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# Age-related Differences in Interlingual Priming: A Behavioural and Electrophysiological Investigation

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Abstract

Reaction time (RT) and the N400 ERP component were measured to examine age-related differences in bilingual language processing. Although young bilinguals appear to access both languages simultaneously (i.e., non-selective access), little is known about language selection in older adults. The effect of language context on language selectivity was investigated using interlingual homographs (IH; i.e., words with identical orthography but distinct semantic features in two languages, e.g., *coin* meaning "corner" in French and "money" in English). Younger and older French/English bilinguals were presented with triplets of letter strings comprised of a language context cue, an IH, and a target word, in a lexical decision semantic priming task. RT and ERP results support non-selective language access in young adults; however, the older bilinguals used the language context cue to bias their reading of the IH. Results are discussed in terms of age-related changes in language processing and context use in bilinguals.

KEYWORDS: aging, bilingualism, context, event-related brain potentials, N400

# Age-related Differences in Interlingual Priming: A Behavioural and Electrophysiological Investigation

Estimates suggest that half of the world's population is bilingual (Fabbro, 1999). This, coupled with continually increasing life expectancy rates, results in a large proportion of older bilingual individuals living in our society; however, interest in language processing in these individuals is a relatively new area of study. Understanding language processing in bilingual older adults is essential given that language is our primary form of communication and has great importance for maintaining social interaction and decreasing social isolation in the older population, which have implications for both the physical and mental health of the older adult (Hall & Havens, 2001; Ryan & Butler, 1996). The purpose of the present experiment was to replicate and extend previous findings for word processing in bilingual younger adults and to investigate age-related changes in bilingual language processing. We examined bilingual language processing in younger and older adults in order to determine whether there are age-related differences in the use of language context when processing a native language (L1) and a second language (L2), using both behavioural and electrophysiological measures.

Bilingual language access has often been investigated using semantic priming, which refers to the facilitation of the processing of a target word (e.g., *cat*) when preceded by a related word (the prime; e.g., *dog*) compared to an unrelated word (e.g., *table*). Behavioural semantic priming effects are robust and are reflected in faster response time (RT) and greater accuracy for semantically-related than for semantically unrelated or neutral prime-target pairs (e.g., Neely, 1977, 1991). Semantic priming effects have been extended to bilinguals with French or English as their native language in both their L1 and L2 (Favreau & Segalowitz, 1983), as well as to other language combinations (e.g., de Groot, Delmaar & Lupker, 2000; Kotz, 2001).

Semantic priming can also be measured electrophysiologically using event-related brain potentials (ERPs) which are extracted from the electroencephalogram (EEG), an ongoing measure of electrical brain activity. Specifically, the N400 component is a negative deflection of the brain wave approximately 400 ms post-stimulus (Kutas & Van Petten, 1994), whose negativity increases as the mismatch between a current stimulus and an expected or primed stimulus increases. However, the amplitude and latency of the N400 varies, which is believed to reflect the strength and timing of the underlying psychological processes (Coles & Rugg, 1995). The N400 priming effect refers to the greater negativity observed in response to an unrelated target relative to a related target. The N400 provides an on-line measure of cognitive processing on the order of milliseconds and is a valuable tool for studying language given its dynamic nature (see Kutas & Federmeier, 2000). RT reflects the end point of a number of processes, including decisional and motor responses. However, ERPs are recorded at the onset of an eliciting stimulus and thus can provide information about psychological processes that are independent of RT (Kotz, 2001; Phillips, Segalowitz, O'Brien & Yamasaki, 2004). Although RT and the N400 can be similarly influenced by priming in general (i.e., shorter RTs and smaller N400 amplitude), they provide non-redundant information because they can reflect processes at differing points in the processing pipeline (e.g., Van Petten & Kutas, 1987).

The present study investigated age-related differences in how bilingual individuals process words that are lexically ambiguous in terms of language. Specifically, we investigated the priming afforded by interlingual homographs (IHs), words that have identical orthography in two languages, but distinct semantic features (e.g., *coin*, meaning "money" in English and "corner" in French). IHs have been used to a large extent to establish whether bilingual language access is non-selective (i.e., both languages are accessed concurrently) or selective (i.e., the two languages are processed separately, with greater and more rapid activation of a native language). Past research has paired IHs with a target word related to each distinct meaning and measured differences in observed semantic priming, as well as contextual influences on bilingual lexical access. Generally, it has provided evidence for the language non-selective view.

For instance, Beauvillain and Grainger (1987) found that an IH primed target words related to its meaning in the non-target language at a short (0 ms) SOA, indicating that initially both meanings of the IH were accessed. However, at a long (750 ms) SOA only the appropriate meaning remained activated. When the IH prime could be biased towards either of the participant's languages there was non-selective access to both meanings of the IH regardless of whether the bias was towards the participants' L1 or L2. This demonstrated that the previously observed non-selective access was language-independent.

More recently de Groot, Delmaar, and Lupker (2000) found further evidence of language non-selective access in a translation recognition task, which necessarily requires the activation of both lexicons. Participants saw word pairs in a translation recognition task where critical word pairs contained an IH. The results showed increased RT and error rates when the stimuli contained an IH, indicating interference caused by the dual meaning of the IH. Furthermore, there was less interference when the IH appeared in the second position, suggesting that the non-homographic first word influenced the reading of the IH. Paulmann, Elston-Güttler, Gunter and Kotz (2006) also found language non-selective access in the presence of a global language context. Participants watched a movie narrated in their L1 or their L2 and subsequently performed a LDT in their L2. It was found that even in an all L2 task with a global L2 context participants were not able to suppress activation of their L1 when performing a lexical decision on prime-target pairs where the prime was an IH.

Evidence for language non-selective access has also been found using ERP measures. Kerkhofs, Dijkstra, Chwilla, and de Bruijn (2006) investigated whether a language unambiguous prime word would influence the reading of a related IH target word. L2 primes were followed by IH targets that varied in relative frequency between languages in a LDT. RT and the N400 priming effect were modulated by the relative frequency of the IH in each language such that RTs were faster and the N400 priming effect was larger when the IH had a high frequency L2/low L1 reading relative to when it had a low L2/high L1 reading. This suggests an influence of the L1 meaning of the IH despite the L2 prime.

In a study directly related to the present investigation, de Bruijn, Dijkstra, Chwilla, and Schriefers (2001) examined the extent to which a surrounding language context modulates access to one semantic representation of an IH. Stimuli were word triplets comprised of a biasing language context cue (i.e., high frequency Dutch or English non-homographic words), an IH prime, and a target word that was either related or unrelated to the English (L2) meaning of the IH. Regardless of the language context, there was both RT and N400 priming for target words related to the IH. That is, an incompatible language cue did not suppress the activation of the meaning of an IH in the non-target language.

Although the studies reviewed here provide compelling support for the language non-selective view of bilingual language access, very little attention has been focused on how bilingual language processing may be affected by aging. Given the cognitive changes that have previously been associated with aging and found to affect language comprehension in older adults (Wingfield & Stine-Morrow, 2000) one may expect to see age differences in bilingual language processing.

Age-related changes in cognition and language have been well-documented (e.g., Craik & Salthouse, 2008), although theories differ with respect to the proposed mechanism of change. The processing-speed theory (Salthouse, 1996) proposes that there is age-related slowing of relatively general cognitive mechanisms which constrains the performance of older adults on a variety of cognitive tasks, including their ability to process language. A second hypothesis, the inhibition deficit hypothesis (Hasher & Zacks, 1988; Zacks & Hasher, 1997), postulates that age-related declines in language comprehension can be accounted for by inefficient inhibitory mechanisms in aging. This results in irrelevant information entering working memory (i.e., a limited-capacity system that is used to hold and manipulate recent information; Baddeley, 1986)) and receiving sustained activation thereby competing for processing resources. Another proposed explanation for age-related changes in language is limitations in working memory that are independent of inhibition (Just & Carpenter, 1992). There exist other alternative views (the transmission deficit hypothesis; MacKay & Burke, 1990), or changes in attentional modulation (Balota, Cortese & Wenke, 2001)). Regardless of the mechanism of change, it is clear that there are age-related changes in language and cognition that could be relevant for the bilingual older adult. Despite these age-related difficulties, the ability of older adults to communicate and functionally use language remain well preserved (Wingfield & Stine-Morrow, 2000). Of relevance to this study is the greater use of contextual information by older relative to younger adults, which may be used as a compensatory strategy.

Early studies of age-differences in the use of linguistic context have found that older adults show greater contextual facilitation for visual word recognition. Cohen and Faulkner (1983) tested younger and older adults in a LDT with visual target words that were preceded by either a sentence with the final word missing or a string of XXXs. Although the younger and older adults used context in a similar fashion when the final word was highly predictable based on the sentence context, when predictability was low only the older adults showed facilitation for the target word. This suggests that the older adults benefitted from or relied on the context to a greater extent than the younger adults. Madden (1988) found a similar result using degraded visual stimuli. Specifically, younger and older adults performed a LDT on sentence terminal target words where the semantic relation between the sentence and the target word and the quality of the visual stimuli were manipulated. Their results again demonstrated greater contextual facilitation in the older relative to the younger adults. Similar results have also been documented in the auditory modality (see Pichora-Fuller, 2008; Pichora-Fuller, Schneider & Daneman, 1995; Sheldon, Pichora-Fuller & Schneider, 2008).

