Facilitatory and Inhibitory Mechanisms in Second Language Reading Fluency

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ABSTRACT

Facilitatory and Inhibitory Mechanisms in Second Language Reading Fluency

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This research focused on whether the efficiency with which bilinguals inhibit representations of irrelevant or facilitate representations of relevant information is a factor contributing to second language fluency. Participants were tested in their first (L1) (English) and second languages (L2) (French). The tasks implemented were negative and positive priming size selection tasks where participants viewed two stimulus words that named units of time (e.g., minute, day) and were asked to press a button corresponding to the position of the stimulus word expressing the longer unit of time. In Experiment 1, participants were tested in separate blocks on positive and negative priming trial-pairs. On a negative priming trial-pair, participants had to respond to a target on a probe trial that appeared as a distractor on the prime trial immediately preceding. On a positive priming trial-pair, participants had to respond to a target on a probe trial that had been presented as a target on the preceding prime trial. It was found that in L1 but not L2 participants were significantly slower to respond on negative priming trials than on neutral trials, indicating evidence of inhibition in L1 but not in L2. It was also found that in both L1 and L2, bilinguals exhibited significant positive priming, indicating efficient facilitation of relevant information in both languages. The second and third experiments investigated the time course of negative and positive priming respectively in relation to L1 and L2 reading. Participants were tested at four different RSIs (response-to-stimulus intervals). In L1, negative priming was found to persist even at the longest RSI whereas in L2 it was found to have dissipated by that time, indicating that bilinguals were able maintain inhibition of irrelevant information for longer periods of time in L1 than in L2. Overall, the research implicates both inhibitory and facilitatory processes in L2 reading fluency.

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Introduction

This thesis investigated the development of second language skill and in particular sought to make a contribution to this area by investigating individual differences in the cognitive mechanisms that may underlie fluency. Fluency, although most often used to describe language use, is relevant across such diverse areas as speaking, reading, skiing or playing chess. In particular, this research looked at issues in the development of fluency in second language (L2) reading.

Fluency can be defined in many ways. Segalowitz (2000) defines performance fluency as the speed, fluidity and accuracy of action. In this view, fluent L2 performance would refer to the idea of speaking or reading as quickly in the second language as in the first and doing so fluidly and without nonnative-like errors. Conversely, a lack of fluency would refer to speaking or reading that is slower, more hesitant and that may include the type of errors not found in native-like speaking and reading.

Fluency of speech can refer to the attainment of automatic procedural skill so that speech is automatic and does not need a great deal of attention or effort (Schmidt, 1992). However, this thesis focusses on reading and reading fluency as defined as the speed, fluidity and accuracy with which text is read.

Although there are many bilinguals who read and speak fluently in two languages, many of these individuals read more slowly in their L2 than in their first language (L1). Thus while these readers may listen and perform reading comprehension tests equally well in L1 and L2, they may read as much as 30% slower in L2 than in L1 (Favreau &

Segalowitz, 1982; Segalowitz, Poulsen & Komoda, 1991).

Why do some individuals attain fluent reading levels in a second language which equal those in their first while others do not? Many theories have been proposed to answer this question that range from the affective to the cognitive to the neuropsychological (Segalowitz, 1997).

Ellis (1994) has suggested seven ways in which individual differences in learning a second language may be classified. These differences consist of the age, aptitude and motivation of the person learning a second language. Other variables encompass learning style, beliefs, affective states and personality. The learning strategy employed by the learner of a second language (L2) and the match or mismatch between that strategy and the specific learning environment could also be meaningful.

Segalowitz (1997) suggests that an understanding of the cognitive mechanisms underlying these factors is also important to the study of the development of fluency. Efficient reading comprehension involves constructing a coherent mental representation from a string of words (Gernsbacher & Faust, 1991). Building this coherent representation involves the interaction of many components and consists of the coordination of many processes such as word recognition, syntactic parsing and the integration of new text with previously read material and current knowledge.

Several cognitive factors have been pinpointed which are thought to contribute to less fluent second language reading. These factors include the less efficient use of phonological codes in memory (Segalowitz & Hebert, 1990), less efficient use of orthographic redundancies (Favreau, Komoda, & Segalowitz, 1980), cross-language influences (Grainger & Dijkstra, 1992) and reduced automaticity of word recognition (Favreau & Segalowitz, 1983).

