976) correction for non-sphericity was employed for within-subjects effects with more than one degree of freedom in the numerator. Following convention, the unadjusted degrees of freedom, the corrected mean square error, the adjusted p-value, and the Huynh-Feldt epsilon value (ε) are reported. Significant main effects are reported first, followed by significant interaction effects. Within-subjects interactions were followed with simple effects analyses and pairwise comparisons. Significant interactions involving the between-subjects variable Age were followed with separate ANOVAs for each age group.

Behavioural analyses

For both RT (i.e., mean RT for correct trials) and accuracy data (i.e., percentage of correct responses), an initial 2 x 2 x 2 x 3 mixed factors ANOVA was conducted with the between subjects factor being Age (young and old) and the within subjects factors being Language (L1 and L2), Relatedness (related and unrelated) and Consistency (exclusive, consistent and inconsistent). The purpose of the initial omnibus ANOVA was to test the hypothesis that performance would be better in L1 relative to L2. These omnibus ANOVAs were followed with separate 2 (Age) x 2 (Relatedness) x 3 (Consistency) mixed factors analyses for L1 and L2.

RT

The omnibus ANOVA revealed no main effect of age (F (1, 18) = 2.03, MSE = 679561.29, p = .17, eta^2 = .10). There was a main effect of Language (F (1, 18) = 10.45, MSE = 21090.79, p = .005, eta^2 = .37) such that participants were faster in their L1 than in their L2. There was also a main effect of Consistency (F (2, 36) = 29.98, MSE = 8131.29, p < .001, eta^2 = .63, ε = .50) such that the RT for inconsistent trials was significantly slower than that for both consistent trials and exclusive trials. Consistent and exclusive trials also differed significantly from each other. Furthermore, there was a main effect of Relatedness (F (1, 18) = 19.78, MSE = 2697.68, p < .001, eta^2 = .52) such that RT for unrelated trials was significantly slower than for related trials. There were no significant interaction effects. Table 3 shows the mean RT and *SD* for the main effects of language, consistency, and relatedness.

The L1 analysis revealed a main effect of Consistency (F (2, 36) = 15.16, MSE = 7997.42, p< .001, eta^2 = .46, ε = .88) such that RT for inconsistent trials was significantly slower than for both consistent trials and exclusive trials, which did not differ from each other (see Table 3). Furthermore, there was a main effect of Relatedness (F (1, 18) = 11.01, MSE = 4457.25, p = .004, eta^2 = .38) such that the RT for trials in which the prime and target were related were significantly faster than those in which the prime and target were unrelated. There were no significant interaction effects. Table 4 shows the mean RT and *SD* for the main effects of consistency and relatedness in L1 and L2.

In L2 there was also a main effect of Consistency (F (2, 36) = 31.15, MSE = 4580.38, p<.001, eta^2 = .63, ε = .95) although in this case all levels of consistency differed significantly from each other (i.e., exclusive trials were significantly faster than

Table 3

Mean RT (ms) and SE for Main Effects of Languge, Consistency, and Relatedness

Condition	Mean	*SE*
	Language	
L1	794.27	53.1
L2	854.87	54.2
	Consistency	
Exclusive	769.32	49.5
Consistent	826.77	53.2
Inconsistent	877.63	58.4
	Relatedness	
Related	809.66	50.8
Unrelated	839.48	55.8

Table 4

Mean RT (ms) and SE for Main Effects of Consistency and Relatedness in L1 and L2

	L1	L2
Condition	Mean (*SE*)	Mean (*SE*)
	Consistency	
Exclusive	747.2 (51.2)	791.4 (48.9)
Consistent	786.3 (54.0)	867.2 (54.8)
Inconsistent	849.3 (59.3)	906.0 (60.3)
	Relatedness	
Related	774.0 (50.2)	845.3 (53.1)
Unrelated	814.5 (57.9)	864.5 (55.7)

consistent trials which were significantly faster than inconsistent trials; see Table 4). As in L1, there was also a main effect of Relatedness (F (1, 18) = 4.75, MSE = 2323.64, p = .043, eta^2 = .21) such that RT for related trials was significantly faster than for unrelated trials (see Table 4). Again there were no significant interaction effects.

Accuracy

The omnibus ANOVA revealed a main effect of Age such that the older adults were more accurate than the young adults. There was also a main effect of Language such that responses were significantly more accurate in L1 than in L2. There was a main effect of Consistency revealing significantly greater accuracy for exclusive and consistent conditions, which did not differ, than for the inconsistent condition (see Table 5 for main effects and significant interactions), that was moderated by a Language by Consistency interaction (see Figure 3). This showed significantly greater accuracy in the exclusive and consistent conditions relative to the inconsistent condition in L2 but no differences between the levels of consistency in L1. An Age by Consistency interaction revealed that the old were more accurate than the young in the inconsistent condition. Furthermore, the young showed significantly greater accuracy for the exclusive and consistent conditions, which did not differ, relative to the inconsistent condition. No difference between the levels of Consistency was found for the old group. There was no main effect of relatedness, but there was a Language by Relatedness interaction which showed significantly more accurate responses for related and unrelated trials in L1 than in L2 (see Figure 4).

The omnibus ANOVA was followed up with separate analyses for L1 and L2 which reproduced the results from the omnibus ANOVA (see Table 6).

Table 5

Omnibus ANOVA for Accuracy

Source	F	df	MSE	eta^2	ε
Age	5.23*	1, 18	105.11	.23	N/A
Language	9.86**	1, 18	80.34	.35	1.00
Consistency	11.84**	2, 36	5.87	.40	.99
Relatedness	0.24	1, 18	7.34	.01	1.00
C x A	6.69**	2, 36	5.87	.27	.99
L x C	5.13*	2, 36	5.91	.22	.95
L x R	5.16*	1, 18	5.22	.22	1.00
C x R	3.23*	2, 36	36.00	.15	1.00

* $p < .05$
** $p < .01$

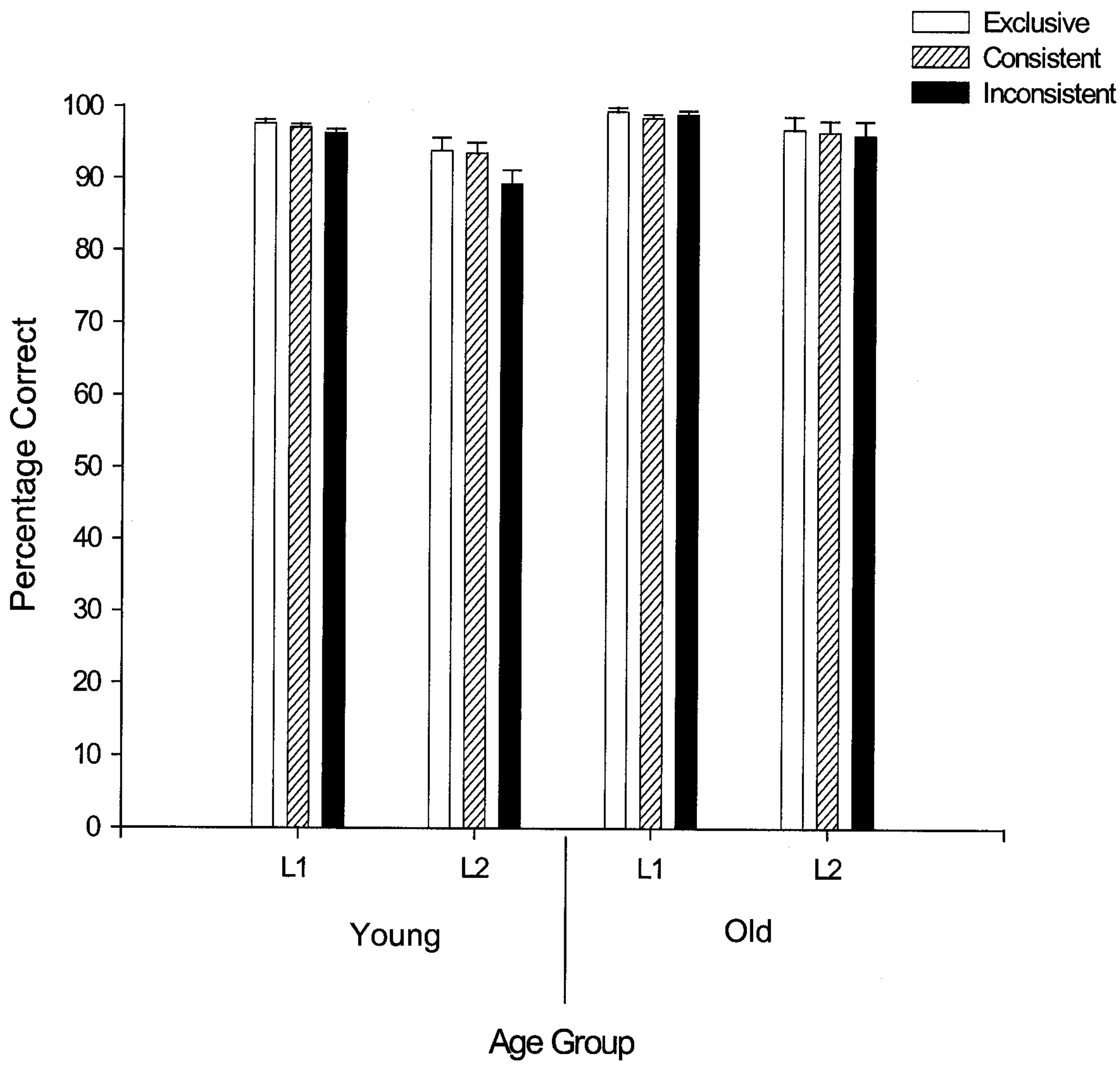

Figure 3. Percentage of correct trials (+*SE*) for different levels of Consistency in L1 and L2 for the young and older groups.