The literature on monolingual lexical ambiguity (i.e., lexical items that have similar orthography but different semantic features within a single language) provides additional support for the spared ability of older adults to use context (see Balota, Cortese & Wenke, 2001). Specifically, Hopkins, Kellas and Paul (1995) found that both younger and older adults showed selective activation for the appropriate meaning of sentence final homographs in a naming paradigm. Furthermore, responses to target words related to the inappropriate meaning of the homograph did not differ from unrelated targets. Paul (1996) extended this finding to situations in which the homograph appears early on in the sentence and disambiguating information occurs later (e.g., *I waited at the <u>bank</u> until the <u>cashier/boat</u> returned for me).* In this situation multiple meanings of the homograph should become activated and, if older adults are not able to make use of the sentence context to direct their interpretation of the homograph, they should show semantic priming for both meanings of the homograph. This was not the case; both younger and older adults showed faster responses to context appropriate targets relative to unrelated targets.

Older adults have similarly demonstrated a spared ability to use context when target words follow a homograph prime that was preceded by a single word context (Balota, Boland & Shields, 1989; Balota & Duchek, 1991) suggesting that the even a single word is sufficient contextual support for older adults.

More recently, using ERPs it has been found that older adults may be more sensitive than younger adults to contextual constraints when listening to sentences terminating in an ambiguous word. Swaab, Brown, and Hagoort (2003) found that younger adults demonstrated activation of both meanings of an ambiguous sentence final word regardless of context whereas older adults did not demonstrate activation of contextually inappropriate subordinate meanings (Swaab, Brown & Hagoort, 1998). Furthermore, Winkler & Swaab (2001) found that younger adults demonstrated multiple activations while older adults demonstrated immediate selection of the appropriate homograph meaning. Taken together, these findings suggest that older adults may actually benefit from contextual support to a greater extent than younger adults when interpreting lexical ambiguity in a single language.

The above described studies all refer to the use of semantic context by older adults, whereas we are interested in the use of language context by older adults to direct their reading of an ambiguous word whose ambiguity is not semantic, but rather is language-related. There are similarities in models of lexical ambiguity resolution in the monolingual literature and models of bilingual word recognition. Specifically, in the monolingual literature a prominent model of lexical ambiguity resolution is the exhaustive access model (see Altarriba & Gianico, 2003). This model proposes that initially all meanings of a homograph are activated followed by selection of the appropriate meaning and suppression of the inappropriate (Simpson, 1984). In terms of bilingual word recognition, the bilingual interactive activation (BIA) model (Dijkstra & van

Heuven, 1998) and its counterpart, the BIA+ model (Dijkstra & van Heuven, 2002) describe the recognition of orthographic representations in terms of an interactive language system rather than a separate system for each language. According to this model, the activation of specific words is caused by the activation of letter nodes and all words that contain the activated letters in the correct positions are activated regardless of language. Furthermore, the model postulates that there is initial non-selective activation followed by selection of the appropriate meaning and suppression of the inappropriate meaning. However, these models have not been assessed in older bilingual adults.

Taken together the research reviewed here suggests that, 1) there is language non-selective access in young bilinguals; 2) there are age-related changes in language processing associated with aging; and 3) older adults demonstrate the ability to use context to support language comprehension and resolve lexical ambiguity, which may surpass the reliance on context of younger adults. The present study attempts to bring these areas of research together and address the question of whether there are age-related differences in bilingual language access which may result in differences in the use of context in a lexically ambiguous situation where the ambiguity is language-related.

Using a paradigm similar to that used by de Bruijn et al. (2001) the present study examined the effects of both a L1 and a L2 language context cue on the processing of an IH in both younger and older bilinguals. By using French/English IHs in a semantic priming paradigm it is possible to determine which of the two meanings of the IH is activated, whether this is affected by a preceding context, and whether this is modulated by age. Unlike previous research, these effects were examined in both directions (i.e., L1 to L2, L2 to L1) in the event that there are asymmetrical effects due to greater L2 experience in the older adults. Critical stimuli were word triplets, where the first word was a cue designed to bias reading towards one language, the second word was an ambiguous IH semantic prime, and the third word was a target word designed to measure which meaning(s) of the IH were activated. Take, for example, the triplet *shoe-coin-money*. *Shoe* is an unambiguous high frequency English word which served as the language context cue and was designed to bias the reader towards the English meaning of subsequent words[1], *coin* is an IH meaning "money" in English and "corner" in French, and *money* is the target word related only to the English reading of *coin*. In this scenario, a priming effect would be expected relative to an unrelated control condition (e.g., *shoe-coin-house*) since the English meaning of *coin* should be activated and would prime *money*. However, if presented with the triplet *soulier-coin-money*, where *soulier* is a high frequency French word intended to bias the reading of the IH towards the French meaning, a priming effect is only expected if the English meaning of *coin* is accessed regardless of the French language context cue. Note that in this design, the contrast is between activation of the target word as a function of the language context cue (i.e., *shoe-coin-money* versus *soulier-coin-money*); similar predictions could have been tested where the target word switched language (e.g., *shoe-coin-money* versus *shoe-coin-ruelle*). However, we reasoned that the first contrast was preferable as it allowed for comparisons between target words that did not switch language.

With respect to general predictions, semantic priming should result in faster RTs in response to targets related to the activated meaning(s) of the IH primes relative to targets unrelated to the IH primes and/or related to the inactivated meaning(s). Similarly, the N400 should be larger for target words unrelated to the IH prime or related to the inactivated meaning(s) relative to target words related to the activated meaning of the IH prime.

Because we did not want the absence of priming effects to be due to low proficiency, we tested bilingual younger and older adults who were highly proficient in their L2. Given that younger adults have been found to simultaneously access both meanings of an IH despite a biasing context (de Bruijn et al., 2001; Kerkhofs et al., 2006), we predicted similar priming effects in this group regardless of whether the context cue and the target were consistent (e.g., *shoe-coin-money*) or inconsistent (e.g., *soulier-coin-money*) in language. Specifically, we hypothesized that the younger adults would show both RT and N400 priming effects (i.e., faster RT and smaller N400 amplitudes for related relative to unrelated targets) regardless of whether the language cue and target word were consistent or inconsistent in language. However, given the evidence indicating the greater use of context by older adults to support language comprehension, the older adults were expected to make use of the language biasing context cue and thus only show semantic priming effects when the context cue and the target were consistent in language (i.e., priming for *shoe-coin-money* but not *soulier-coin-money*). Furthermore, it was expected that there would be no difference in RT and N400 amplitude for target words unrelated to the IH and those related to the IH when the language cue and target word were inconsistent in language, indicating the use of the language context cue to direct the reading of the IH. With respect to N400 latency, we expect it to be delayed in older adults, as has been found previously (e.g., Phillips & Lesperance, 2003).

The results of the present investigation extend previous findings in younger adults. More importantly, to our knowledge, this study will be the first to examine lexical priming processes in older bilingual adults and will specifically determine whether older bilinguals rely more heavily on contextual cues in the activation of word meaning in their two lexicons.

## Method

*Participants*

Twenty-four French/English bilingual younger adults were tested, but seven were excluded based on their results from an animacy judgement task (described below) which indicated that they were not equally proficient in their L1 and L2. An eighth younger adult was excluded following inspection of the ERP waveform which was of poor technical quality. The final sample included 16 individuals (7 males) between the ages of 19 and 35 years of age ($M$=24.3, $SD$=5.2), recruited from a participation pool and posted advertisements at Concordia University, Montreal, Canada. Seven participants identified English as their L1.

In total 16 older adults were tested; however, one was excluded following inspection of the ERP waveform which was of poor technical quality. The final sample of older adults consisted of 15 individuals (6 males) between the ages of 60 and 81 ($M$=71.9, $SD$=5.6) recruited from databases within the Cognitive Psychophysiology and the Psychology Aging Research Laboratories at Concordia University. Four participants identified English as their L1 and four reported that they had learned both English and French simultaneously from birth.

Participants completed a self-report health and language questionnaire that was administered via a telephone interview prior to testing. Based on this questionnaire and an animacy judgement task (described below), all participants were comparably proficient in their L1 and L2, had self-reported good health, no prior history of any diseases or conditions and were not taking any medications known to affect cognitive functioning. With the exception of two older adults[2] whose data were examined separately and deemed comparable, participants did not have knowledge of any languages other than French and English. The animacy judgment task was used as an objective measure of each individual's level of bilingualism (Segalowitz &

Frenkiel-Fishman, 2005), and all participants had become fluent their L2 before the age of 16. Thus, despite the fact that participants self-reported themselves to be equally proficient in both languages and performance on the animacy judgement task supported this, the majority of participants had learned one language first and this was designated as their L1. Of the four older adults who learned their languages simultaneously, they all reported being somewhat more comfortable in one language (e.g., due to social use) and this was designated as their L1.

Due to the linguistic nature of this study, all participants were right handed with the exception of one young participant. This participant was included in the analysis following careful examination of their data to ensure that there was no difference in ERP topography relative to right handed participants (i.e., there was no indication that the scalp distribution of the ERPs differed in the left handed participant, suggesting that similar neural generators were recruited). The groups were matched on demographic and neuropsychological variables as can be seen in Table 1.