Word recognition, and indeed many of the components of text reading, can be characterised by the blend of automatic (fast, less variable and effortless) and controlled (slow, less stable and effortful) processes that contribute to efficient reading. Thus if many components such as letter or word recognition can be carried out automatically, more time can be allocated to the more complex processes such as integration of new material with previous knowledge.

Favreau and Segalowitz compared a group of bilingual L2 readers who read equally well in both languages with a second group of bilingual but less fluent L2 readers (the unequal group). They found that the difference between the two groups was not in processing speed but in the lack of L2 automatic word recognition in the unequal group. Thus reduced L2 fluency was accompanied by reduced automatic word recognition.

Much research has focussed on how training can bring about a change in the blend of automatic and controlled processes. Extended consistent practice has been found to bring about a qualitative change in the blend of automatic and controlled processes (Schneider, Dumais & Shiffrin, 1984; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). This qualitative change may indicate a restructuring in that some of the slower, less efficient components contributing to performance drop out as compared to a general speed up of component processes (Segalowitz & Segalowitz, 1993).

Another factor that is thought to differentiate fluent from less fluent readers is the ability to select appropriate information for further processing (Neumann, McCloskey & Felio, 1999). Selection of appropriate information for further processing - be it letters, words or pictures - is thought to involve two general mechanisms - facilitation and inhibition (Hasher & Zacks, 1988; Neumann & DeSchepper, 1992; Tipper, 1985; Yee, 1991). Facilitation (also called enhancement) is important for the activation of appropriate information and suppression is important for the inhibition of interfering, intrusive or inappropriate information.

It is an open question as to whether the processes implicated in individual differences in L1 reading are the same as those implicated in L2 reading. In the case of L1 reading, individual differences may be based on many factors, ranging from the neuropsychological to simply the amount and kind of practice. However, cognitive factors such as the change from controlled to automatic processing have also been implicated in the development of first as well as second language fluency. So although it is possible that the processes may be somewhat different in L2 as compared to L1, certainly studies in L1 reading can suggest interesting hypotheses about the processes implicated in L2 reading.

Current research has found that inhibition has been implicated in many studies investigating individual differences. It has been found, for example, that elderly adults show reduced efficiency of inhibition as compared to young adults (Hasher, Stoltzfus, Zacks & Rypma, 1991). Children also show a reduced ability to employ inhibition

(Tipper, Bourque, Anderson, & Brehaut, 1989).

Inhibition (also called suppression) has also been implicated in studies of individual differences in language processing. The ability to employ suppression as a general comprehension mechanism has been studied extensively by a team of researchers investigating individual differences in reading skill in relation to the ambiguities present at the word, phrase and sentence levels (Gernsbacher & Faust, 1995; Gernsbacher & Robertson, 1999; Gernsbacher, Varner & Faust, 1990). This research will be discussed in detail below.

Ambiguities arise in part as a result of superfluous information activated while reading. Previous research has found that reading a word activates orthographic, phonological and semantic information (Coltheart, Davelaar, Jonasson & Besner, 1977). For example, when reading the word "rows", the word "rose" may be activated at the same time (van Orden, 1987; van Orden, Johnston, & Hale, 1988). Thus the phonological information associated with the word "rows" activates the word "rose" (a homophone). Similarly a word such as "watch" which has several different meanings (a homograph) may activate all of those different meanings. Eventually, only the meaning appropriate to the context of the sentence is selected for further processing (Onifer & Swinney, 1981; Swinney, 1979).

Similarly, when reading in a second language, interference may occur at many levels. Superfluous activation may occur from multiple meanings of ambiguous words, from the activation of words or phrases which are no longer relevant to the current sentence context or from cross-language ambiguities.

This thesis explored within language interference which occurs in the on-line processing of second-language readers at the word level. Also investigated was how the efficiency and speed with which that interference is inhibited may in turn affect reading speed. A second focus was to investigate how the efficiency with which we activate relevant information influences reading fluency.

Current Research on Inhibition and Language Comprehension

Gernsbacher and colleagues, as discussed previously, have performed many experiments studying inhibition in L1 (or suppression as these authors call it) as a general comprehension mechanism. In one experiment these researchers investigated the ability of skilled and less skilled readers to suppress the inappropriate meanings of homophones (Gernsbacher & Faust, 1991). Participants were selected on the basis of scores on a multi-media comprehension battery and were assigned to groups of more and less skilled comprehenders from the top and bottom third of this distribution.