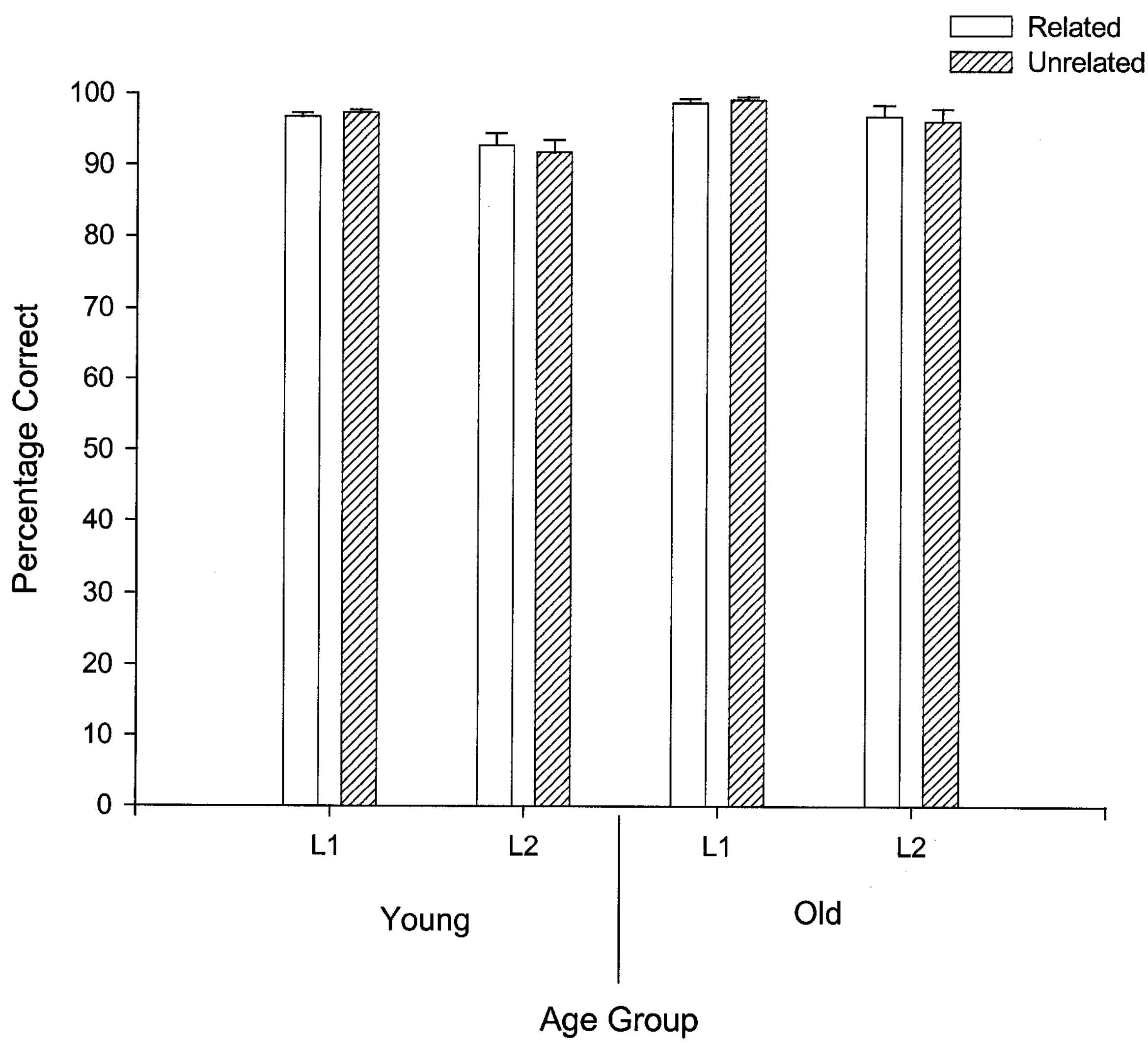

Figure 4. Percentage of correct trials (+*SE*) for related and unrelated trials in L1 and L2 for the young and older groups.

Table 6

Accuracy Results for Separate L1 and L2 ANOVAs

Source	F	df	MSE	eta^2	ε
			L1		
Age	9.50**	1, 18	11.14	.35	N/A
Consistency	2.18	2, 36	3.97	.11	1.00
Relatedness	1.52	1, 18	4.89	.08	1.00
			L2		
Age	3.00	1, 18	174.34	.14	N/A
Consistency	11.92**	2, 36	7.51	.40	0.99
Relatedness	2.77	1, 18	7.68	.13	1.00
C x A	6.39**	2, 36	7.51	.26	0.99

* $p < .05$
** $p < .01$

Electrophysiological analyses

Due to technical problems during data acquisition two older participants were missing data from electrode site P3 and one older participant was missing data from site Pz. These missing data were replaced with the mean of the remaining older participants at the corresponding electrode site and condition and these unbiased estimates were used for all analyses.

Separate analyses were conducted comparing midline sites alone, and comparing left hemisphere to right hemisphere lateral sites. Results from midline sites are presented first followed by results from the lateral sites only when they provided additional information. Furthermore, following initial analyses, it appeared as though some effects may have been dampened by the inclusion of the exclusive language conditions. Due to the small sample size, we decided it was reasonable to conduct supplementary analyses with the exclusive language conditions excluded.

For the analysis of the midline sites, a 2 x 2 x 3 x 5 x 8 mixed factors repeated measures ANOVA was conducted for L1 and for L2, with the between subjects factor of Age (young and old) and the within subjects factors of Relatedness (related and unrelated), Consistency (exclusive, consistent and inconsistent), Site (Fz, FCz, Cz, CPz, and Pz) and Time interval (300-350, 350-400, 400-450, 450-500, 500-550, 550-600, 600-650 and 650-700 ms post-target). For the analysis of left versus right lateral sites two levels of Laterality and three levels of Anteriority were created by averaging the mean amplitude for each time interval at specific electrode sites: F3 and FC3 created an anterior left region; F4 and FC4 created an anterior right region; C3 and C4 represented the central left and central right regions respectively; CP3 and P3 created a posterior left region and; CP4 and P4 created a posterior right region (see Figure 5). A 2 x 2 x 2 x 3 x 3 x 8 mixed factors ANOVA was conducted for L1 and L2 with the between subjects factor ofAge and the within subjects factors of Relatedness, Consistency, Laterality (left and right), Anteriority (anterior, central and posterior) and Time interval. Only main effects and interactions involving experimental variables (i.e., Age, Language, Relatedness and Consistency) are reported in the text although all significant effects are reported in the corresponding tables.

L1

The L1 analysis of the midline revealed no main effects for the experimental variables. However, there was a Relatedness by Time by Age interaction effect (F (7, 126) = 4.66, MSE = 5.07, p = .001, ε = .64) suggesting different patterns of Relatedness effects in each age group. This effect was further supported by the hemispheric analysis where a similar Relatedness by Time by Age interaction was found (F (7, 126) = 3.59, MSE = 4.52, p = .008, ε = .63). Separate ANOVAs were conducted for each age group for both the midline and comparing the lateral hemispheric sites.

Young adults. Grand average waveforms for L1 for all three levels of consistency for the young group are shown in Figure 6; note that negativity is plotted upward. Important in this figure is the large negativity peaking at approximately 350 ms, and the difference in the amplitude of this negativity for related and unrelated conditions at each level of consistency. Inspection of the waveforms reveals the characteristic centro-parietal distribution of the N400 priming effect (i.e., greater N400 amplitudes for unrelated conditions relative to related conditions) for exclusive and consistent conditions. In the inconsistent condition however, the N400 priming effect appears across

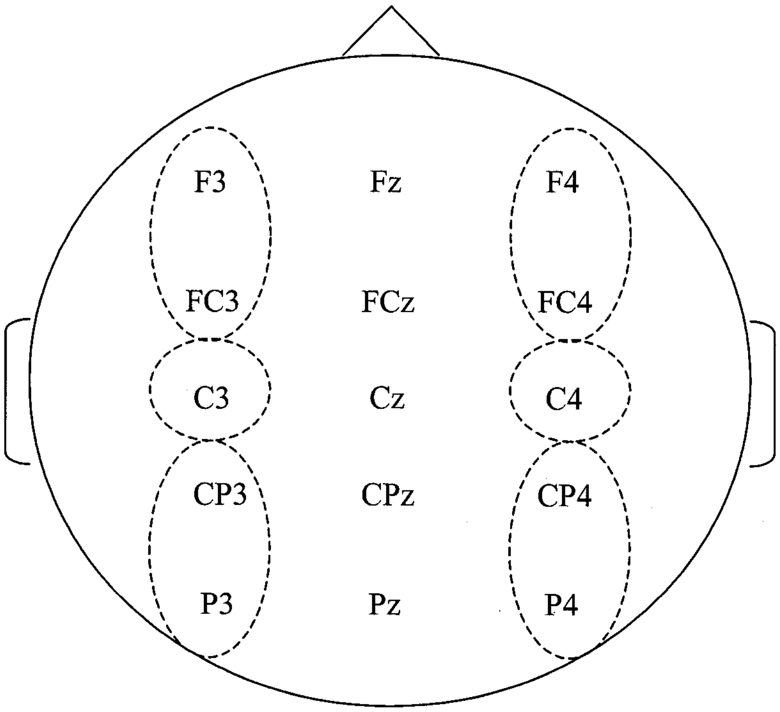

Figure 5. Different regions of the scalp comprising the midline and different levels of laterality and anteriority. Dashed ovals represent the electrode sites that comprise each of the levels of anteriority (anterior, central and posterior) and laterality (left and right).

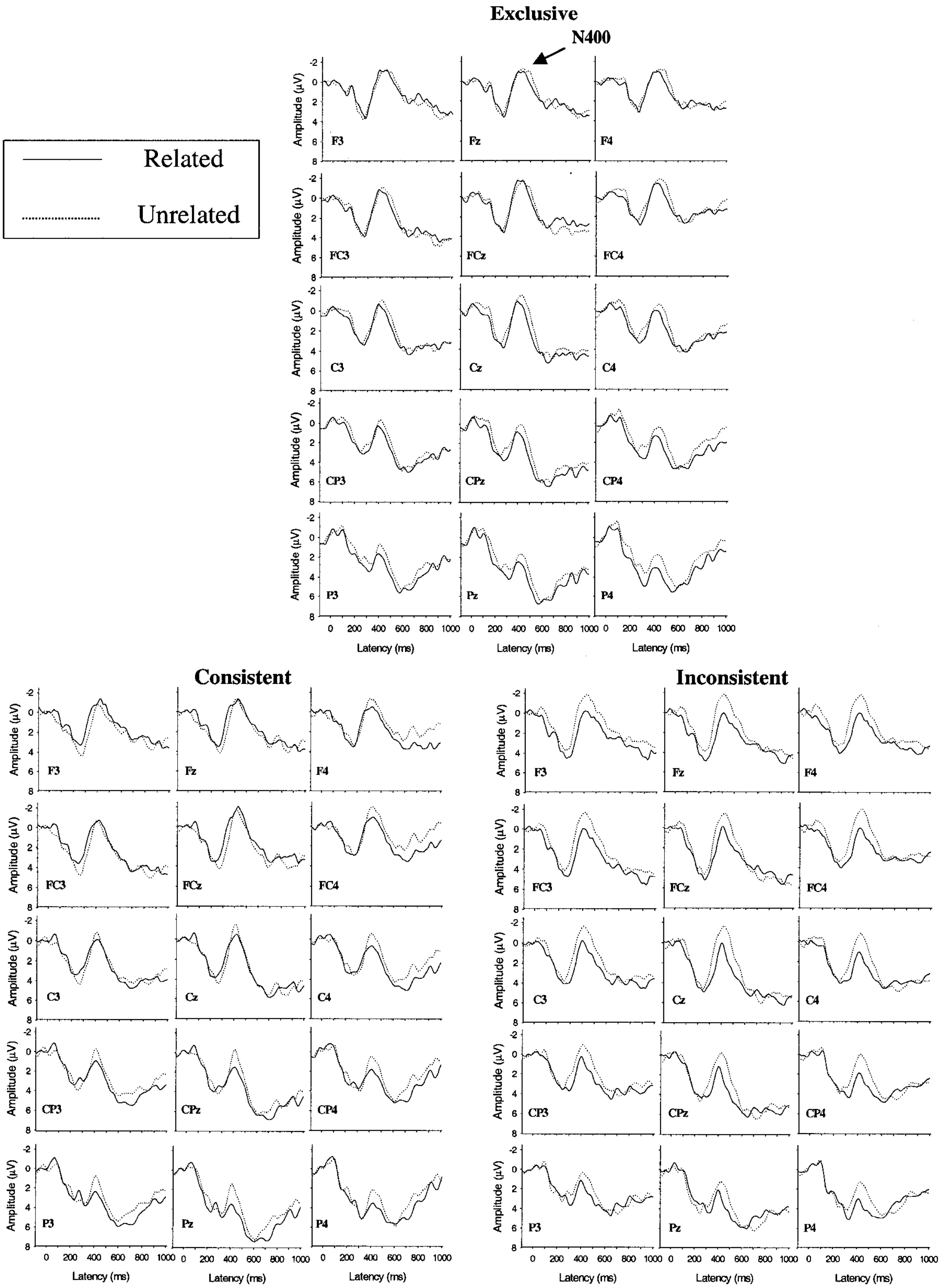

Figure 6. Grand average waveforms comparing related versus unrelated trials for young adults in L1 for all levels of consistency.

all midline and lateral sites, suggesting differences in processing resulting from an inconsistent contextual cue.