This study was approved by the Concordia University Research Ethics Committee. Participants recruited from the participation pool received course credit for their participation; all other participants were compensated $10 CAD per hour of participation.

*Materials and Apparatus*

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

*Animacy judgment task.* Participants were required to judge, as quickly and accurately as possible, whether a noun referred to a living or nonliving object which produced an objective measure of an individual's language proficiency (Segalowitz & Frenkiel-Fishman, 2005). As used here, it consisted of 72 nouns in French and 72 nouns in English, divided into two blocks (one in French and one in English). Each block consisted of 64 nouns preceded by 8 practice trials. The stimuli were presented using Inquisit version 1.32 presentation software (Millisecond Software, Seattle, WA) on a Dell Inspiron 5100 laptop with a Pentium 4 processor and Microsoft Windows XP operating system. Stimuli were presented at the center of the monitor, in yellow 20 point Arial font on a black background with a response-stimulus interval of 0 ms. The task was designed such that the different blocks were balanced in terms of the number of animate (e.g., *A QUEEN, A CAMEL* in English and *UN ACTEUR, LE DÉBUTANT* in French) and inanimate nouns (e.g., *THE CEILING, THE STORE* in English and *UN GÂTEAU, UN CAHIER* in French) as well as the number of same/different responses relative to the previous trial and there were no translation equivalents.

*MoCA.* The MoCA is a 10-minute cognitive screening test that has been shown to have very good to excellent sensitivity and specificity for detecting 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.

*Lexical decision/semantic priming task.* The lexical decision/semantic priming task consisted of 400 experimental triplets, containing all real words and 300 filler triplets, containing at least one non-word. The experimental triplets were comprised of: a language context cue consisting of either a high frequency non-homographic French or English word (i.e., a word unique to that language); an IH prime; and a target word, which was a non-homographic French or English word that was either related or unrelated to the same-language meaning of the homograph (e.g., an English target word could be related or unrelated to the English meaning of the IH). We manipulated the consistency between the language of the context cue and the target, as well as the semantic relatedness between the prime and target in order to generate 4 conditions in each of the participants' L1 and L2. Table 2 illustrates the 8 experimental conditions including our predicted outcomes for the younger adults assuming non-selective access, for the older adults if they demonstrate language non-selective access (as was expected in the younger adults), and for the older adults if they use the language context cue to bias their reading of the IH as we hypothesized. Note that the examples included in Table 2 assume an L1 of English and are for illustrative purposes only; target words were not repeated in the experiment. There were 50 trials in each of the 8 conditions. There were two levels of Consistency: consistent, where the prime was an IH and the language cue and target were in the same language (see Table 2, lines a, b, e, and f, for examples); and inconsistent, where the prime was an IH and the language cue and target were not in the same language (see Table 2, lines c, d, g, and h, for examples). Although it may appeal to some to refer to the inconsistent condition as language switching, this can be misleading because the prime in these trials is language ambiguous. Thus, there is only a switch in language if the language context cue is used to bias the reading of the prime. It is for this reason that we refer to the relationship between the context cue and the target word as consistent or inconsistent. There were two levels of Relatedness: related, where the target was semantically related to the same language meaning of the IH prime (e.g., *shoe-coin-money* or *soulier-coin-money,* where the English word *money* is related to the English meaning of the IH *coin*); and unrelated, where the prime and target were not semantically related. Due to the nature of the paradigm it was necessary to include both related and unrelated conditions in order to measure any facilitation of related targets relative to unrelated targets. Note that references to stimuli in

L1 and L2 describe the language of the target word and not necessarily the language of the context cue (e.g., if an individual has English as their L1 and was presented with the triplet *soulier-coin-money*, this would be an L1 inconsistent related trial and *coin* should prime *money* if the English meaning of *coin* is accessed regardless of the inconsistent language cue). Of the 300 filler triplets, 90% contained a single non-word, appearing an equal number of times in each of the three positions within the triplet, and 10% contained two non-words appearing an equal number of times in each combination of two positions within the triplet. These non-words were all phonologically legal and were derived from both French and English words by substituting one letter using pseudoword version 1.5beta5 software (Van Heuven, 2000).

A list of IHs was generated and 100 were selected, based on plausibility judgements of the words by native English and French speakers within the Cognitive Psychophysiology Laboratory, for inclusion in the present experiment. The IHs were then divided into four lists 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). Due to a lack of norms in French, the English translation was used to obtain the concreteness, imageability, and familiarity norms for the French words. Using a Latin square design, the four lists were then combined to create eight lists of 50 IHs such that each IH appeared four times, once in a related and once in an unrelated condition in both English and French contexts. Note that while the IH primes were repeated due to the difficulty identifying an adequate number of stimuli that met our inclusion criteria, the target words were not repeated over the course of the experiment.

The language context cues were 100 French and 100 English unambiguous high frequency words that were matched across languages using a similar procedure as that used for the IHs. Target words were also exclusively French or English words and were matched across conditions using the same procedure as was used for the language cues and IHs. 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[3].

Due to the repetition of the IHs the stimuli were divided into two equivalent lists, such that participants only saw the same IH twice per testing session (i.e., once following an English language context cue and once following a French language context cue) in order to reduce the possibility of repetition priming for the IHs. The different conditions were intermixed with the stipulation that the same lexical decision 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).

*Procedure*

All participants were tested individually on two separate occasions lasting approximately two hours each within seven days of each other except for one participant who completed both testing sessions on one day due to time constraints. Participants were seated in a comfortable chair and informed consent was obtained at the beginning of the first testing session.

On the first testing day, the participant underwent a cognitive screening (i.e., the MoCA) prior to completing the lexical decision/semantic priming task. A score demonstrating normal cognitive fundtioning on the MoCA was required to continue with the study; no participants were excluded due to poor cognitive functioning. Half of the participants also completed the language screening (the animacy judgement task) on the first day, the other half completed it on the second testing day. Participants then completed the lexical decision/semantic priming task for which the list order was counterbalanced and EEG recording took place.

*Animacy judgment task.* Participants were seated at a comfortable distance from the computer and were asked to categorize nouns as animate or inanimate as quickly and accurately as possible. Participants used their index fingers to respond and pressed a green key (the 'c' key on the keyboard) or a red key (the 'm' key on the keyboard) to categorize the stimuli.

*Lexical decision/semantic priming task during EEG recording.* Participants were instructed to respond with one of two keys on a keypad if all three of the words were real English or French words, and with the other key if at least one was not a real word. Participants were not given any additional information regarding the nature of the stimuli (e.g., that the second word in the triplet may be a word in both languages; that the first word in the triplet would never be a word in both languages) and the 'correct' response key was counterbalanced across subjects. The language cue and the prime were presented simultaneously, on either side of the center of the monitor, for 1000 ms immediately followed by the target which remained on the screen until the participant responded. This timing ensured that the older adults had ample time to process the stimuli given the proposal that processing speed declines in aging (Salthouse, 1996). For all but the first three younger and two older participants, the target was presented between 0.06 and 0.20 degrees of visual angle to the right of center (i.e., in the position previously occupied by the prime from the previous language cue-prime presentation). The positioning of the stimuli in this manner minimized any eye movements between the presentation of the cue-prime phase and the target phase. Following the presentation of each triplet sequence, there was a participant-controlled pause denoted by a blue rectangle presented at the center of the monitor until the participant pressed any key on the keypad indicating their readiness to continue.

*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 and 23 lateral sites according to the international 10-20 system of electrode placement 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 and all active sites were referenced on-line to the left ear and re-referenced off-line, using Scan 4.3 computer software (Neuroscan, El Paso, TX, USA), to linked ears. We recorded the horizontal electro-oculogram (EOG) from electrodes placed at the outer canthi of both eyes and the vertical EOG 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 100 Hz in a DC to 30 Hz bandwidth with electrical impedances below 5 kΩ. Vertical EOG artefacts were corrected off-line using a spatial filter (Neuroscan, EDIT4.3) and trials with horizontal EOG artefact exceeding peak amplitudes of ±50 μV were excluded from averaging. Trials containing deflections exceeding ±100 μV were also excluded. The electrophysiological time epoch was 1100 ms per trial and consisted of 100 ms prior to the onset of the target word and 1000 ms following its presentation. All averages were baseline corrected to a 0 μV average of the 100 ms pre-stimulus interval. Waveforms were averaged based on the 8 conditions previously described and only correct trials on the LDT were included.

## Results

*Animacy judgment task.* The coefficient of variability (CV; a measure of cognitive efficiency based on intra-individual differences in RT variability; see Segalowitz & Segalowitz, 1993) was calculated for each participant by dividing the *SD* of each participant's RT for correct trials by his/her mean RT for correct trials. Trials for which the RT was less than 200 ms or greater than three standard deviations of the mean were excluded prior to calculating the CV. This was done separately for each language. The mean RT, mean *SD*, and mean CV for each group are presented in Table 3. Note that in Table 3 we have separated each age group based on their stated L1. Independent samples t-tests revealed no differences in the CV in L1 or L2 for the young and older groups with English and French as their L1. Paired samples t-tests revealed no differences between the CV in L1 and the CV in L2 within each group indicating that, although each person declared a nominal L1, they were equally proficient in both languages.