Participants were asked to read a sentence and were then presented with a test word. They were asked to decide whether the test word matched the meaning of the sentence they had just read. Half of the sentences for which a "no" response was required had a homophone as the final word in the sentence. Each test word represented the alternate meaning of the homophone in the experimental condition. The other half of the sentences for which a "no" response was required were neutral sentences and did not have a homophone as the final word.

Gernsbacher and Faust compared how long it took participants to reject a test word like "CALM" after reading a sentence with a homophone as the final word as compared to a neutral sentence in which there was no homophone.

For example:

He had lots of patients CALM Correct Response = "no"

He had lots of students CALM Correct Response = "no"

Test words were presented at both 100 milliseconds (immediate presentation) after the last word in the sentence was presented and 1000 ms (delayed presentation) after the last word was presented. When the test words were presented 100 milliseconds after reading each sentence, both the skilled group and the less skilled group had trouble rejecting the test word in the homophone condition as compared to the nonhomophone or control condition, suggesting that activation from the inappropriate meanings caused interference for both more and less skilled readers at the immediate test interval. However, at the 1000 millisecond interval the skilled group had no trouble rejecting the test word as compared to a control condition, indicating that for the skilled group, there was less interference at the delayed time interval and that the inappropriate meanings of homophones had become less activated, perhaps through suppression.

The less skilled group took longer to reject the inappropriate meanings of homophones as compared to a control condition, both at the 100 and at the 1000 millisecond interval, indicating that the inappropriate meanings were still highly activated.

These results were interpreted as indicating that less skilled readers were less efficient at inhibiting or suppressing the inappropriate meanings and that perhaps because of this, these readers may shift their current representation of text meaning to match that of the inappropriate meaning because they are unable to the suppress inappropriate information. This would result in the cluttering of working memory with irrelevant information, creating competitive noise, interfering with understanding of the text and slowing down the reading process.

Gernsbacher et al. (1990) also investigated whether less skilled readers were less skilled at suppressing the inappropriate meanings of homographs than more skilled readers. Homographs are words which have the same spelling but which have entirely different meanings (e.g. *spade* which can refer to a shovel or a playing card suit). In this experiment, similar to the previous experiment with homophones, participants were again asked to read a sentence, were presented with a test word (either 100 or 850 milliseconds after reading the sentence-final word) and asked to decide whether the test word matched the meaning of the sentence they had just read. In this experiment the comparison was made between sentences in which homographs formed the last word in the sentence and control sentences in which there was no homograph.

When test words were presented 100 milliseconds after reading the sentences, both the skilled and the less skilled group took longer to reject the test word after homograph sentences as compared to the nonhomograph or control sentences. However, at the 850 millisecond interval, the skilled group did not take longer to reject the test word for the homograph sentence as compared to a control or nonhomograph sentence, indicating that for the skilled group the inappropriate meanings of homographs had become less activated, perhaps through suppression.

However, the less skilled group still had trouble rejecting the inappropriate meanings of homographs at the 850 millisecond interval indicating that the inappropriate meanings were at that time highly activated. These results were interpreted as indicating that less skilled readers were less skilled at inhibiting or suppressing inappropriate meanings.

Gernsbacher and Faust (1991) also investigated whether skilled and less skilled comprehenders differed in their ability to enhance the activation of relevant or appropriate information. Similar to the task described above, participants were presented with short sentences, followed by a test word. However in this task the experimenters were interested in the speed with which participants responded "yes" to sentences with biasing verbs as compared to neutral ones. The test words were presented 100 ms after participants finished reading the sentence and after a 1000 ms delay. It was found that both more and less skilled comprehenders benefitted from the biasing context (faster responses to sentences with biasing verbs) at both time delays but that less skilled comprehenders profited to a significantly greater extent, indicating that less skilled comprehenders do not have more difficulty enhancing relevant or appropriate information than more skilled comprehenders.

These authors have extended their research on suppression and enhancement to examine many forms of interference and suppression which may occur in lexical access, metaphors, anaphoric reference (how referents for anaphors such as pronouns are understood), syntactic parsing and individual differences in reading comprehension (Gernsbacher & Robertson, 1999).

To summarize, the research by Gernsbacher and colleagues suggests that less skilled first language readers do not suppress irrelevant or inappropriate information as efficiently as more skilled first language readers. Nonetheless, less skilled first language readers are not less efficient at enhancing the activation of relevant or appropriate information.