Analysis of the midline sites for the young group revealed no significant main effects for the experimental variables (see Table 7). A significant interaction between Relatedness, Consistency, and Time was found, demonstrating an N400 priming effect for time intervals between 300 and 550 ms in the inconsistent condition only. The hemispheric analysis revealed a similar N400 priming effect in the inconsistent condition as well as an N400 priming effect for the consistent condition in the interval from 400-450 ms. Table 6 provides the relevant statistics for main effects and significant interactions for the Young group in L1 including all levels of consistency.

Supplementary analyses comparing only the consistent and inconsistent conditions revealed no significant main effects for the experimental variables. There was a Relatedness by Consistency by Site by Time interaction at the midline sites showing a widespread N400 priming effect at all sites for the inconsistent condition but only at CPz and Pz for the consistent condition. The simple effects analysis of Time indicates that the difference between the related and unrelated conditions began earlier for the inconsistent condition than the consistent condition. However, as can be seen in Figure 6, the N400 priming effect appears to be larger for the inconsistent condition therefore, the interaction with Time may reflect a difference in the size of the effect, rather than a difference in its timing. A similar analysis for the lateral sites demonstrated Relatedness by Consistency by Time interaction showing an N400 priming effect at lateral sites for the inconsistent condition at time intervals between 300 and 550 ms but only for the time interval from 400 to 450 ms for the consistent condition. As in the midline sites, the interaction with

Table 7

Main Effects and Significant Interactions for Young Group in L1 Including All Levels of Consistency

Source	*F*	df	*MSE*	eta^2	ε
			Midline sites		
Relatedness	1.29	1, 9	151.44	.13	1.00
Consistency	0.15	2, 18	213.60	.02	.92
Site	11.30**	4, 36	211.16	.56	.48
Time	14.74**	7, 63	252.41	.62	.26
C x S	3.22*	8, 72	18.39	.26	.42
R x T	3.94**	7, 63	5.70	.31	.68
R x C x T	2.15*	14, 126	4.74	.19	.65
			Lateral sites		
Relatedness	1.92	1, 9	160.41	.18	1.00
Consistency	0.17	2, 18	189.33	.02	.93
Anteriority	8.86**	2, 18	201.11	.50	.68
Laterality	0.95	1, 9	307.99	.10	1.00
Time	13.66**	7, 63	212.87	.60	.26
An x C	3.94*	4, 36	6.24	.30	.67
An x T	3.37*	14, 126	11.44	.27	.23
R x T	3.00*	7, 63	4.90	.25	.68
L x R x T	3.23*	7, 63	1.09	.26	.46
L x An x T	4.73**	14, 126	2.46	.35	.21
R x C x T	2.56**	14, 126	3.85	.22	.68

* $p < .05$
** $p < .01$

Time likely reflects a difference in the size of the effect, rather than a difference in the timing. An Anteriority by Consistency interaction reflected an increase in N400 amplitude across all three levels of anteriority for the consistent condition (anterior: $M = 1.14\ \mu V$, $SE = 1.08$; central: $M = 2.35\ \mu V$, $SE = 0.91$; posterior: $M = 3.72\ \mu V$, $SE = 0.91$), while in the inconsistent condition, only the anterior ($M = 1.25\ \mu V$, $SE = 1.14$) and posterior ($M = 2.98\ \mu V$, $SE = 0.81$) regions differed significantly. Table 8 provides the relevant statistics for main effects and significant interactions for the young group in L1 excluding the exclusive language conditions.

Older adults. Grand average waveforms for L1 for all three levels of consistency for the older group are shown in Figure 7; note that negativity is plotted upward. Important in Figure 7 is the negativity peaking at approximately 350 ms as well as the greater amplitude of the negative peak for unrelated trials relative to related trials for the consistent condition. This N400 priming effect is absent in both the exclusive and inconsistent conditions. Furthermore, note the lower peak amplitudes relative to those observed in Figure 6 for the young participants. Inspection of the waveforms at each of the three levels of Consistency appears to show greater overall N400 amplitudes in consistent and inconsistent conditions relative to the exclusive condition.

Analysis of the older participants in L1 revealed no significant effects for the midline sites. However, there was a significant Relatedness by Anteriority by Consistency by Time interaction for the lateral sites (see Table 9) which reflected significantly larger N400 amplitudes for unrelated trials in the consistent condition than in the exclusive condition. No such difference was found for related trials. Furthermore, there was a significant decrease in N400 amplitude moving from anterior sites to

Table 8

Main Effects and Significant Interactions for Young Group in L1 Excluding Exclusive Language Condition

Source	*F*	df	*MSE*	*eta*^{2}	ε
			Midline sites		
Relatedness	3.01	1, 9	49.76	.26	1.00
Consistency	0.00	1, 9	295.99	.00	1.00
Site	12.03**	4, 36	117.45	.57	.51
Time	14.78**	7, 63	153.57	.62	.28
R x C	5.56*	1, 9	17.06	.38	1.00
C x S	4.14*	4, 36	17.89	.32	.62
R x C x S	3.66*	4, 36	6.31	.29	.57
R x C x T	3.16**	7, 63	3.76	.26	.86
R x C x S x T	2.48*	28, 252	0.61	.22	.31
			Lateral sites		
Relatedness	3.87	1, 9	72.57	.08	1.00
Consistency	0.14	1, 9	265.38	.02	1.00
Anteriority	8.50**	2, 18	132.69	.49	.66
Laterality	1.41	1, 9	67.89	.27	1.00
Time	13.20**	7, 63	132.73	.60	.28
L x C	5.98*	1, 9	7.45	.40	1.00
An x C	5.31*	2, 18	7.12	.37	.78
L x An x T	4.81**	14, 18	1.47	.35	.22
R x C x T	4.12**	7, 63	3.29	.31	.86

* $p < .05$
** $p < .01$

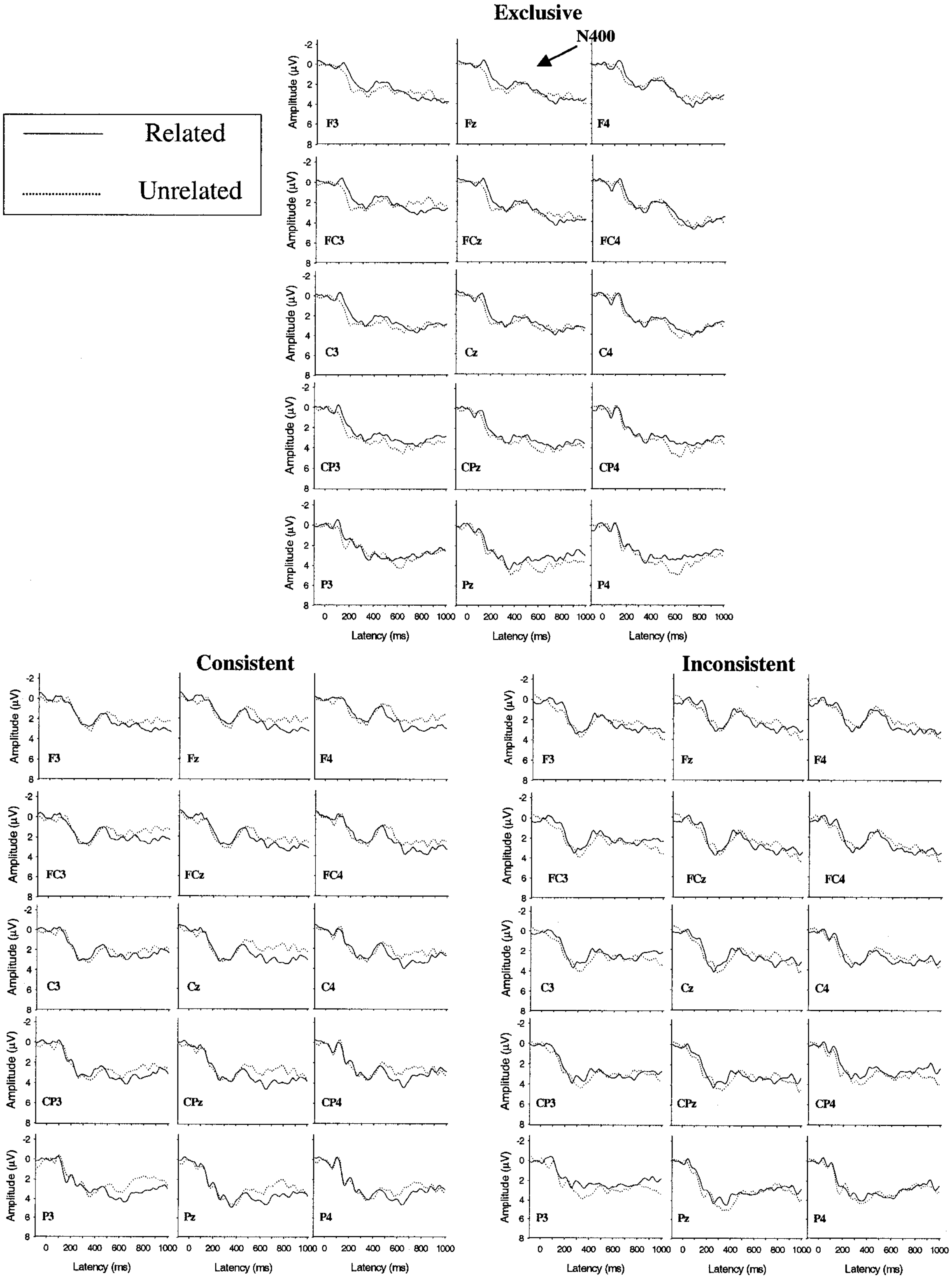

Figure 7. Grand average waveforms comparing related versus unrelated trials for older adults in L1 for all levels of consistency.

Table 9

Main Effects and Significant Interactions for Older Group in L1 Including All Levels of Consistency

Source	*F*	df	*MSE*	eta^2	ε
			Midline sites		
Relatedness	0.03	1, 9	95.81	.00	1.00
Consistency	0.31	2, 18	107.54	.03	1.00
Site	2.66*	4, 36	125.07	.23	.58
Time	0.86	7, 63	176.09	.09	.32
			Lateral sites		
Relatedness	0.01	1, 9	92.17	.00	1.00
Consistency	0.36	2, 18	94.66	.04	1.00
Anteriority	3.29	2, 18	109.95	.27	.70
Laterality	0.05	1, 9	297.75	.01	1.00
Time	1.25	7, 63	140.83	.12	.33
C x T	2.10*	14, 126	3.99	.19	.70
R x An x C x T	3.28**	28, 252	0.46	.27	.26

* $p < .05$
** $p < .01$

posterior sites for: exclusively related trials at the time interval from 450-500 ms; consistent related trials from 400-550 ms and consistent unrelated trials from 400-500 ms, thus demonstrating an anterior N400 effect. The simple effects of Time were not significant. Follow up analyses excluding the exclusive language condition were conducted and no significant effects were found (see Table 10).

L2

The L2 analysis revealed no significant main effects for the experimental variables. However, there was a significant interaction between Time and Age (F (7, 126) = 7.15, MSE = 200.56, p = .003, ε = .28) indicating a different time course of activation between the two age groups. This effect was further supported by the hemispheric analysis where a Laterality by Time by Age interaction was found (F (7, 126) = 4.17, MSE = 9.03, p = .018, ε = .33) indicating that this effect was not confined to the midline. These effects were followed up with separate ANOVAs for each of the age groups.

Young adults. Grand average waveforms in L2 for all three levels of consistency for the young group are shown in Figure 8; note that negativity is plotted upward. It is important to notice the large negativity peaking at approximately 350 ms and overall larger peak N400 amplitudes in the inconsistent condition.