*Lexical decision/semantic priming task.* First the behavioural results will be presented, followed by the electrophysiological results. Repeated measures analyses of variance (ANOVAs) were conducted on both the behavioural and ERP data using SPSS v.11.0 statistical software. For all analyses with more than one degree of freedom in the numerator, the Huynh and Feldt (1976) correction for non-sphericity was employed. Following convention, the unadjusted degrees of freedom, the corrected mean square error, the adjusted *p*-value, and the Huynh-Feldt epsilon value ($\varepsilon$) are reported. An initial omnibus mixed ANOVA was conducted, the main purpose of which was to determine whether there were significant age differences. Age was included as the between-subjects variable; within subjects variables included Language (L1, L2), Consistency (consistent, inconsistent), and Relatedness (related, unrelated). All main effects are reported first, followed by significant interaction effects that were further examined with Bonferroni-corrected simple effects analyses. All effects reported below are significant at an alpha level of .05.

Separate repeated measures ANOVAs within each age group (young and older) were also conducted to further examine within group differences between L1 and L2. These analyses were conducted because it was clear that the results of the omnibus ANOVAs were being driven by effects in the younger adults and potentially obscuring interesting effects in the older adults. We also ran an initial ANOVA on the RT data for the L1 consistent condition for each age group alone and included Native Language as a factor (i.e., Native Language x Relatedness). Given that there was no main effect of Native Language, no interactions involving this factor, and no differences between the English and French native speakers in our proficiency measures, we collapsed across Native Language for all subsequent analyses.

*Behavioural Analyses*

Figure 1 depicts the RT data. The omnibus ANOVA revealed a significant main effect of Age ($F$ (1, 29)=5.4, $MSE$=383815.2, $p$=.03, $\eta^2_p$ =.16), demonstrating faster responses for the younger adults relative to the older adults. There was also a main effect of Language ($F$ (1, 29)=5.0, $MSE$=21354.2, $p$=.03, $\eta^2_p$ =.15), demonstrating faster responses in L1 relative to L2, and of Consistency ($F$ (1, 29)=13.8, $MSE$=11292.5 $p < .01$, $\eta^2_p$ =.32), such that responses to targets in consistent conditions were faster than those in inconsistent conditions. A main effect of Relatedness ($F$ (1, 29)=13.0, $MSE$=10668.3, $p < .01$, $\eta^2_p$ =.31), demonstrated faster responses to related targets relative to unrelated targets. There were no interaction effects.

The within group analysis for the young group yielded the same main effects as the omnibus analysis. However, the within group analysis for the older group revealed a main effect of Relatedness ($F$ (1, 14)=5.6, $MSE$=18646.75, $p$=.03, $\eta^2_p$ =.28), demonstrating faster responses for related targets relative to unrelated targets; and a Language x Consistency interaction ($F$ (1, 14)=6.3, $MSE$=5001.9, $p$=.03, $\eta^2_p$ =.31), demonstrating faster responses in the consistent condition relative to the inconsistent condition for L1 targets only (i.e., L1-IH-L1 faster than L2-IH-L1). There was no main effect of Language ($F$(1,14)=0.4, $p$>.05); however, there was a trend for faster responses in consistent relative to inconsistent conditions (i.e., main effect of Consistency ($F$(1, 14)=3.9, $MSE$=20693.0, $p$=.07, $\eta^2_p$ =.22) in the older adults.

*Electrophysiological Analyses*

Separate analyses were conducted comparing the midline sites, and comparing the electrodes over left- versus right-hemisphere lateral sites. As in the behavioural analysis we were interested in group differences, therefore Age was included as the between-subjects factor and within-subjects factors included Language, Consistency, and Relatedness. Given that the N400 is maximal over centro-parietal scalp locations (Kutas & Hillyard, 1982), we restricted our initial analysis to midline sites including Fz, FCz, Cz, CPz, and Pz, which yielded the factor of Site. The N400 has also been found to be larger over the right relative to the left hemisphere (Kutas & Hillyard), therefore we compared the two hemispheres by creating a Laterality factor with two levels (left/right) and an Anteriority factor with three levels by averaging data from individual electrode sites together, as is illustrated in Figure 2. Given that we were interested in the N400 component of the ERP and this component has been found to be both delayed and attenuated in older adults (e.g., Phillips & Lesperance, 2003) we examined a time window consisting of eight consecutive 50 ms epochs from 300 ms to 700 ms post-target (i.e., 300-350, 350-400…650-700 ms) which yielded the factor Time. The dependent variable in these analyses was the mean ERP amplitude for each 50 ms epoch. Thus, by including eight consecutive 50 ms epochs we were able to examine amplitude differences over time. Results from the midline sites are presented first followed by those from the lateral sites when they provide additional information.

Figures 3 and 4 show the grand averaged waveforms of the young adults to target words in L1 and L2, respectively. Both figures show a negative deflection in the waveform peaking at approximately 400 ms following the target stimulus, which, based on our experimental manipulations, we take to be the N400. In L1 (see Figure 3), the amplitude of the N400 in response to unrelated targets appears larger than to related targets, and this difference is largest in the inconsistent condition (i.e., the negative deflection begins earlier and ends later). In L2 (see Figure 4), N400 amplitude also appears larger for unrelated targets; however, the difference in N400 amplitude between related and unrelated targets (i.e., N400 priming effect) appears to be smaller in L2 than in L1. Figures 5 and 6 show the grand averaged waveforms of the older adults to target words in L1 and L2, respectively. These waveforms also show a negative deflection of the waveform following the presentation of the target; however, this deflection occurs later and appears flatter (i.e., the peak is less obvious) compared to that observed in the young adults. Age-related differences in the timing and magnitude of the N400 are well-known (Federmeier & Kutas, 2005; Phillips & Lesperance, 2003) and cause statistical comparisons between age groups to be challenging as they can yield somewhat non-meaningful interactions which merely reflect these timing and absolute magnitude differences that are not related to the experimental manipulations *per se*. Given this, we conducted an omnibus analysis on the midline and lateral sites separately in order to determine whether there were experimental effects interacting with age. These were followed by individual age analyses on both the midline and lateral sites and two supplemental analyses on the midline sites only to further investigate the L2 consistent condition in the young adults and the L1 inconsistent condition in the older adults. In total eight ANOVAs were performed (i.e., three each for the midline and lateral sites and two supplemental analyses).

The omnibus analysis involving midline electrode sites revealed a main effect of Relatedness ($F$ (1, 29)=5.2, $MSE$=99.6, $p$=.03, $\eta^2_p$ =.15). There was also an Age x Site x Time interaction ($F$ (28, 812)=4.6, $MSE$=18.9, $p < .01$, $\eta^2_p$ =.14, $\varepsilon = .14$), an Age x Language x Relatedness x Time interaction ($F$ (7, 203)=4.6, $MSE$=6.4, $p<.01$, $\eta^2_p$ =.14, $\varepsilon = .62$), and an Age x Language x Relatedness x Consistency x Time interaction ($F$ (7, 203)=2.7, $MSE$=96.2, $p$=.04,

$\eta^2_p$ =.09, $\varepsilon$ = .47) revealed in the analysis of the midline sites. In addition to this, analysis of the lateral sites revealed an Age x Laterality x Time interaction (*F* (7, 203)=5.1, *MSE*=15.4, *p*=.01, $\eta^2_p$ =.15, $\varepsilon$ = .27), as well as Age x Language x Relatedness x Consistency x Time interaction (*F* (7, 203)=3.4, *MSE*=8.1, *p*=.02, $\eta^2_p$ =.11, $\varepsilon$ = .43). These results are reported to demonstrate that there are age differences in the timing and overall amplitude of the N400; however, no attempt to interpret these interactions was made. Rather, they are further decomposed using separate age analyses for both midline and lateral electrode sites.

Within group analysis of the midline for the young adults revealed a main effect of Relatedness (*F* (1, 15)=4.7, *MSE*=96.2, *p*=.05, $\eta^2_p$ =.24), demonstrating more negative waveforms for unrelated targets relative to related targets. This analysis also revealed a Language x Relatedness x Time interaction (*F* (7, 105)=4.1, *MSE*=9.4, $p < .01$, $\eta^2_p$ =.22, $\varepsilon$ = .59), demonstrating N400 priming in L1 from 300-500 ms and in L2 from 450-500 ms as well as a trend from 500-550 ms (*p*=.06) and 550-600 ms (*p*=.06). Analysis of the lateral sites revealed a Language x Relatedness x Consistency x Anteriority x Time interaction (*F* (14, 210)=3.1, *MSE*=0.9, *p*=.03, $\eta^2_p$ =.17, $\varepsilon$ = .27), demonstrating N400 priming at central and posterior sites for the L1 consistent (L1-IH-L1) condition and at all three levels of Anteriority (i.e., anterior, central, and posterior) for the L1 inconsistent (L2-IH-L1) and L2 inconsistent (L1-IH-L2) conditions. Given that the waveforms appeared more negative for unrelated relative to related targets in the top panel of Figure 4, we decided to test this condition alone to determine if the effect was reliable. Specifically, we compared related and unrelated targets for the L2 consistent condition only in a repeated measures ANOVA. The Relatedness x Time interaction yielded a trend (*F* (7, 105)=2.8, *MSE*=12.8, *p*=.06, $\eta^2_p$ =.16, $\varepsilon$ = .38), and the simple effects analysis revealed significantly more negative waveforms for unrelated relative to related targets from 450-500 ms. Taken together, these findings demonstrate language non-selective access to the IH meaning regardless of the language context in the younger adults, although semantic priming occurs later in L2 relative to L1.