Research by Neumann, et al. (1999) investigated inhibition and second language fluency and is discussed later. First of all, however, the relationship between enhancement, inhibition and working memory capacity is discussed.

Theories of Working Memory

The efficiency with which we inhibit or suppress inappropriate or irrelevant information can be related to two different theories of working memory. Conway and Engle (1994) proposed that working memory capacity drives the ability to activate relevant information and inhibit irrelevant information and that inhibition is resource dependent. They suggest further that individuals differ in the size of working memory capacity so that individuals with a high working memory capacity are more likely to be able to inhibit interfering information than those with a low working memory capacity. Thus by this definition working memory capacity drives inhibition.

Hasher and Zacks (1988), in contrast, suggest that working memory capacity refers to the contents of working memory and that an efficient inhibitory mechanism regulates the contents and therefore working memory capacity. According to this theory, an inhibitory mechanism is hypothesized to prevent irrelevant concepts from gaining entrance to working memory (Gernsbacher et al. 1990; Hasher & Zacks, 1988) and also serves to suppress activation of concepts in working memory that are no longer relevant (Gernsbacher, 1989). The less efficient inhibition is, the more likely it is that working memory will be cluttered with irrelevant information. Thus the presence of extraneous information can be expected to interfere with the development of an understanding of the meaning of the text in less skilled readers. It is therefore possible that irrelevant items are maintained in working memory, interfering with and disrupting processing unless inhibition dampens the activation of these interfering and distracting items. On the other hand, the efficient inhibition of irrelevant information should allow an increase in the functional capacity available as discussed above.

Negative Priming

Much of the support for the concept of suppression or inhibition comes from the phenomenon of negative priming. The first experiment to investigate negative priming was carried out by Dalrymple-Alford and Budayr (1966 as cited in Neill, Valdes, & Terry, 1995) with a Stroop task (1935). In the Stroop task participants were asked to name the ink colour in which words were written. It has previously been found that subjects' responses are slowed if the words and colours conflict (e.g. BLUE written in red ink) suggesting that automatic reading of the word conflicts with naming of the colour. This is known as the Stroop effect. Dalrymple-Alford and Budayr, using a list procedure task, found that responses were slowed to an even greater extent if the word ignored in the immediately preceding presentation was the colour to be named on the current trial. For example, if *Green* were presented in red ink followed by *Yellow* in green ink then responses were slowed in comparison to the situation where there was no relationship between the word previously ignored and the present colour to be named. They proposed that participants had to suppress the response to the word in order to name the ink colour and that if the suppressed item was needed to name the next ink colour then that response would be slowed. Extensive research has now been carried out across many different types of negative priming tasks and modalities (for reviews see Fox, 1995; May, Kane, & Hasher, 1995; Neill et al. 1995).

In a typical negative priming experiment, two types of trials are implemented - primes and probes. On prime trials participants are asked to respond to a target item while ignoring a distracting item. On subsequent probe trials, participants are again asked to respond to a target item while ignoring a distracting item. Trial-pairs are set up so that the ignored stimuli on a prime trial becomes the target stimuli on a probe trial. These trial-pairs are referred to as negative priming trial-pairs. It has been found that responses to the target on probe trials (the distractor on the previous prime trial) are slowed as compared to control/neutral trial-pairs in which there is no relation between prime and probe trials. This slowing of response is thought to indicate that the ignored stimulus (distractor) on the prime trial has been inhibited.

In this thesis a trial refers to one presentation (either prime or probe trials) and a trial-pair refers to both prime and probe trials. In the negative priming literature trial-pairs in which the distractor on the prime trial becomes the target on the probe trial are sometimes called ignored repetition trials but for the purposes of this thesis they are referred to as negative priming trial-pairs.

The results of many negative priming experiments have been taken to indicate that negative priming is related to selective attention in that inhibition aids in the selection of relevant information for further processing by excluding irrelevant information before it reaches phenomenal awareness. An alternative view is that inhibition may also function after selection to delete information from working memory which has become no longer relevant or to prevent information which is no longer relevant from becoming reactivated (Hasher, Zacks & May, 1999).