Analysis of the young group revealed no significant main effects for the experimental variables. There was a significant interaction between Consistency and Time, which showed greater amplitude differences over time at the different levels of consistency, although the simple effects were not significant. Table 11 provides the relevant statistics for main effects and significant interactions for the young group in L2 including all levels of consistency.

Table 10

Main Effects and Significant Interactions for Older Group in L1 Excluding Exclusive Language Condition

Source	*F*	df	*MSE*	*eta*^{2}	ε
			Midline sites		
Relatedness	0.42	1, 9	53.10	.05	1.00
Consistency	0.04	1, 9	147.64	.00	1.00
Site	3.02	4, 36	243.08	.25	.63
Time	1.09	7, 63	116.30	.11	.33
R x T	3.48*	7, 63	7.87	.28	.37
			Lateral sites		
Relatedness	0.10	1, 9	57.32	.01	1.00
Consistency	0.03	1, 9	121.43	.00	1.00
Anteriority	3.19	2, 18	89.93	.26	.65
Laterality	0.02	1, 9	205.79	.00	1.00
Time	1.34	7, 63	91.22	.13	.35
R x T	3.21*	7, 63	6.89	.26	.39

* $p < .05$
** $p < .05$

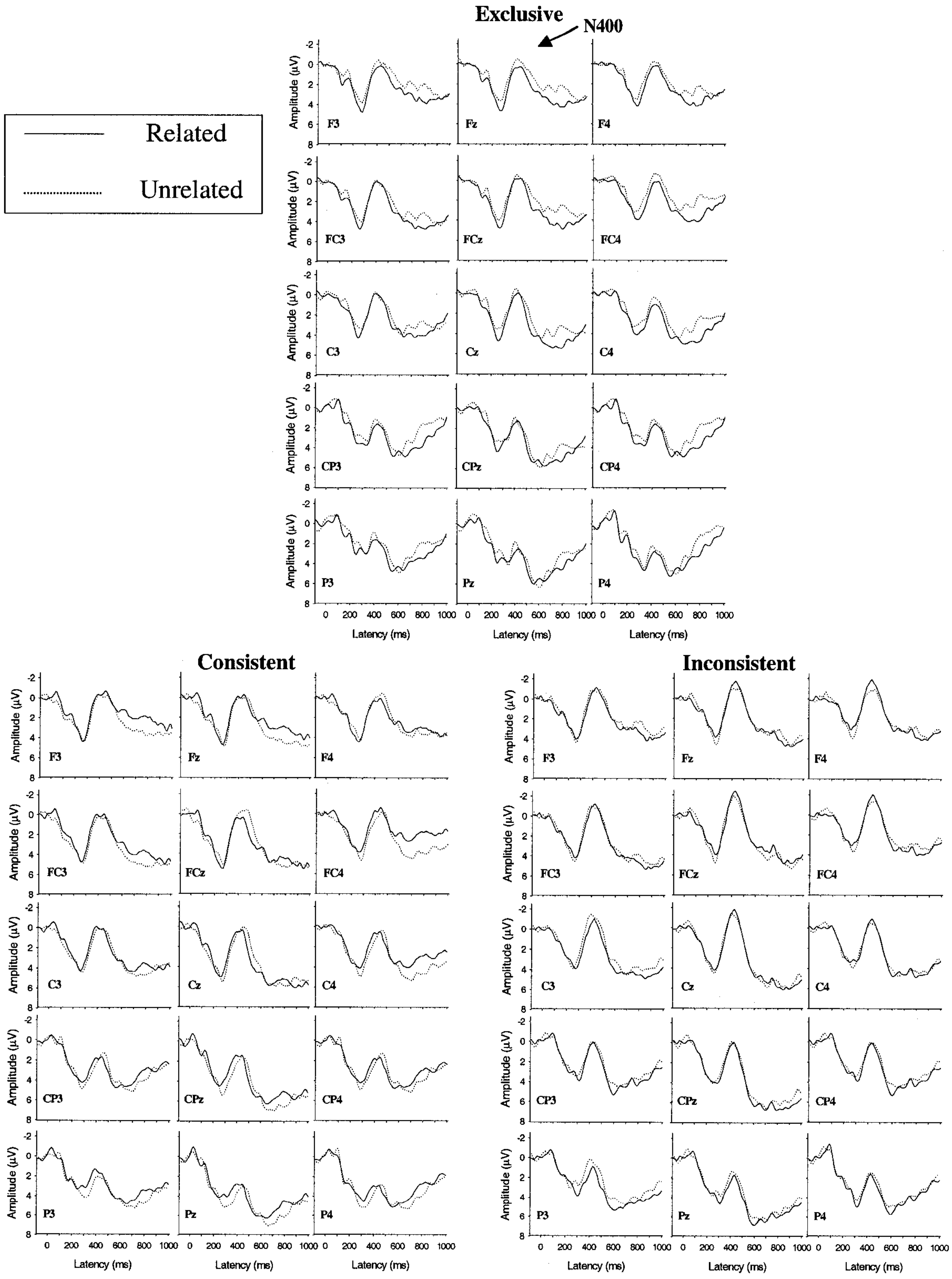

Figure 8. Grand average waveforms comparing related versus unrelated trials for young adults in L2 for all levels of consistency.

Table 11

Main Effects and Significant Interactions for Young Group in L2 Including All Levels of Consistency

Source	*F*	df	*MSE*	eta^2	ε
			Midline sites		
Relatedness	0.34	1, 9	80.59	.04	1.00
Consistency	0.73	2, 18	162.66	.08	.92
Site	7.87**	4, 36	217.23	.47	.46
Time	14.08**	7, 63	226.85	.61	.29
C x T	2.54*	14, 126	13.69	.22	.48
S x T	4.54**	28, 252	10.42	.34	.17
			Lateral sites		
Relatedness	0.35	1, 9	87.15	.04	1.00
Consistency	0.45	2, 18	143.01	.05	.95
Anteriority	5.83*	2, 18	160.91	.39	.71
Laterality	1.76	1, 9	73.93	.16	1.00
Time	14.53**	7, 63	177.83	.62	.30
C x T	2.50*	14, 126	11.85	.22	.46
L x An x T	4.31*	14, 126	21.53	.32	.17

* $p < .05$
** $p < .01$

In order to keep the L2 analyses analogous to the L1 analyses ANOVAs were conducted with only the consistent and inconsistent conditions. No significant effects were found in the midline analysis, however, the analysis comparing the lateral sites revealed a Laterality by Relatedness by Consistency by Time interaction (see Table 12). This demonstrated significantly larger N400 amplitudes in the right hemisphere, relative to the left hemisphere, in response to related target words that were inconsistent with the language context cue ($M = -0.451$ μV, $SE = 1.22$) than to those that were consistent with the language context cue ($M = 0.986$ μV, $SE = 1.41$; mean consistent-inconsistent amplitude difference = 1.437, $SE = 0.54$).

Older adults. Grand average waveforms in L2 for all three levels of consistency for the old group are shown in Figure 9; note that negativity is plotted upward. Important to notice is the negativity peaking at approximately 400 ms and the attenuated amplitude relative to those seen in Figure 8, for the young group. Inspection of the waveforms appears to show N400 priming effects for only the inconsistent condition suggesting that the failure to find any significant effects is the consequence of a lack of power resulting from the small sample size.

Analysis of all three of the consistency conditions for both the midline sites and the hemispheric comparison in the older group in L2 revealed no significant effects (see Table 13).

Keeping congruous with the L1 analyses, further analyses were conducted with only the consistent and inconsistent conditions. Similar to the analysis including all three levels of consistency, no significant effects were found in either the midline or hemispheric analyses (see Table 14).

Table 12

Main Effects and Significant Interactions for Young Group in L2 Excluding Exclusive Language Condition

Source	*F*	df	*MSE*	eta^2	ε
			Midline sites		
Relatedness	0.01	1, 9	101.55	.00	1.00
Consistency	1.11	1, 9	195.38	.47	1.00
Site	7.86**	4, 36	153.85	.47	.47
Time	16.09**	7, 63	154.89	.64	.30
S x T	3.58*	28, 252	9.33	.28	.16
			Lateral sites		
Relatedness	0.01	1, 9	82.30	.00	1.00
Consistency	0.53	1, 9	192.01	.06	1.00
Anteriority	5.76*	2, 18	733.52	.39	.68
Laterality	0.91	1, 9	72.22	.09	1.00
Time	16.33**	7, 63	120.90	.65	.30
An x T	2.77*	14, 126	5.82	.24	.27
L x An x T	3.31*	14, 126	1.79	.27	.18
L x R x C x T	3.82*	7, 63	0.62	.30	.43
R x An x C x T	2.90*	14, 126	1.06	.24	.24

* $p < .05$
** $p < .05$

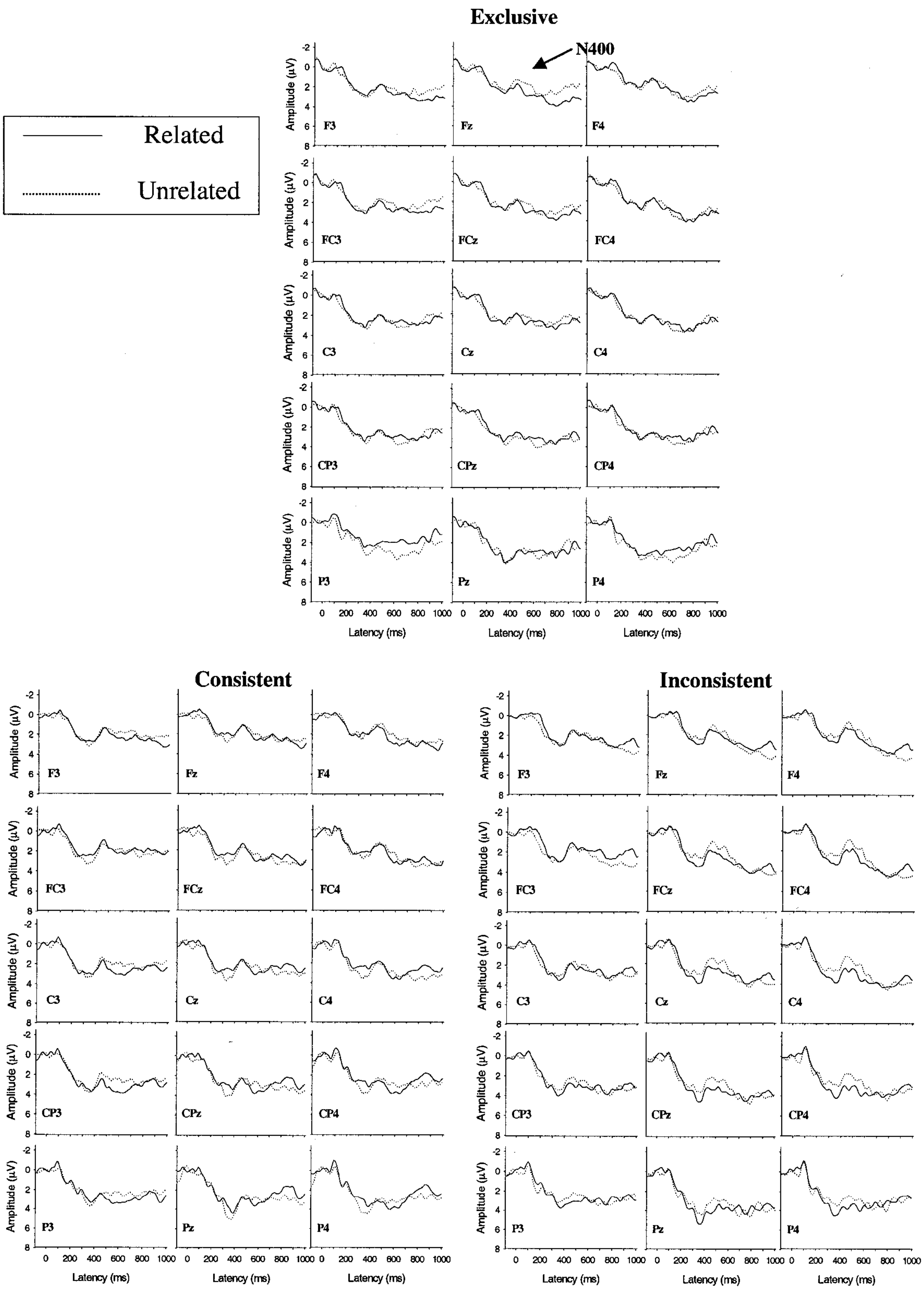

Figure 9. Grand average waveforms comparing related versus unrelated trials for older adults in L2 for all levels of consistency.