Within group analysis of the midline sites for the older adults revealed no significant main effects; however, there was a Relatedness x Time interaction ($F$ (7, 98)=3.2, $MSE$=7.4, $p$=.03, $\eta^2_p$ =.19, $\varepsilon$ = .48), which demonstrated a trend towards more negative waveforms for unrelated targets relative to related targets from 400-450 ms ($p$=.09) and from 450-500 ms ($p$=.07). However, analysis of the lateral sites revealed a Relatedness x Consistency x Anteriority x Time interaction ($F$ (14, 196)=3.0, $MSE$=0.24, $p$=.01, $\eta^2_p$ =.18, $\varepsilon$ = .48), demonstrating more negative waveforms for unrelated relative to related targets for the consistent conditions at posterior sites from 500-550 ms; at the anterior and central sites this effect was a trend ($p$=.08 and $p$=.06 respectively). Similar to the supplemental analysis conducted for the younger adults, we specifically examined the apparent N400 priming effect in the L1 inconsistent condition for the older adults. However, neither the main effect of Relatedness ($p$=.19) nor the Relatedness x Time interaction ($p$=.19) was significant[4].

Note that we also examined a later time-window (i.e., 650 -1000 ms) in order to determine if there were any significant effects indicating later integration of related target words, particularly in the inconsistent conditions. There was no support for this[5].

## Discussion

The goals of the present study were twofold. First we wanted to replicate previous findings demonstrating non-selective language processing of IHs in younger adults when the language context cue was in their L1 and the target word was related to the L2 meaning of the IH (de Bruijn et al., 2001). We also wanted to extend these findings to situations in which the language context cue was in the participant's L2 and the target word was related to the L1 meaning of the IH. Second and more importantly, we investigated age-differences in the use of a language context cue in the processing of an IH prime in a semantic priming paradigm using both RT and ERP measures, with the prediction that older adults would rely more on the language context cue than younger adults to disambiguate language ambiguous words (i.e., IHs).

In terms of our first objective, we found behavioural priming in the younger adults that did not interact with Consistency or with Language. The electrophysiological analyses revealed N400 priming for the L1 consistent condition and inconsistent conditions in both language directions (i.e., L1-IH-L1, L2-IH-L1, and L1-IH-L2) and in the L2 consistent condition. The critical finding here is that in conditions where the language context cue and the target word were inconsistent in language (i.e., L2-IH-L1 and L1-IH-L2) we observed N400 priming. Specifically, with the simultaneous presentation of a language context cue and an IH prime, the inappropriate meaning of the IH was activated irrespective of the language context. These results indicate that the language context provided by the first word of the triplet was not sufficient to inhibit the initial activation of both language meanings of the IH in younger adults.

These results both replicate and extend the findings of de Bruijn et al. (2001). They found that young native Dutch speakers were not influenced by context when reading IHs. An L2 English target related to the IH was responded to faster and elicited smaller N400 amplitudes relative to unrelated targets regardless of whether the language context was English or Dutch, demonstrating language non-selective access. In our experiment this corresponds to conditions in which the target language was L2. We also observed semantic priming, thus replicating the findings of de Bruijn et al. Furthermore, in the conditions they did not test, we found N400 priming effects for both the consistent and inconsistent conditions (i.e., L1-IH-L1 and L2-IH-L1, respectively), thus extending the finding of language non-selective access of IHs to situations in which the target language is L1. The present investigation also found behavioural priming that was not modulated by Language or Consistency further demonstrating language non-selective access. Of course, these findings should not be surprising given that the target is in L1; however, it demonstrates similar non-selective priming effects in both directions, at least for the young balanced bilinguals tested in this study. Thus, both languages are activated when the individual is confronted with a word that is lexically ambiguous in terms of language, regardless of whether the individual is in an L1 or an L2 context. Although this result is not surprising, it was necessary to test this before examining language selectivity in older adults.

With regard to our central goal, it was hypothesized that older adults would rely on contextual constraints to a greater extent than younger adults in order to process the language ambiguous prime. In the present experiment the context was comprised of a high frequency word unique to one language, and was intended to bias the reading of the IH prime toward the same language meaning as the contextual cue. We found longer RTs as well as later and smaller peak N400 amplitudes for older adults, consistent with previous research in monolinguals (Federmeier & Kutas, 2005; Phillips & Lesperance, 2003). Although the behavioural results partially support our hypothesis, the electrophysiological results provide clear support. In terms of RT, the older adults demonstrated overall semantic priming effects. There was also an interaction between Consistency and Language, demonstrating faster responses for target words in the consistent condition relative to the inconsistent condition in L1 only (i.e., L1-IH-L1 vs. L2-IH-L1). This suggests that the older adults were using the language cue to bias their reading of the IH prime which caused interference when the target was in the other language and resulted in increased RTs in the L2-L1 direction[6].

The electrophysiological data for the older adults also revealed N400 priming at posterior scalp locations for the consistent conditions only (i.e., L1-IH-L1 and L2-IH-L2). The timing of this effect was late (i.e., between 500 and 550 ms) relative to the standard N400 time window, although visual inspection of Figures 5 and 6 shows that this is the final phase of the N400 peak. The priming observed for the consistent conditions (i.e., L1-IH-L1 and L2-IH-L2) in the absence of such priming in the inconsistent conditions (i.e., L2-IH L1 and L1-IH-L2) provides support for our hypothesis. That is, the older adults used the language context cue to bias their reading of the IH and thus did not access the meaning of the IH in the inappropriate language under these circumstances. Only when a consistent language context cue was present did they access the corresponding meaning of the IH[7].

Our data are consistent with previous findings demonstrating that older adults can use linguistic context to aid in visual word recognition (Cohen & Faulkner,1983; Madden, 1988), lexical ambiguity resolution in a single language (Balota, Cortese & Wenke, 2001), and speech processing in less than optimal listening situations (e.g., Pichora-Fuller, Schneider & Daneman, 1995; Sheldon, Pichora-Fuller & Schneider, 2008; Wingfield, Aberdeen & Stine, 1991). However, until now it was unclear how language context might direct their reading of words that are ambiguous in terms of language. We have demonstrated that bilingual older adults use a preceding language context in order to facilitate the reading of a word with distinct meanings in two languages.

In addition, our findings demonstrating language non-selective access to IH meaning in the younger adults provide support for models such as the BIA (Dijkstra & van Heuven, 1998) and BIA+ (Dijkstra & Van Heuven, 2002), which postulate an an interactive language system. The predictions of the BIA+ model for IH recognition are similar to the predictions for monolingual homograph recognition (i.e., the exhaustive access model); thus, it is reasonable to think that initially both meanings of an IH are accessed, followed by selection of the appropriate language meaning when a language context is present. In the case of a bilingual lexically ambiguous situation, one would expect to see initial behavioural and N400 priming for targets words inconsistent in language with the language context cue that should be attenuated following a delay between the presentation of the prime and the target. In the present study, as well as in de Bruijn et al. (2001) the interstimulus interval between the prime and target was not manipulated thus making it difficult to address this question directly. However, given that de Bruijn et al. used a 400 ms SOA and the present investigation used a 1000 ms SOA we would expect different findings between the studies if there was late selection of the language appropriate meaning of the IH; however, both studies found evidence for non-selective access. The present results replicate and extend the de Bruijn et al.'s findings, suggesting that a single word language context is not sufficient to support the later selection of the language appropriate meaning of an IH. One possibility is that a richer semantic context is necessary in order for the ambiguity to be resolved when the ambiguity is language related. Consistent with this, Libben and Titone (2009) found that bilingual language processing is non-selective at early stages of processing, but high semantic constraint provided by a sentence context allows for the rapid resolution of cross-language ambiguity.

In the monolingual literature the role of working memory in the resolution of lexical ambiguity has been investigated. Although the results of these studies are not entirely consistent it has been suggested that readers with a large working memory capacity can maintain multiple meanings of an ambiguous word activated longer than those with low working memory (Miyake, Just & Carpenter, 1994). More recently, Gunter, Wagner and Friederici (2003) concluded that inhibition is the cognitive mechanism used to resolve lexical ambiguity by readers with a high working memory span, whereas low span readers maintained both meanings of an ambiguous word activated. Given that aging has been associated with declines in working memory as well as declines in inhibitory function, the present results lend further support to the idea that older adults may be using context as a compensatory strategy. That is, if low span readers (e.g., aged adults with declines in working memory) have more difficulty maintaining more than one activated meaning, they may be more likely to use contextual cues to direct their attention to the appropriate meaning. Similarly, if inhibition is the cognitive mechanism used to resolve lexical ambiguity, as is suggested by Gunter et al., then older adults may rely on contextual constraints to a greater extent than younger adults in order to reduce the burden on less-than-optimal inhibitory processes.