Negative Priming and Bilinguals

Neumann et al., (1999; Experiment 2) used a between language negative priming procedure to investigate the efficiency of inhibition in English/Spanish bilinguals whose first language was English. Two groups of participants were tested, a group designated as more proficient and a second group designated as less proficient in Spanish. On negative priming prime trials the participant was presented with two words in English, one in uppercase and one in lowercase and asked to name the lowercase word (e.g. door, DOG). On subsequent probe trials, two letter strings were presented, an uppercase distractor word in English and a lowercase letter string (Spanish word or nonword). The participant's task was to make a lexical decision (to decide if a letter string was a word) about the lowercase item (e.g. perro, SOLON; perro = dog in Spanish).

It was found that the more proficient readers of Spanish exhibited significant negative priming (longer reaction times) on negative priming probe trials as compared to probe trials in a control condition while the less proficient readers of Spanish did not. These results suggested that the more proficient bilinguals exhibited more efficient inhibition while less proficient bilinguals exhibited less efficient inhibition.

The authors suggested that inhibition spread from the English distractor on the prime trial (naming of the prime) to the Spanish translation equivalent on the probe trial, thereby delaying the processing of this word. The most important finding of cross-language negative priming effects for proficient bilinguals but not for less proficient bilinguals indicated that there was more efficient inhibitory processing for more proficient bilinguals in a between language negative priming task.

Alternative Theories to Inhibition as an Explanation of Negative Priming Effects

Several alternative theories have been postulated to account for negative priming effects, one of which is the semantic mismatch theory (MacDonald, Joordens, & Seergobin, 1999).

MacDonald et al. (1999), in a series of experiments, examined negative priming in a situation where both targets and distractors are "attended". These researchers reasoned that if inhibition is related to selective attention, and functions to prevent information from reaching phenomenal awareness, that a negative priming task in which both items are attended would cause serious problems for a theory of inhibition as an explanation of negative priming. Accordingly, they performed a set of experiments that used several size-selection tasks. In one of these tasks (Experiment 2A) participants were presented with two words representing "units of time" and asked to name the largest "unit of time". As in previous negative priming studies, participants were asked to respond to a target on a probe trial that had appeared as a distractor (word to be ignored) on the prime trial immediately preceding it. On neutral trial-pairs neither targets nor distractors were repeated across trials. MacDonald et al. found that participants responded 91 milliseconds slower to probe trials in the negative priming condition as compared to probe trials in the neutral condition. In another experiment MacDonald et al. used a size-selection task in which participants were asked to judge which "animal" was larger (Experiment 1A). In this experiment participants responded 103 ms slower on negative priming probe trials than on neutral probe trials. MacDonald et al. argue that these results indicate that, because both distractor and target were "attended" at the time of the prime presentation and therefore reached phenomenal awareness, that negative priming effects may not be the result of "selective attention". They propose that several theories may account for their results but that "selective attention" is not plausible. They suggest instead that their results can be accounted for by the episodic or the semantic mismatch theories (these theories will be discussed in detail below) or by selective responding. They suggest that a theory of selective responding could possibly accommodate their results on the view that inhibition acts to suppress *responses* to distractors although both targets and distractors are attended.

However, it is possible that inhibition could be associated with negative priming if one assumes that inhibition serves not just to block irrelevant information from awareness or working memory but to remove information which is no longer relevant, whether at the level of phenomenal awareness or response. In this view a distractor could be attended and then ignored or inhibited when no longer relevant without recourse to discussion of selective attention.

MacDonald and Joordens (2000) have proposed that if selection on a negative priming trial-pair is based on a semantic feature, then selection-feature mismatches may lead to negative priming. For example, if the words "mouse" and "goat" were presented on a prime trial, "goat" would be selected as the larger animal. "Mouse" as the smaller animal would be encoded "smaller". If "mouse" is presented on the probe trial along with "flea", it must now be encoded as "larger". According to these authors, the change in the relative size status ("smaller" to "larger") of the repeated item from prime to probe results in a semantic mismatch. A semantic mismatch may be difficult to resolve and result in enhanced negative priming.