Table 13

Main Effects and Significant Interactions for Older Group in L2 Including All Levels of Consistency

Source	*F*	df	*MSE*	*eta*^{2}	ε
			Midline sites		
Relatedness	0.14	1, 9	177.52	.02	1.00
Consistency	0.08	2, 18	110.62	.01	1.00
Site	1.65	4, 36	109.12	.16	.65
Time	0.98	7, 63	174.36	.10	.25
			Lateral sites		
Relatedness	0.12	1, 9	153.69	.01	1.00
Consistency	0.02	2, 18	97.21	.13	1.00
Anteriority	2.56	2, 18	84.39	.22	.73
Laterality	0.16	1, 9	253.64	.02	1.00
Time	1.33	7, 63	138.27	.13	.27

* $p < .05$
** $p < .01$

Table 14

Main Effects and Significant Interactions for Older Group in L2 Excluding Exclusive Language Condition

Source	*F*	df	*MSE*	*eta*^{2}	ε
			Midline sites		
Relatedness	0.21	1, 9	153.72	.02	1.00
Consistency	0.12	1, 9	135.28	.01	1.00
Site	2.26	4, 36	68.44	.20	.25
Time	1.18	7, 63	114.86	.12	.14
			Lateral sites		
Relatedness	0.35	1, 9	153.29	.04	1.00
Consistency	0.02	1, 9	122.98	.00	1.00
Anteriority	3.58	2, 18	56.18	.29	.72
Laterality	0.24	1, 9	156.18	.03	1.00
Time	1.56	7, 63	86.20	.15	.29
L x T	3.54*	7, 63	6.91	.28	.30

* $p < .05$
** $p < .01$

Discussion

In discussing the results it is important to consider that the sample used is comprised of only 10 individuals in each of the age groups. This small sample size has created a reduced power in the statistical analyses and increased the likelihood of type II error in the results.

The omnibus analyses for both the RT and the accuracy data demonstrate superior performance in L1 regardless of Age, that is, responses were faster and more accurate in L1 than in L2. This is important since participants were considered balanced bilinguals and still showed better performance in their L1, demonstrating L1 dominance regardless of L2 proficiency. An additional effect revealed by the omnibus accuracy analysis was a Language by Relatedness interaction showing significantly greater accuracy for both related and unrelated trials in L1 than in L2, with a greater decrease in accuracy for unrelated trials in L2 relative to related trials in L2, providing further support for better performance in L1 than in L2. The fact that in L1 both the related and unrelated trials were facilitated relative to both related and unrelated trials in L2 shows that participants benefited more from a prime when the target language was their L1.

The RT analysis revealed no effect of age demonstrating similar performance for the young and older participants. This analysis did reveal main effects of Consistency and Relatedness, showing typical behavioural priming effects, as well as a RT gradient such that participants were fastest when there was no IH in the word triplet and slowest when the language cue and the target word were inconsistent in language. Participants were significantly slower in the consistent condition than in the exclusive condition, suggesting that participants were accessing both meanings of the IH causing a delay in their responses. This interpretation stems from the fact that, in the consistent trials the prime is an IH and, since the task requires participants to determine whether letter strings are real words or not, they must search both of their lexicons, causing them to take longer to respond. Furthermore, the slower RT for inconsistent trials relative to consistent trials suggests that participants were using the contextual cue to bias their reading of the IH. However, this pattern was not identical in L1 and L2. The separate language analyses revealed slower RT for the inconsistent condition than both the exclusive and consistent conditions (which did not differ), whereas in L2, all three levels of consistency differed significantly from each other. The greater RT for the consistent condition (i.e., triplet sequence: L2-IH-L2) than the exclusive condition (triplet sequence: L2-L2-L2) in L2, but not in L1, demonstrated a perseverance of the activation of the L1 meaning of the IH regardless of an initial L2 context. Furthermore, individuals appeared to be using the language context to aid in inhibiting the language inappropriate meaning of the IH. That is, for L1 the inconsistent condition (i.e., triplet sequence: L2-IH-L1) was significantly slower than the exclusive condition, and for L2 the inconsistent condition (i.e., triplet sequence L1-IH-L2) was significantly slower than both the exclusive and consistent conditions. This indicated that in L1, responses to IH primes in the consistent condition were similar as those to non-homograph primes and only targets preceded by an L2 context cue (i.e., the inconsistent condition) required significantly longer for responding. This suggested that the L2 meaning of the IH was accessed and therefore responding to a L1 target was more effortful. In L2, all three levels of consistency differed significantly from each other indicating that participants were using the language cue and that the inhibition of the L1 meaning of the homograph was more effortful causing RT to be significantly longer for consistent trials (i.e., L2-IH-L2; where the L1 meaning had to be inhibited), than exclusive trials, and even longer when the L2 meaning may not have been accessed in inconsistent trials (i.e., L1-IH-L2). Another possible interpretation is that there was a baseline level of activation of IHs in an individual's L1 that was greater than that in the individual's L2, thus, unless there was a preceding L2 context the default reading of the IH was in L1. That is, when an individual encountered an IH, regardless of whether both meanings were initially activated, the L1 reading received a greater level of baseline activation than the L2 reading. Therefore, if an L2 context was not present individuals were more likely to read the IH in their L1 and inhibit the L2 reading if it was, in fact, initially activated.

The overall accuracy analysis showed greater accuracy in the older group providing evidence to support spared semantic memory in aging (Zacks, Hasher & Li, 2000). This, taken together with the absence of age differences in the RT results, suggested that the sample of older adults was a select group who were high functioning, and may not be representative of the larger population of aging individuals. The older participants showed no difference in error rate across the three levels of Consistency and were significantly more accurate than young adults for the inconsistent condition. The young group, however, showed greater accuracy for exclusive and consistent conditions than the inconsistent condition, in L2 only. This, combined with the lack of differences between the levels of consistency for the older group, suggested that, in L2, the young were using the language context cue to inhibit the irrelevant meaning of the IH in both the consistent condition (i.e., L2-IH-L2) and the inconsistent condition (i.e., L1-IH-L2) to a greater extent than the older adults. That is, the young adults were actually using the inconsistent language cue to inhibit the irrelevant meaning of the IH, which, in cases where the target was inconsistent in language with the cue (i.e., L1-IH-L2), caused them to make more errors in the LDT. This further supports the possibility of a baseline level of activation for the L1 meaning of an IH since an increase in error rate was only observed when the language cue and target were inconsistent. Furthermore, the fact that older adults were more accurate than the young adults for the inconsistent condition supports the IDH (Hasher & Zacks, 1988) since older adults appeared to be accessing both meanings of the IH, despite the presence of a language cue intended to bias the reading of the IH towards the language of the cue.

The ERP data paint a different picture providing support for the idea that the electrophysiological measures assess different phenomena than the behavioural measures (Kotz, 2001). This is not surprising since the behavioural task at hand required participants to make a mindful decision in response to letter strings, which involves several stages of processing, whereas the ERPs measure the underlying cognitive processes involved in the semantic activation and processing of the target words. Cognitive processes involve both automatic processes and controlled processes, and the question that arises is whether the N400 component of the ERP measures one or both of these processes. In terms of RT, semantic priming effects at very short SOAs (150 ms) are thought to be a result of automatic spreading of activation (automatic processes), whereas at longer SOAs (>500 ms) they are thought to be expectancy induced (controlled processes; Neely, 1991). There is evidence to support the N400 as a measure of both automatic and controlled processing in semantic priming (see Kiefer, 2002; Titone & Salisbury, 2004), depending on the SOA. In this experiment participants were presented with the language cue and target for 1000 ms thus the N400 measures are more likely a result of controlled processes rather than automatic processes. It is noteworthy to mention that a long SOA was intentionally used in order to increase the likelihood that participants would use the contextual cue to bias their reading of the IH in conditions where an IH was present.

As a consequence of the small sample size I have chosen to discuss trends appearing in the grand average waveforms, in addition to the statistical analyses. Furthermore, since attenuation of the N400 has been observed in older adults (Gunter, Jackson & Mulder, 1998; Kutas & Iragui, 1998) the lack of statistical power may be exacerbated in this group, providing further reasoning for including the waveforms in my interpretations.

Prior to discussing the details of the results it is noteworthy that there were no overall significant differences between the young and older groups for N400 amplitude or latency, further supporting the behavioural data, suggesting that the older group represents a high functioning sample. Furthermore, there was no N400 priming for the exclusive conditions which was very unexpected since this condition was intended to serve as a baseline priming condition and similar stimuli (Phillips, Mercier & Klein, 2004) have been shown to demonstrate priming in the auditory modality in young adults.

The grand average waveforms for the young adults in L1 appear to show N400 priming effects for all three levels of consistency, although this effect appears to be more prominent for the inconsistent condition. The statistical analysis showed this effect to be significant, in the young adults, for the inconsistent condition at midline sites and at lateral sites for the inconsistent and consistent conditions. The broader topography of the

N400 priming effect in the inconsistent condition supports the idea that the younger adults were using the language cue to influence their reading of the IH. When the language cue and the target were consistent in language, N400 responses were small in the consistent condition relative to the inconsistent condition, however, when an inconsistent language cue was introduced, the L2 meaning of the IH became activated and the unrelated target, being unrelated to both language meanings of the homograph, resulted in a relatively large N400. This effect was not seen in the analysis of the older group, however, examination of the waveforms suggests a trend towards an N400 priming effect in the consistent condition for the older adults in L1. Older adults showed evidence of an N400 priming effect in conditions where an IH was present and the language cue and target were consistent in language suggesting that they may have benefited from the contextual cue and were processing the IHs more deeply than the non-homograph primes.

The fact that neither of the age groups showed priming effects in the exclusive conditions, where similar stimuli (Phillips, Mercier & Klein, 2004) have been shown to demonstrate priming in the auditory modality in young adults, is evidence that, in the presence of an IH, stimuli were being processed more deeply. More specifically, since the LDT required participants to decide whether letter strings were real words or not they may have been recognizing words that were exclusively in their L1 without the same degree of semantic processing required to identify IHs, which require a search through two lexicons rather than just one. If this were indeed the case we would expect to see a similar trend in the inconsistent condition. N400 priming for the inconsistent condition was present for the young participants, however, there was no such trend in the older group. One possible explanation for this is that the older adults were actually using the language cue and processing the IH in their L2 such that, regardless of the relatedness of the target word, due to the fact that it was in their L1, it was identified as being unrelated to the prime.

For the older adults processing the target in their L1 there was a significant Relatedness by Anteriority by Consistency by Time interaction in the lateral sites, showing significantly larger N400 amplitudes for unrelated trials in the consistent (i.e., L1-IH-L1) condition relative to the exclusive condition (i.e., L1-L1-L1). Furthermore, this effect was larger moving towards the anterior lateral sites. This suggests that the older adults may have been processing the prime (an IH) in the consistent condition more deeply than exclusively L1 primes. Since this effect was not seen for the inconsistent condition perhaps the L2 context provided by the language cue caused them to read the IH in their L2 and thus the L1 target became unrelated by virtue of the language switch from their non-dominant to their dominant language.