It should be noted that all participants included in this study were deemed equally proficient in their L1 and their L2 based on self-report and the CV (Segalowitz & Segalowitz, 1993). Nevertheless, our data suggest that L1 remains dominant despite attained proficiency. Specifically, younger adults demonstrated faster RTs and earlier N400 peaks in L1 relative to L2, supporting the idea that processing occurs more quickly and easily in L1. This is consistent with previous findings in bilingual young adults (Ardal, Donald, Meuter, Muldrew, & Luce, 1990; Phillips, Klein, Mercier, & de Boysson, 2006; Phillips & Segalowitz, O'Brien, & Yamasaki, 2004). Interestingly, this pattern was not observed in the older adults. One can speculate that this may be due to the decades of experience that the older adults have with their L2.

One challenge to our interpretations comes from a language switching study which demonstrates that older adults have difficulty switching between languages relative to younger adults (Hernandez & Kohnert, 1999). Although this initially seems like a possible explanation for the present results, we maintain that older adults were using the language context cue to bias their reading of the IH, possibly as a compensatory strategy to improve language comprehension. That is, the present experiment is not a language switching paradigm and despite the switch in language between the contextual cue and the target word in inconsistent conditions, the IH prime itself remained language ambiguous. If the older adults were not using the language context cue to bias their reading of the IH then, effectively, there would be no language switch between the IH and the target word in inconsistent conditions. Therefore, it is unlikely that age-related difficulties in language switching alone can account for the reported results.

Another alternative explanation may be that older adults simply fail to activate both meanings of the IHs. That is, the finding that older adults only access the meaning of the IH that is consistent with the language context cue is not the result of the use of context in a compensatory way, but rather a failure to activate the alternate language meaning. However, Lustig, Hasher and Zacks (2007) cite several lines of evidence demonstrating preserved activation processes in aging, including neuroimaging evidence. Based on this, we believe that the older adults in this study are using context in a compensatory manner. Specifically, given the changes in cognition and language that have been associated with aging (e.g., Craik & Salthouse, 2008), and that older adults maintain the ability to functionally use language (Wingfield & Stine-Morrow, 2000), we believe that these data support a greater reliance on context by older adults as a means to overcome age-related difficulties and maintain normal functioning. It is possible that younger adults possess the cognitive capacity to maintain more than one meaning of a word active, while older adults do not. That is, due to age-related declines in cognition, older adults have less cognitive capacity to maintain more than one meaning active and therefore rely on context to direct their attention to the appropriate meaning of an ambiguous word, thus reducing cognitive load.

In summary, the present study finds support for the use of context by older adults in a lexically ambiguous situation where the ambiguity is the result of multiple language meanings. This extends previous findings demonstrating that older adults can use linguistic context to aid in language processing to situations where information is ambiguous with respect to the identity of the language. That is, we have demonstrated that bilingual older adults use a preceding language context in order to facilitate the reading of a word with distinct meanings in two languages. We have taken these results as support for an increase in the use of context by older adults as a compensatory strategy to support language comprehension. However, it is important to remember that all of our participants were highly proficient French/English bilinguals. Recent findings have shown that the effects of aging on cognitive function may be dissimilar for bilingual and monolingual individuals. Specifically, bilingual older adults have been found to demonstrate spared executive and attentional functioning relative to their monolingual counterparts (see Bialystok, 2007, 2009); therefore the present findings are confined to bilingual older adults. This suggests that although the older adults in the present study were successfully able to use the linguistic context provided by a single word to direct their reading of an IH, a different pattern of context use may be observed in monolinguals. Future research should examine differences in the processing of lexical ambiguity between monolingual and bilingual older adults directly using lexical ambiguity in a single language (i.e., L1 homographs; words with identical orthography in a single language but with multiple semantic representations, e.g., *bank* meaning “a financial institution” or “the edge of a river”).

In conclusion, we replicated previous findings demonstrating language non-selective access in response to IHs in the L1-L2 direction and extended these findings to the L2-L1 direction in younger adults. Furthermore, we found that under the conditions of the present experiment, older adults use a language context cue to bias their reading of an IH, suggesting the use of a compensatory strategy. These findings contribute to our present understanding of age-related changes in language processing in the bilingual older adult.

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Table 1

*Demographic and Neuropsychological Data for Young and Older Participants*

| | Young | | Older | |
|---|---|---|---|---|
| | English L1 (n=7)<br>M (*SD*) | French L1 (n=9)<br>M (*SD*) | English L1 (n=4)<br>M (*SD*) | French L1 (n=11)<br>M (*SD*) |
| Age | 25 (*5.5*) | 23.7 (*5.2*) | 70.5 (*5.0*) | 72.4 (*6.0*) |
| Education | 15.1 (*1.4*) | 15.5 (*0.5*) | 14.0 (*2.4*) | 15.1 (*2.4*) |
| MoCA | 28.7 (*1.4*) | 27.6 (*1.7*) | 26.5 (*1.9*) | 27.0 (*2.0*) |
| Coefficient of variability L1 | .23 (*.12*) | .22 (*.10*) | .17 (*.10*) | .20 (*.08*) |
| Coefficient of variability L2 | .25 (*.11*) | .20 (*.07*) | .22 (*.09*) | .20 (*.08*) |

Table 2

*Experimental Conditions, Sample Stimuli (assuming L1 is English), and Predictions for the Presence (+) or Absence (-) of Facilitation*

| Condition | Language Context Cue | Prime | Target | Predictions: Younger adults | Predictions: Older adults if non-selective access | Predictions: Older adults if use of context |
|---|---|---|---|---|---|---|
| **L1 Consistent** | **L1** | **IH** | **L1** | | | |
| a. Related | shoe | coin | money | + | + | + |
| b. Unrelated | shoe | coin | house | | | |
| **L1 Inconsistent** | **L2** | **IH** | **L1** | | | |
| c. Related | soulier | coin | money | + | + | - |
| d. Unrelated | soulier | coin | house | | | |
| **L2 Consistent** | **L2** | **IH** | **L2** | | | |
| e. Related | soulier | coin | ruelle | + | + | + |
| f. Unrelated | soulier | coin | maison | | | |
| **L2 Inconsistent** | **L1** | **IH** | **L2** | | | |
| g. Related | shoe | coin | ruelle | + | + | - |
| h. Unrelated | shoe | coin | maison | | | |

Table 3

*Results from the Animacy Judgement Task and the Coefficient of Variability (CV) in L1 and L2 for Young and Older Participants with English (English L1) and French (French L1) as their Native Language*

| | Young | | | | Older | | | |
|---|---|---|---|---|---|---|---|---|
| | English L1 (n=7) | | French L1 (n=9) | | English L1 (n=4) | | French L1 (n=11) | |
| | L1 | L2 | L1 | L2 | L1 | L2 | L1 | L2 |
| Mean RT *(SD)* | 764.4 *(167.3)* | 820.0 *(166.2)* | 837.3 *(92.2)* | 847.5 *(83.4)* | 939.7 *(155.4)* | 1064.8 *(130.0)* | 908.7 *(117.3)* | 935.4 *(147.8)* |
| Mean SD *(SD)* | 183.7 *(131.4)* | 216.9 *(122.3)* | 190.7 *(92.0)* | 168.4 *(66.7)* | 157.0 *(77.2)* | 233.9 *(98.3)* | 189.6 *(100.7)* | 190.1 *(98.8)* |
| Mean CV *(SD)* | .23 *(.12)* | .25 *(.11)* | .22 *(.09)* | .20 *(.07)* | .17 *(.10)* | .22 *(.09)* | .20 *(.08)* | .20 *(.08)* |

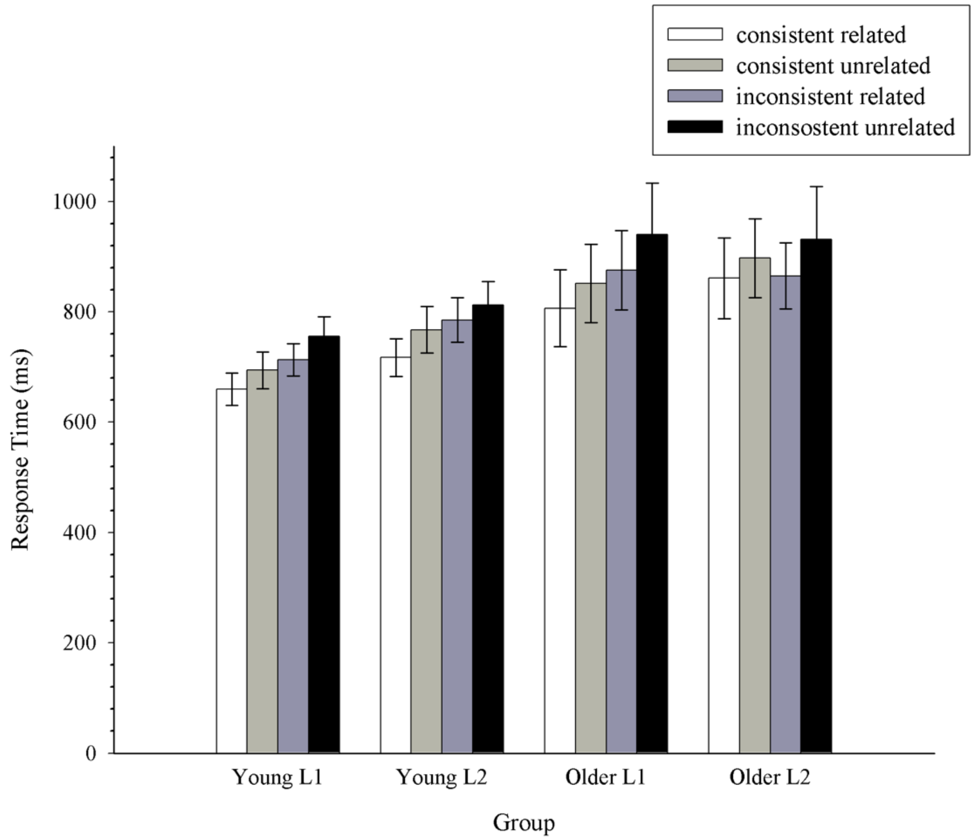


*Figure 1*. RT (± *SE*) data for younger and older adults as a function of Language, Consistency, and Relatedness.

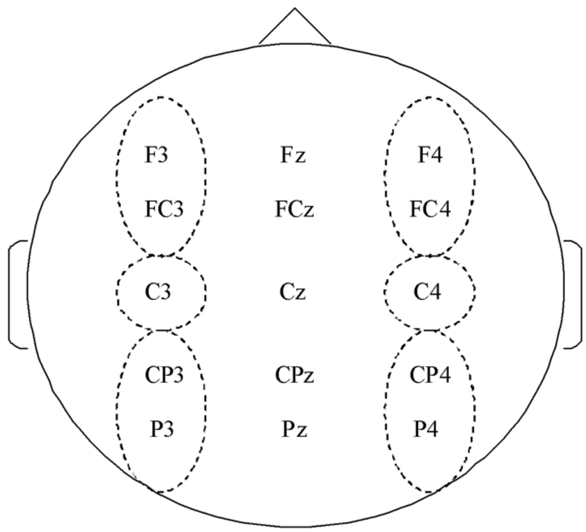


*Figure 2.* Different regions of the scalp comprising the midline and different levels of laterality and anteriority. Dashed ovals represent the electrode sites that comprise each of the levels of laterality (left and right) and anteriority (anterior, central and posterior).

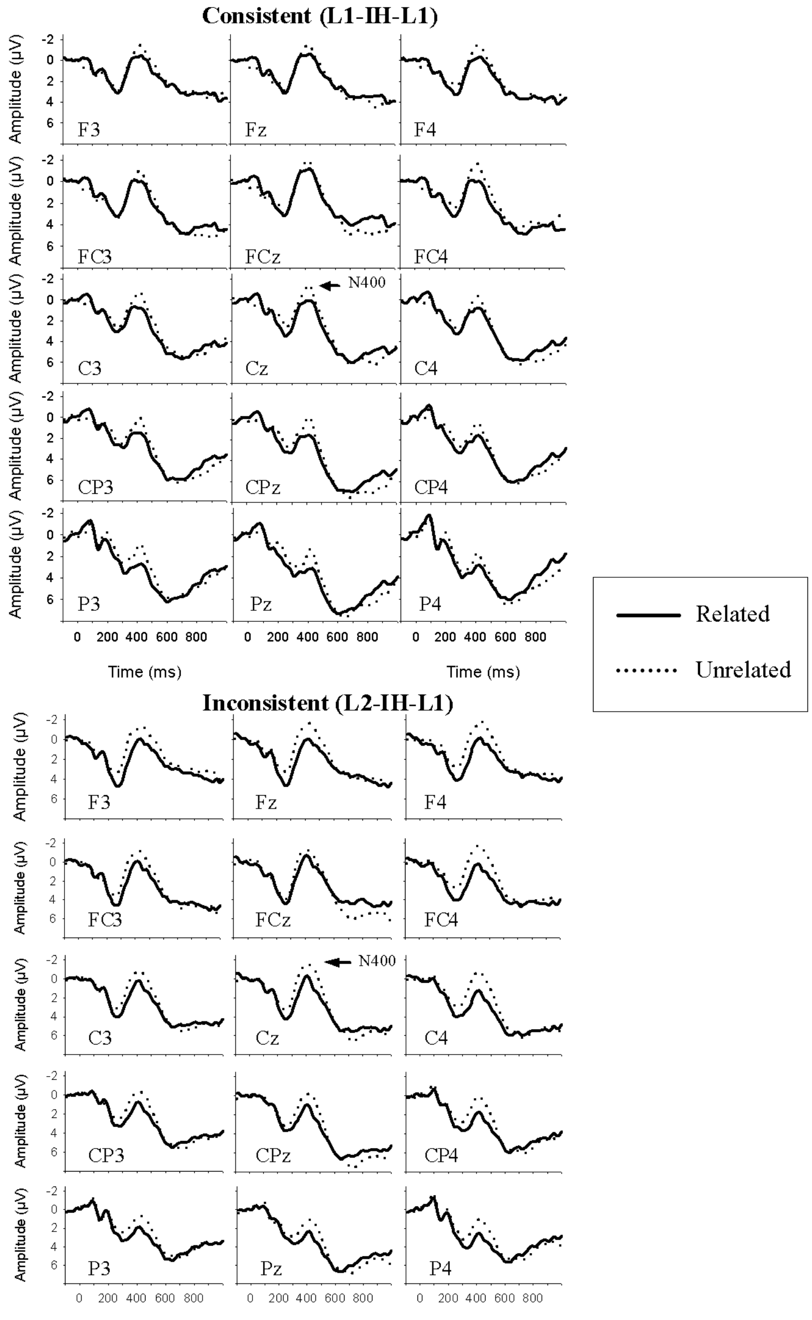


*Figure 3.* Grand averaged waveforms comparing related and unrelated targets for young adults in L1 for the consistent (top panel) and inconsistent (bottom panel) conditions.

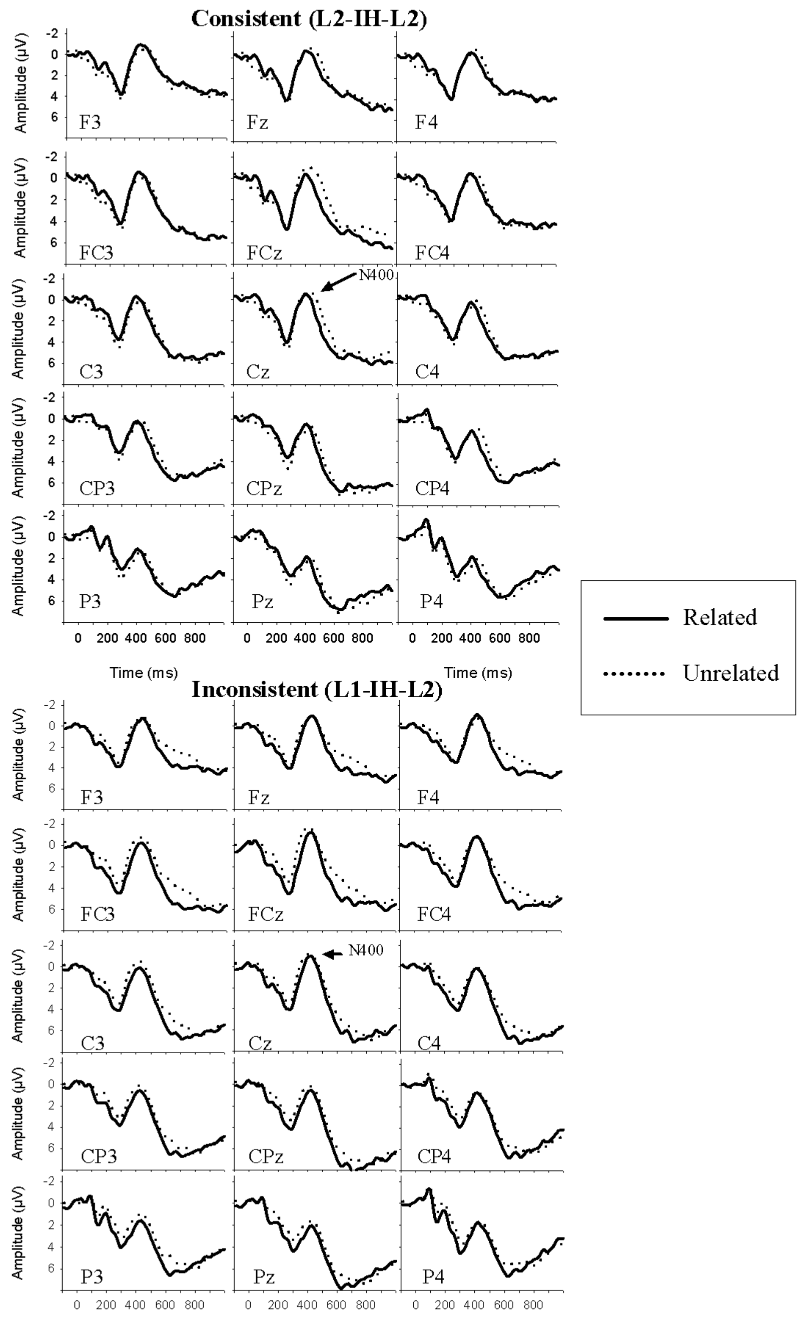


*Figure 4*. Grand averaged waveforms comparing related and unrelated targets for young adults in L2 for the consistent (top panel) and inconsistent (bottom panel) conditions.