The supplementary analysis excluding the exclusive condition in the young group for L1 showed different N400 topography and latency for the consistent and inconsistent conditions. The N400 priming effect was spread over more scalp locations and was earlier for the inconsistent condition (i.e., L2-IH-L1) than the consistent condition (i.e., L1-IH-L1; see Figure 6). This demonstrates persistence of the activation of the L1 meaning of the IH even in the presence of an L2 language context. In an L2 context (i.e., L2-IH-L1), the N400 was significantly larger when the target word was unrelated to the prime than when it was related to the prime, showing that the L1 meaning of the IH was activated. The fact that there was a larger N400 when the target was unrelated in the inconsistent condition, relative to unrelated trials in the consistent condition, may be because the target was unrelated to both meanings of the IH.

Use of the contextual cue in the young group is further supported by the L2 analysis which, although the results were not statistically significant, showed a trend towards an N400 priming effect in the exclusive condition only (see Figure 8). Persistence of the L1 reading of the IH is demonstrated by the fact that there were no N400 priming effects in any of the conditions containing an IH, suggesting that L2 target words were perceived as 'unexpected' whether they were related to the L2 reading of the IH or not. Furthermore, N400 amplitude in response to both related and unrelated targets in the inconsistent condition (i.e., L1-IH-L2) appears to be greater than those seen in either the exclusive or consistent conditions. This suggests that the contextual cue caused the reading of the IH to be biased towards the L1 reading, causing both related and unrelated target stimuli to be identified as being unrelated due to the language switch.

There were also significantly greater N400 amplitudes in the right hemisphere than the left hemisphere for related targets that were inconsistent in language with the context cue (i.e., L1-IH-L2). Since N400 priming effects (i.e., larger N400 amplitude for unrelated target words) has been found to be larger over the right hemisphere (Holcomb, 1988), this further supports the idea that the young adults were accessing the L1 meaning of the IH in the inconsistent condition. Specifically, the larger N400 amplitude in response to related targets indicates that the L2 target was perceived as unexpected, which would be the case if the L2 reading of the IH was not initially activated, or was later inhibited, as a function of the L1 context provided by the language cue.

No statistically significant effects were found in L2 for the older adults although grand average waveforms show a trend towards an N400 priming effect in the inconsistent condition (i.e., L1-IH-L2), suggesting that older adults were not using the context cue to bias their reading of the IH towards L1, and they were activating the L2 meaning of the IH. The difficulty with this interpretation is that there were no priming effects in either the exclusive condition or in the consistent condition. This lack of an N400 priming effect may actually be an attenuation of the effect since smaller and later N400s have been found to accompany aging (Gunter, Jackson & Mulder, 1998; Kutas & Iragui, 1998). The fact that the effect can be seen in the inconsistent condition suggests that perhaps the switch in language between the language cue and the target adds an additional component of unexpectancy, causing an even greater N400 when the IH and the target are unrelated, since the target is unrelated to both readings of the IH.

The present study followed similar procedures as those used by de Bruijn et al. (2001), thus it was expected that results in the young group would replicate their findings. De Bruijn et al. investigated only the second language of young participants and found that RT and N400 priming effects were not affected by the language of the contextual cue. That is, regardless of context, related targets in the participants' L2 showed faster RT and smaller N400 amplitudes than unrelated targets in the participants' L2, which de Bruijn et al. interpret as evidence against the influence of context on the reading of IHs. The results of the present study provide mixed support for their interpretation. The conditions in the present experiment which are equivalent to those used by de Bruijn et al. are the L2 consistent condition (i.e., L2-IH-L2) and the L2 inconsistent condition (L1-IH-L2). RT results in the present study suggest that both meanings of the IH were accessed regardless of the language context, for both younger and older participants, which supports the results of de Bruijn et al. The ERP results from the present study however, do not support those found by de Bruijn et al. In the present study, no N400 priming effects were found for either the L2 consistent or inconsistent conditions for the young participants. The interpretation is that, in the present study, the young participants were persistently activating the L1 reading of the IH, regardless of the context. When the language cue and target were inconsistent in language they perceived both related and unrelated L2 targets as 'unexpected', suggesting that they were using the language cue to access the relevant meaning of the IH. Differences between the results of de Bruijn et al. and the present results may be due to the longer presentation of the language cue and prime in the present experiment. De Bruijn et al. presented the language cue and prime simultaneously for 500 ms, whereas in the present experiment the language cue and prime were presented simultaneously for 1000 ms, which may have given participants sufficient time to initially access both meanings of the IH and inhibit the irrelevant meaning.

Previous research has suggested that older adults exhibit a similar capacity as young adults, to use a sentence context to inhibit irrelevant information from working memory (Hopkins et al., 1995; Paul, 1996). In these studies both young and older participants were successful at inhibiting the irrelevant meaning of a monolingual homograph, and only showed facilitation for target words that were related to the relevant meaning of the homograph, regardless of the meaning dominance. If these results hold in a bilingual situation this would suggest that, in the present experiment, results for the younger and older participants should be similar in terms of consistency effects. That is, both groups should be successfully using context to bias their reading of an IH towards the language appropriate meaning. This is not what was found. Results from the present experiment differed between the young and older groups, demonstrating that they do not use the contextual cue in the same way. That is, the young adults appear to use the language context cue, in their L1 and their L2, to bias the reading of the IH towards the appropriate meaning while there is a perseverance of the L1 meaning regardless of the context. Older adults on the other hand, appear to make use of the contextual cue when the cue is intended to bias their reading of the IH towards L2, but not when the cue is intended to bias their reading of the IH towards their L1.

It has been suggested that when processing IHs there are frequency effects demonstrating differences in the processing of IHs that are dependant on the relative frequency of the IH in each language (Beauvillain & Grainger, 1987; de Groot, Delmaar, & Lupker, 2000). More specifically, it has been suggested that the higher frequency meaning of the IH is accessed regardless of a biasing context (Beauvillain & Grainger) and that there is a baseline level of activation for IHs that is greater for the higher frequency meaning (de Groot, Delmaar, & Lupker). It is possible that the present results demonstrate such frequency effects, however, this is unlikely considering that the stimuli were matched for frequency across conditions. Regardless of whether frequency plays a role or not, if there were an effect of context it should be evident in the present results regardless of frequency effects since the relative frequency of occurrence in each language for IHs was matched across all conditions. It is more likely that there is a baseline language effect whereby the L1 reading of the IH receives greater baseline activation than the L2 reading, as was suggested by the RT results.

Following the two testing sessions participants completed the IH checklist in order to establish whether they were familiar with the dual meaning of the IHs. Although no statistical analyses were conducted on these data, examination of the checklists demonstrated that individuals were aware of the existence of two meanings for the majority of the IHs. However, since the participants were not asked to provide the definition of the IH in each language, it is uncertain whether they were familiar with the meaning in each language. That is, they may have been conscious that that there were two meanings but, whether or not they were familiar with the actual definitions in each language remains unknown. Post-experiment feedback from participants indicated that, for the most part, participants were not aware of the presence of the IHs during the experiment. Furthermore, inspection of their responses for the IHs that were not identified as such in the checklist showed that 7 of the 10 young participants identified these IHs as being words in their L1, whereas this was only seen for 1 of the older adults. The remaining participants showed no language bias. This suggests that younger adults read the IHs in their L1 when there is no preceding L2 context, whereas the older adults do not. The older adults seem to be using a different strategy to select the reading of the IH. A more thorough investigation of the IHs and participants' knowledge of their dual meaning is necessary in order to substantiate this suggestion.

Another potential problem with this study is the nature of stimuli themselves. That is, due to the distinct meaning of the IHs in each language there were commonly differences between the word class that each meaning belonged to. For example, the letter string LOIN, which is a noun in English, means 'far' in French, and is an adverb. Necessarily, the targets also varied in word class and the number of words from each word class in each condition was not controlled. It was not anticipated that this would be problematic, however, it has been suggested that there are differences in word-class processing, demonstrating different ERP effects in response to verbs and nouns (Federmeier, Segal, Lombrozo, & Kutas, 2000; Khader, Scherag, Streb, Rösler, 2003). It is noteworthy that these two studies only examined nouns and verbs, and, furthermore they did so using a sentence context, therefore, it is uncertain how the variety of word classes present in the stimuli from the present experiment may have affected the results. It is possible that if each word class is, in fact, processed differently the results are confounded by these effects and are not truly measuring language context effects.

Creating further difficulties in interpreting our results is that recent evidence has suggested that the being bilingual may provide a buffer against age-related declines in executive processes (Bialystok, Craik, Klein, & Viswanthan, 2004), and specifically in inhibitory mechanisms (Zied, et al. 2004). The argument here is that bilingual individuals are frequently inhibiting one of their languages, which implies that older adults, who have had many years of experience manipulating two languages, actually have spared inhibitory functioning relative to their monolingual counterparts. Since all of the older participants were highly proficient in their L2 and had learned, and used, their L2 from an early age, they may not have demonstrated the declines that were expected based on previous literature. Unfortunately, due to the bilingual nature of the experiment a monolingual sample could not be used as a control group in order to further examine this hypothesis.

Due to the small sample size it is important to interpret these results with caution. However, it seems apparent that there are differences between the processing of IHs in an

L1 and an L2 context, and, furthermore, there appear to be age differences in the processing of IHs. This is particularly evident in the ERP waveforms. The best interpretation concerning the present results is that there is baseline activation of the L1 meaning of the IHs and only in the presence of an L2 context is the L2 meaning accessed. That is, when an sL2 context is provided the L2 meaning is simultaneously activated, but otherwise only the L1 meaning is accessed. Future research should examine the effects of context in individuals with varying degrees of L2 proficiency, which may provide insight, not only into context effects, but also into differences in the sparing of inhibitory mechanisms as a function of L2 proficiency. A different task may also be considered, such as an animacy judgement task instead of a LDT. That is, since participants were told that the words could be in French or English they may have been attending to the language of the word and using an animacy judgement task would eliminate this possibility. Furthermore, more controlled stimuli would reduce the possibility confounding frequency or word class effects. However, this is extremely difficult in view of the fact that ERP studies require large numbers of trials in each condition, and the nature of the IHs are such that stringent control reduces the number of possible stimuli that can be integrated into an experiment.

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Appendix A

Health and Language Questionnaire

History Questionnaire

We are interested in your personal history because it may help us to better understand the results of our study. Your answers to a few short questions will aid us in this effort. All answers will be kept strictly confidential. Thank you for your help.

Demographics:

1. Date of Birth (D/M/Y):______________ 2. Age:___________

3. Gender: *(circle response)* (1) Male (2) Female

4. Handedness: *(circle response)* (1) LEFT (2) RIGHT (3) BOTH

5. Present marital status: *(circle response)*(1) Single – never married
(2) Married
(3) Separated
(4) Divorced
(5) Widowed
(6) Cohabit

Language

6. Place of Birth:____

7. Languages Spoken (in order of fluency):_________________________________

8. Primary Language/Language of choice:__________________________________

9. Language at home:_______________________ 10. At Work:________________

11. Language of Education:___________________________________

12. At what age did you first learn English/French? ______________________

13. At what age did you become fluent in it?______________________

14. How would you rate, from 1 to 5[1], your level of proficiency in the languages you speak?

Language	Rating (**L**istening, **R**eading, **S**peaking, **W**riting):
1. ___________________	L:____ R:____ S:____ W:____
2. ___________________	L:____ R:____ S:____ W:____
3. ___________________	L:____ R:____ S:____ W:____
4. ___________________	L:____ R:____ S:____ W:____

[1] 1: No ability at all; 2: Very little; 3: Moderate; 4: Very good; 5: Native-like ability

15. .How many years of education do you have at this time? (i.e., what is the highest level achieved?)