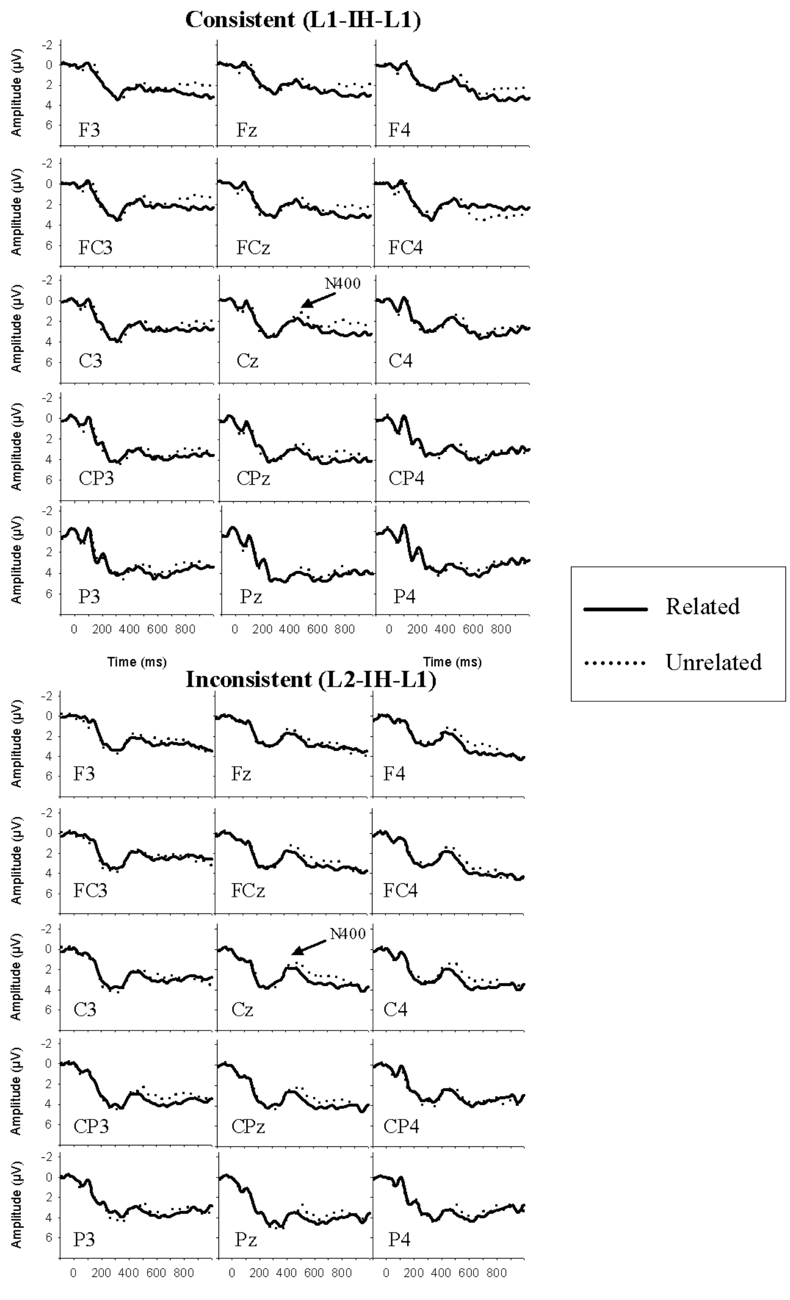


*Figure 5.* Grand averaged waveforms comparing related and unrelated targets for older adults in L1 for the consistent (top panel) and inconsistent (bottom panel) conditions.

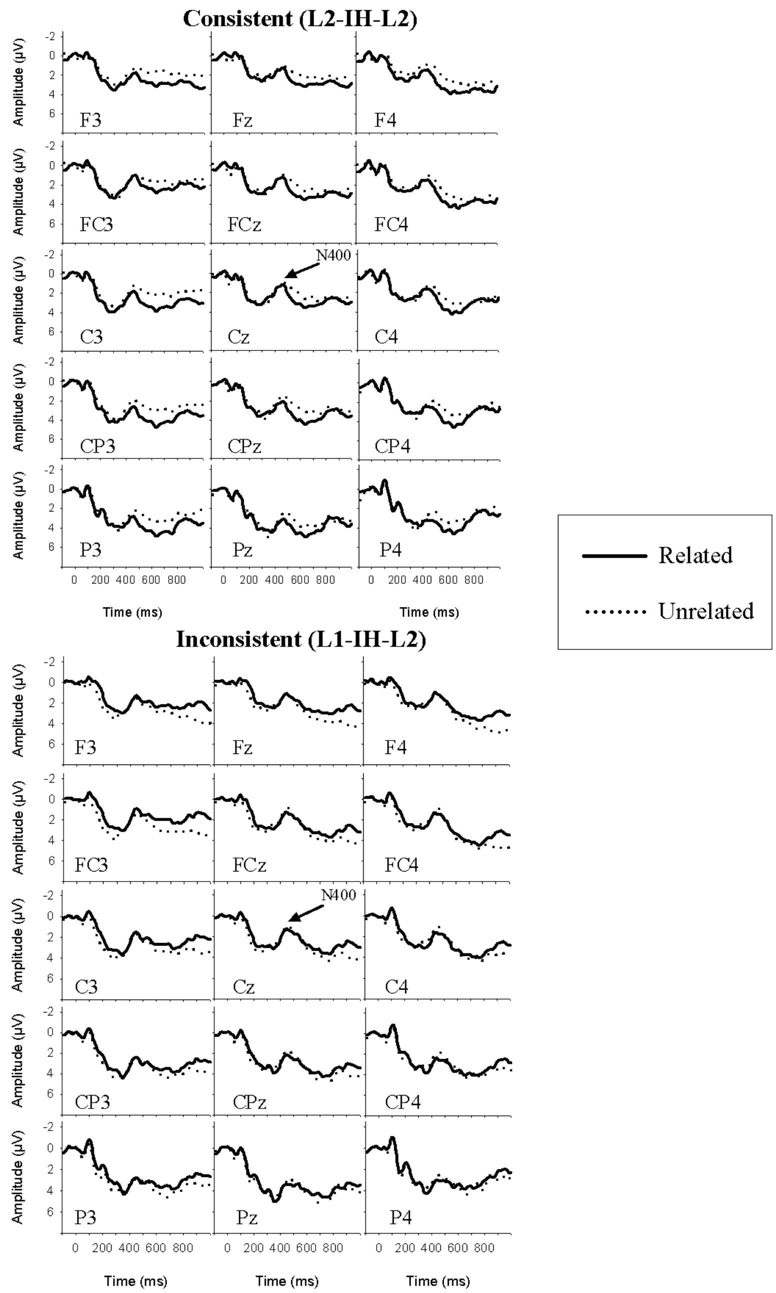


*Figure 6*. Grand averaged waveforms comparing related and unrelated targets for older adults in L2 for the consistent (top panel) and inconsistent (bottom panel) conditions.

Footnotes

[1] Note that the unambiguous language context cue was designed only to bias the reading of subsequent words in the triplet; it did not bear any semantic relationship to the IH or the target.

[2] One older adult had some knowledge of Italian but was not fluent. A second older adult was learning German at the time of testing.

[3] It should be noted that due to the distinct meaning of the IHs in each language there were commonly differences in word class. For example, the letter string *loin* is a noun in English, but is an adverb in French meaning “far.” As a result, the target words also varied in word class. It has been suggested that 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). These studies only examined nouns and verbs, and did so using a sentence context; therefore, it is uncertain how word class may affect the present results. However, the majority of the IH (86%) were either nouns or verbs, the proportion of which did not vary systematically across conditions.

[4] We do not believe the absence of this effect was due to low statistical power; the observed power for this interaction was .66.

[5] Recently van de Meerendonk, Kolk, Vissers and Chwilla (2008) have found that a late positive shift (i.e., P600) is related to conflict between expected and encountered linguistic events. By this account a large P600 is elicited when the conflict is strong enough to trigger reanalysis. In the present experiment, it is conceivable that some conditions may trigger this reanalysis; however, in the present experiment there is semantic conflict (i.e., unrelated target words) as well as language conflict (i.e., inconsistent conditions), therefore predictions involving the P600 are

not straightforward. In spite of this, the analysis that we conducted did not provide evidence for a late positive effect.

[6] Alternatively, it is possible that rather than the inconsistent L2 language cue causing interference, there was facilitation of the processing of the IH in the presence of the consistent L1 language cue. There was not a neutral baseline against which to compare these alternative accounts; however, the electrophysiological findings would favour the former explanation. Given that the target was in L1 in both of these conditions, the observed effect can only be the result of the language context manipulation.

[7] One limitation to this interpretation is that it is based on the failure to find a significant N400 priming effect for the inconsistent conditions. It is possible that we have somewhat limited power due to the sample size. Although our sample size was modest, we note that it is consistent with other studies that have observed significant effects in older adults (e.g., Faustmann, Murdoch, Finnigan, & Copland, 2007; Neumann, Obler, Gomes, & Shafer, 2009).