1 2 3 4 5 6	7 8 9 10 11	12 13	14 15 16	17 18 19 20	21 22 23 24 25
Elementary	Secondary	Cegep	Undergrad	Graduate	Professional

16. In what field did you complete your degree? ______________________________

17. Did you skip or repeat a grade?
    A) NO / YES
    B) Which one (s):____

18. Did you have any particular difficulty with any subject in school?

19. What is or was your main occupation? __________________________________

Medical History

20. Do you have now, or have you had in the past -*(please circle your response)*

- Visual problems: A) Nearsighted / Farsighted
    B) Glasses / Contact lenses[2]
    C) Cataract: Left / Right
    D) Colour blind: NO / YES

    - Trouble hearing: E) NO / YES
    F) Hearing Aid: Left / Right

21. Have you ever been unconscious[3], had a head injury or had blackouts[4]?
    A) NO / YES
    B) Cause:____
    C) Duration:____
    D) Treatment:____
    E) Outcome:____

22. Have you been seriously ill or hospitalized in the past 6 months?
    A) NO / YES
    B) Cause:____
    C) Duration:____

---

[2] If participant usually wear contact lenses, he/she will have to wear glasses on ERP testing sessions (to prevent blinking).

[3] Falling unconscious ≠ Fainting

[4] Exclude: Substantial head injury relatively recently, several concussions, & coma.

Do you have now, or have you had in the past (conditions susceptible or influencing cognitive functions)...

23. a) A stroke? b) [5] Transient ischemic attack (mini-stoke[5])?	NO / YES NO / YES	
24[s]. Bypass surgery?	NO / YES	
25[S] Heart disease?	NO / YES	Nature (myocardial infarction [MI], angina, narrowing of arteries):
26 [S] High blood pressure?	NO / YES	Is it controlled? NO / YES What medication? ________
27 [S]. High cholesterol?	NO / YES	Is it controlled? NO / YES What medication? ________
28 [S]. a) Diabetes? b) Insulin dependent?	NO / YES	Type 1 / Type 2 Age of onset: ________ Treatment: ________
29. Other Surgery?	NO / YES	
30. Seizures?	NO / YES	Age Onset: ________ Frequency: ________ Cause: ________ Treatment: ________
31. Epilepsy?	NO / YES	
32. Thyroid disease?	NO / YES	
33. Frequent headaches?	NO / YES	Tension / migraine
34. Dizziness?	NO / YES	
35. Trouble walking Unsteadiness?	NO / YES NO / YES	
36. Arthritis?	NO / YES	
37. Any injuries to the lower limb? (e.g. hip, knee, ankle)	NO / YES NO / YES	
38. Serious illness (e.g. liver disease)?	NO / YES	
39. Neurological disorders[6]? (e.g. lupus)	NO / YES	
40. Exposure to toxic chemicals (that you know of)?	NO / YES	
41. Depression?	NO / YES	Did you seek assistance or feel the need to do so? Is it controlled?

[5] Mini-stroke: symptoms less than 24 hours.

[S] Risk factors for stroke. Exclusion criterion: More than one of those factors, if older participants.

[6] Automatic exclusion

42. Anxiety?	NO / YES	Did you seek assistance or feel theneed to do so? Is it controlled?
43. Other psychological difficulties?	NO / YES	
44. Hormone replacement?	NO / YES	
45. Steroids?	NO / YES	

46. Medication: Please list the medication you are currently taking and any other medication that you have taken in the past year.

Type of medication		Reason for consumption	Duration of consumption and dose
A			
B			
C			
D			
E			
F			

47. Do you drink alcohol? a) YES, frequently.
b) YES, but infrequently.
c) NO.
If YES, approximately how many drinks[7] of alcohol do you have per week? ____________________

48. Do you use non-prescription drugs such as homeopathic medications, vitamins, laxatives, syrups ? NO / YES
If YES, which one (s): ____________________________________
How many times per week?
a) Occasionally b) 1 - 3 c) 4 - 6 d) more than 6

49. Do you use non-prescription drugs for recreational purposes?
NO / YES
If YES, How many times per week?
a) Occasionally b) 1 - 3 c) 4 - 6 d) more than 6

---

[7] 1 drink = 1 beer, 1 glass of wine, 1 oz of liquor. 2 drinks/day is considered moderate drinking.

50. Do you smoke[8]?
NO / YES
If YES, How many packs a day (or average quantity)? ____

51. Current problems: Are you currently troubled by any of the following[8]?
a) Concentration / Attention problems?
NO / YES
Nature: ______________________________
b) Memory problems?
NO / YES
Nature: ______________________________
c) Difficulties finding words?
NO / YES
Nature: ______________________________

52) How would you rate your health? *(circle response)*
1) poor 2) fair 3) good 4) very good 5) excellent

Participant contact information:

Name: ______________________________

Address: ______________________________

____

____

____

Phone Number: ______________________

Are you willing to be contacted for future research? NO / YES

What year will you graduate? ______________________

Can we give your information to other Concordia researchers? NO / YES

[8] Please remind potential older participants who are interested in participating to research because of memory concerns that we do NOT provide full clinical assessments

Appendix B

List of Interlingual Homographs and Norms in English

Table B

List of Interlingual Homographs and Norms in English

Interlingual Homograph	Frequency	Concreteness	Familiarity	Imageability
ail	-	385	370	391
allure	0.99	-	-	-
appoint	5.92	-	-	-
as	7149.90	158	586	224
attend	53.25	324	545	386
bail	6.90	441	485	480
ballot	11.83	455	453	437
bond	45.36	403	454	380
bout	6.90	-	-	-
bribe	0.99	367	531	425
but	4320.51	227	603	206
cane	11.83	590	442	608
cap	26.63	-	429	-
chair	65.09	606	617	610
chandelier	2.96	-	-	-
char	0.99	-	-	-
choir	7.89	567	526	567
chose	36.49	-	-	-
coin	9.86	581	564	603
comment	41.42	-	-	-
communal	3.94	-	-	-
dent	1.97	517	480	486
destitution	-	-	-	-
devise	7.89	-	-	-
dire	0.99	-	-	-
dispenser	0.99	-	-	-
dresser	0.99	560	526	556
employer	14.79	-	-	-
fade	1.97	-	-	-
file	79.88	480	504	442
fin	1.97	-	-	-
fond	12.82	-	556	363
forage	2.96	-	-	-
four	354.04	365	553	491

gaze	11.83	-	-	-
impair	3.94	-	-	-
impotent	1.97	-	-	-
isolation	15.78	-	-	-
labourer	-	-	-	-
lame	1.97	-	-	-
lecture	15.78	451	624	564
lent	4.93	-	-	-
lien	1.97	332	204	317
lit	16.77	-	-	-
location	62.13	-	-	-
loin	0.99	-	-	-
main	117.36	324	574	309
manger	-	-	-	-
mare	15.78	549	460	529
miser	-	-	-	-
net	33.53	577	514	540
on	6648.92	262	614	268
once	492.11	315	539	322
pain	86.79	426	569	502
partition	5.92	-	-	-
pays	-	-	-	-
pester	0.99	-	-	-
pet	7.89	557	541	589
pin	15.78	600	524	576
pour	8.88	356	545	495
primer	-	-	-	-
raisin	0.99	-	-	-
rampant	3.94	-	247	337
rang	20.71	-	-	-
ranger	1.97	-	-	-
rate	206.11	308	527	311
rater	-	-	-	-
rayon	-	-	-	-
rebut	5.92	-	-	-
rein	2.96	537	440	478
relevant	22.68	-	-	-
rentable	-	-	-	-
ride	48.32	424	576	483

rider	15.78	-	-	-
river	162.72	585	565	633
rot	7.89	-	-	-
sale	43.39	364	555	422
sang	28.60	-	-	-
seize	5.92	-	-	-
sensible	13.81	-	507	334
singe	-	-	-	-
singer	9.86	553	548	575
slip	18.74	448	537	497
son	163.71	-	607	560
sort	161.74	-	-	-
stage	171.60	-	-	-
store	72.98	548	562	506
talon	-	-	-	-
tape	34.52	564	567	573
taper	2.96	362	384	372
taupe	-	-	-	-
tenant	4.93	-	-	-
tentative	14.79	-	442	266
tire	21.70	563	546	511
ton	12.82	473	501	475
tremble	9.86	-	-	-
van	31.56	606	542	572
vent	9.86	-	-	-
venue	-	-	-	-
vie	-	-	-	-

Notes: 1. Frequencies have been transformed from Kučera and Francis (1967) and represent the number of occurrences per million, thus they are directly comparable to the French frequency norms.

2. '-'represents missing data.

Appendix C

List of Interlingual Homographs and Norms in French

Table C

List of Interlingual Homographs and Norms in French

Interlingual Homograph	Frequency	Concreteness	Familiarity	Imageability
ail	0.96	636	509	565
allure	50.89	-	-	-
appoint	16.32	353	505	394
as	5.76	-	-	-
attend	-	317	577	357
bail	8.64	371	504	426
ballot	128.66	-	-	-
bond	21.12	389	539	494
bout	259.24	459	493	483
bribe	5.76	-	-	-
but	167.07	482	554	556
cane	-	606	529	632
cap	19.20	-	-	-
chair	46.09	597	483	567
chandelier	5.76	-	-	-
char	14.40	622	634	638
choir	5.76	331	537	351
chose	725.88	350	587	358
coin	111.38	533	556	556
comment	334.13	195	593	230
communal	15.36	-	-	-
dent	59.53	619	578	624
destitution	0.96	300	447	362
devise	19.20	-	-	-
dire	2434.95	-	-	-
dispenser	21.12	316	552	310
dresser	70.09	-	-	-
employer	140.18	-	-	-
fade	3.84	-	570	373
file	13.44	477	591	491
fin	440.71	320	592	462
fond	236.20	-	587	436
forage	3.84	-	590	390
four	8.64	593	577	599

gaze	1.92	-	-	-
impair	0.96	-	-	-
impotent	2.88	-	-	-
isolation	4.80	-	-	-
labourer	0.96	-	-	-
lame	27.84	584	517	568
lecture	63.37	377	581	436
lent	50.89	293	602	377
lien	56.65	488	474	481
lit	148.82	635	636	635
location	5.76	-	-	-
loin	323.57	302	587	411
main	564.57	604	601	598
manger	120.98	486	529	563
mare	5.76	623	506	599
miser	2.88	403	527	453
net	92.17	392	610	454
on	5094.58	270	614	389
once	32.65	502	565	457
pain	-	622	611	619
partition	3.84	-	-	-
pays	788.29	465	592	539
pester	-	363	484	415
pet	0.96	-	-	-
pin	16.32	592	557	617
pour	7663.95	245	603	216
primer	8.64	-	-	-
raisin	4.80	611	532	591
rampant	2.88	-	-	-
rang	71.05	-	-	-
ranger	48.01	311	490	478
rate	7.68	-	-	-
rater	25.92	372	586	447
rayon	56.65	502	476	539
rebut	6.72	-	-	-
rein	20.16	-	-	-
relevant	-	450	564	471
rentable	19.20	-	-	-
ride	11.52	-	-	-

rider	1.92	-	-	-
river	5.76	-	-	-
rot	0.96	-	-	-
sale	29.76	-	589	485
sang	107.54	613	571	620
seize	39.37	-	-	-
sensible	62.41	-	550	434
singe	25.92	566	531	588
singer	0.96	-	-	-
slip	1.92	-	-	-
son	68.17	502	597	497
sort	62.41	363	484	415
stage	36.49	-	-	-
store	-	443	531	485
talon	14.40	579	524	597
tape	1.92	511	521	542
taper	15.36	-	-	-
taupe	0.96	590	484	567
tenant	10.56	-	-	-
tentative	46.09	313	558	302
tire	-	-	-	-
ton	1.92	-	-	-
tremble	2.88	-	-	-
van	0.96	-	-	-
vent	104.66	552	592	535
venue	26.88	-	-	-
vie	1015.84	361	598	482

Notes: 1. Frequencies have been transformed from Baudot (1992) and represent the number of occurrences per million, thus they are directly comparable to the English frequency norms.
2. '-'represents missing data.

Appendix D

Interlingual Homograph Checklist

Word	French	English	Both	Word	French	English	Both
abondant				century			
absurde				cerf			
acteur				chair			
adulte				chalk			
agony				chameau			
ail				chandelier			
alarme				char			
allure				charcoal			
almond				charpentier			
ancre				chemise			
ange				choir			
angel				chose			
appoint				citrus			
arctique				coffee			
as				coin			
attend				comment			
award				communal			
bagage				contre			
bail				coude			
bain				courbature			
ballot				curtain			
barley				dawn			
basement				dent			
bateau				dentiste			
beach				despair			
bijou				dessus			
blanket				destitution			
bond				devise			
bout				dire			
bribe				dismay			
brush				dispenser			
bug				dresser			
burden				earring			
but				egg			
cabanon				employer			
cabbage				encore			
cadeau				fade			
calme				fame			

cane				farine			
cap				field			
carotte				file			
carpet				fin			
carte				fog			
pin				fond			
plancher				forage			
plume				forest			
poivre				four			
poulet				fugitive			
pour				garden			
priest				garlic			
priest				gaze			
primer				genius			
raisin				glace			
rampant				graine			
rang				hand			
ranger				impair			
rate				impotent			
rater				isolation			
rayon				judge			
rebut				knock			
recto				labourer			
rein				lame			
relevant				lecture			
renard				lent			
rentable				lien			
retain				lit			
ride				location			
rider				loin			
river				main			
robin				manger			
rot				mare			
salaire				mint			
sale				miser			
sang				mitaine			
seize				net			
sensible				odeur			
singe				on			

singer				once			
skull				oreille			
slip				oven			
sollicite				pain			
son				pants			
sort				paradise			
sound				partition			
sourcils				pays			
stage				permettre			
steeple				pester			
stop				pet			
store				tire			
sugar				toit			
tablier				ton			
talon				toujours			
tape				tourment			
taper				town			
tapis				tremble			
taupe				vache			
tenant				van			
tentative				vent			
voile				venue			
woman				vie			

Appendix E

Consent Form

Consent Form
Electrophysiological Investigation of Bilingual Language Processing

Purpose of the Study:

I have been informed that the purpose of this research is to examine the effects of age on a lexical decision task in order to increase our present understanding of age-related changes in bilingual language processing and the brain processes associated with those changes.

Details of the Study:

The study will take place in the Cognitive Psychophysiology laboratory of the Department of Psychology at Concordia University. The electroencephalogram (EEG) is a recording of electrical brain activity measured at the scalp (similar to an EKG recording of heart activity). To record the EEG, a nylon cap containing small sensors (electrodes) will be placed on my head. To obtain proper recordings, the scalp area underneath each sensor will be lightly rubbed with electrolytic gel. The gel resembles a facial scrub and is used to prepare the skin surface.

The study will be conducted in a small testing room. I will be seated in a comfortable chair and will be presented with letter strings on a computer monitor. I will be asked to read each letter string silently and asked to indicate, using a keypad, whether or not the words were real words. I understand that I may make errors but the most important thing is that I will try to do my best. I will also be asked to complete a colour naming task, in which I will be asked to name colours and read colour words, and a living/nonliving judgement task in which I will be asked to judge whether words refer to living or nonliving objects, in French and English. Two other paper and pencil tasks will be used to assess my cognitive performance, these include the Montreal cognitive assessment and the digit-symbol coding subtest of the Wechsler Adult Intelligence Scale, 3rd edition.

I will be asked to visit the Laboratory at Concordia University on two occasions and each testing session will last approximately 2 hours. I understand that I will not be required to complete any tasks other than the ones mentioned above and I have been informed that certain demographic information (age, sex, education, language, and health status) will be recorded. I understand that this test is for research purposes only and that it is not diagnostic, meaning that it will not yield any results about my health. I understand that my individual results will not be provided to me, however, I will be informed of the general findings of the study. In the unlikely event that any potentially significant abnormality in my EEG is observed, this information will be forwarded to my family physician with my permission.

Disadvantages and Risks of Participating in the Study:

EEG testing is a painless and non-invasive procedure (using no foreign substances like medications, tubes, or needle injections). Nevertheless, while the scalp is being prepared for recording, some people may experience a mild and temporary discomfort where the skin is being rubbed. It is also possible that this task will lead to fatigue and frustration because I may not be able to accurately read or judge all the information with which I will be presented. However, I am asked to do the best that I can and I will be given frequent breaks whenever required to avoid this. I understand that, in the *unlikely* event that any finding of possible clinical significance is made and communicated to my physician, it may be recommended that I have additional testing which would not have taken place if I had not participated in this study.

Advantages to Participating in the Study:

The researchers hope to learn more about the different brain processes that are involved when a bilingual person reads words in their native language and in their second language and how these processes are affected by age. Although this will not benefit me directly, this research could add to our scientific understanding of age related differences in language comprehension and communication. In addition, I will gain knowledge about how psychological research is conducted.

Confidentiality:

I understand that my participation in this study is *confidential*, that is, the researcher will know but will not disclose my identity in any published report or scientific communication. My records will not be identified by name; instead a subject code will be used. If the present study is published, only group results will be mentioned, ensuring my confidentiality as a participant in this experiment.

Withdrawal from the Study:

I understand that my participation in this study is voluntary and, if I agree to participate, I may withdraw my consent and discontinue participation *at any time* without negative consequences.

Participant's Rights:

I have fully discussed and understood the purpose and procedure of this study and have had the opportunity to ask any questions.
The following is the name, address, and telephone number of the researcher whom I may contact for answers to questions about the research or any injuries or adverse reactions which might occur: **Dr. Natalie Phillips, Department of Psychology, Concordia University, 7141 Sherbrooke Street West, Montreal, Quebec, H4B 1R6; tel: 848-2424 ext. 2218**

Signature:

I have understood the contents of this consent form and have had the opportunity to ask questions. I agree to participate in this study.

Date___________________

Signature of Subject	Print Name
Signature of Investigator	Print Name
Signature of Person explaining Informed Consent	Print Name

Appendix F

Debriefing Sheet

Debriefing Sheet

Bilingualism and Aging: Electrophysiological measures of interlingual priming

Using a single word to vary language context we are investigating the effect of context on the reading of interlingual homographs (words with identical orthography but different meanings in French and English, e.g., COIN meaning 'corner' in French and 'money' in English). It is hypothesized that older adults will rely on context to a greater extent than young adults. The two groups in this study are young bilingual adults and older bilingual adults. The dependent variables we are examining are electrical brain activity (event-related brain potentials) and reaction time measures. This study has implications for future research in the area of aging and bilingualism, as well as potential importance for research into age-related diseases such as Alzheimer's disease. We hope to provide insight into possible age-related declines in bilingual language processing, as well as examine some of the advantages afforded by being bilingual, and apply this knowledge to patient populations.

For further information or questions regarding this study please contact the experimenter, Shanna Kousaie, or the faculty supervisor, Dr. Natalie A. Phillips, at 848-2424 ext.7546. For ethical concerns regarding this study please contact Adela Reid at the University Office of Research (adela.reid@concordia.ca or 848-2424 ext. 7481) or Dr. Adam Radomsky from the Psychology Department Ethics Committee (adam.radomsky@concordia.ca).

Suggested Readings:

De Bruijn, E.R.A., Dijkstra, T., Chwilla, D.J., & Schriefers, H.J. (2001). Language context effects on interlingual homograph recognition: evidence from event-related potentials and response times in semantic priming. *Bilingualism: Language and Cognition, 4*, 155-168.

Hasher, L., & Zacks, R.T. (1988). Working memory, comprehension, and aging: A review and a new view. In G.H. Bower (Ed.), *The Psychology of Learning and Motivation* (pp. 193-225). San Diego, USA: Academic Press, Inc.

Appendix G

ANOVA Table for Omnibus L1 ERP Analysis

Table G

Main Effects and Significant Interactions for Omnibus L1 ERP Analysis

Source	*F*	df	*MSE*	*eta²*	ε
			Midline sites		
Age	0.04	1, 18	1897.88	.00	N/A
Relatedness	0.97	1, 18	123.62	.05	1.00
Consistency	0.01	2, 36	163.54	.00	.93
Site	13.05**	4, 72	160.70	.42	.54
Time	10.05**	7, 126	217.60	.36	.28
T x A	6.78**	7, 126	217.60	.27	.28
C x S	2.84*	8, 144	14.60	.14	.42
S x T	3.21*	28, 504	21.88	.15	.12
R x T	2.40*	7, 126	5.07	.12	.64
R x T x A	4.66**	7, 126	5.07	.21	.64
			Lateral sites		
Age	0.31	1, 18	1340.84	.02	N/A
Relatedness	1.13	1, 18	126.29	.06	1.00
Consistency	0.06	2, 36	141.24	.00	.96
Anteriority	12.03**	2, 36	151.12	.40	.71
Laterality	0.44	1, 18	192.20	.02	1.00
Time	11.16**	7, 126	180.14	.38	.28
T x A	4.86*	7, 126	180.14	.21	.28
An x T	3.20*	14, 252	19.43	.15	.16
R x T x A	3.59**	7, 126	4.52	.17	.63
L x R x T	3.02*	7, 126	0.67	.14	.62
L x An x T	6.09**	14, 252	3.88	.25	.16
R x C x T	2.03*	14, 252	4.20	.10	.65
L x R x An x C x A	2.67*	4, 504	1.06	.13	.94

*$p < .05$
**$p < .01$

Appendix H

ANOVA Table for Omnibus L2 ERP Analysis

Table H

Main Effects and Significant Interactions for Omnibus L2 ERP Analysis

Source	*F*	df	*MSE*	*eta*^{2}	ε
			Midline sites		
Age	0.00	1, 18	2348.18	.00	N/A
Relatedness	0.41	1, 18	129.05	.02	1.00
Consistency	0.23	2, 36	132.79	.01	.94
Site	8.76**	4, 72	157.96	.33	.54
Time	10.55**	7, 126	200.56	.37	.28
T x A	7.15**	7, 126	200.56	.28	.28
R x T	3.70*	7, 126	3.94	.17	.70
S x T	2.72*	28, 504	19.79	.13	.12
			Lateral sites		
Age	0.06	1, 18	1679.04	.00	N/A
Relatedness	0.39	1, 18	120.42	.02	1.00
Consistency	0.22	2, 36	121.66	.01	.96
Anteriority	8.36**	2, 36	120.31	.32	.73
Laterality	0.96	1, 18	163.78	.05	1.00
Time	12.04**	7, 126	156.04	.40	.29
T x A	6.21**	7, 126	156.04	.26	.29
An x T	3.23*	14, 252	16.20	.15	.15
L x T x A	4.17*	7, 126	9.03	.19	.33
L x An x T	5.89**	14, 252	3.10	.25	.18
R x An x C x T	3.48**	28, 504	0.67	.16	.28

*$p < .05$
**$p < .01$