These authors tested out this theory in three experiments. They compared the amount of negative priming in a block of trials in which the selection criterion did not change versus a block of trials in which the selection criterion changed from prime trial to probe trial. Thus, on one block the participants were asked to name the larger of two animals on both the prime and probe trials (selection criterion remains the same). On the other block, participants were asked to name the smaller of two animals on the prime trial and to name the larger of the two on the probe trial (here the selection criterion changes from prime to probe). In this condition the word that is inhibited on the prime is targeted on the probe, similar to previous negative priming experiments, but there is a semantic switch in that on the prime, one is asked to name the "smaller" animal and on the probe one is asked to name the larger animal. For example, in a prime trial one would be asked to name the smaller animal of the pair "pig" and "turtle". On the subsequent probe trial the participant would be asked the name the larger item of the pair "pig" and "mouse". In this last condition we see that there are a number of conflicting features. As in the normal negative priming trial-pair, the item that is ignored on the prime is the same item that is targeted on the probe. However there is an additional conflict or semantic switch in that one is asked to name the smaller item on the prime and the larger item on the probe. Two kinds of neutral trial-pairs were incorporated into the study. In one, participants were asked to name the larger item on both prime and probe trials but there was no relationship between the words. In the other there was also no relation between the words but participants were asked to switch from naming the smaller to the larger animal. The results showed negative priming in the block containing nonswitch trial-pairs but nonsignificant positive priming in the block containing switch trial-pairs. MacDonald and Joordens suggest that because negative priming occurred only in the condition where there was a semantic mismatch (regular negative priming condition) and not in the condition where the repeated item was congruent in terms of the selection feature ("pig" remains as the larger item from prime to probe), that it is the selection feature mismatch that is the primary determinant of negative priming effects in this situation.

Another influential theory is episodic retrieval (Neill & Valdes, 1992; Neill, Valdes, Terry & Gorfein, 1992). This theory was adapted from Logan's instance theory (Logan, 1988). Logan suggested that processing is mediated by either an automatic retrieval process or an algorithmic computation. Each encounter with a stimulus causes an instance or episode to be set down in memory. Episodic retrieval emphasizes the processing that occurs at the time of the probe trial rather than that which occurs at the time of the prime trial. Neill et al. (1992) suggested that, during presentation of the prime, an episodic memory is encoded that could include explicit response information such as "ignore this" or "respond to this". Negative priming is caused when an episode retrieved during a probe trial has response information that a particular stimulus was ignored in a past processing episode and that this information conflicts with the current response requirements. The most recent relevant processing episode is the one most likely to be retrieved. In the case of negative priming trial-pairs this would be the preceding prime trial in which the current target stimulus served as a distractor. If the retrieved information conflicts with the current response requirements ("ignore this" vs "respond to this") then reliance on slower algorithmic processing occurs and negative priming results. In the control condition, in contrast, the most recent processing episode involving the target stimulus is most likely relatively temporally distant from the current episode and should not conflict with and therefore slow processing on that trial. One of the methods used to study the issue of episodic retrieval as an alternative to inhibition is the time course of negative priming effects.

The Time Course of Negative Priming

There has been considerable debate over the duration or persistence of negative priming with some studies finding a significant dissipation or decay of negative priming over a few seconds (Neill & Valdes, 1992; Neill, et al., 1992, Experiment 1; Neill & Westbury, 1987) and other studies failing to find significant decay over similar intervals (Hasher et al., 1991; Hasher, Zacks, Stoltzfus, Kane & Connelly, 1996).

The persistence of negative priming has been investigated by manipulating the time delay between participants response on the prime trial and the presentation of the probe trial (RSI). The persistence of negative priming was examined by Neill and

Westberry (1987) with a Stroop-colour naming task and manipulating RSIs . The greatest amount of negative priming was found at the earliest RSI's of 20 and 520 ms with a drop at 1020 ms and no significant negative priming at 2020 ms.

Tipper, Weaver, Cameron, Brehaut and Bastedo (1991) on the other hand, in a picture-naming task found no decay in negative priming over RSIs of 1350, 3100 and 6,600 ms. Likewise Hasher, et al. (1991) found no decay over RSIs of 500 and 1200 ms in a letter naming task.

Neill and Valdes (1992) pointed out that a methodological difference exists between these sets of experiments that may have been the source of the discrepant results. Neill and Westberry (1987) varied RSI using a within-subjects randomized design. In contrast Tipper et al. (1991) manipulated RSI between subjects while Hasher et al. (1991) manipulated RSI between experiments.

Neill and Valdes (1992) suggested, therefore, that negative priming appears to dissipate in within subjects randomized designs while it persists in experiments which manipulate RSI between groups. They pointed out that in experiments that manipulate RSI between groups the RSI is always the same whereas in within subjects randomized designs, although the RSI between prime and probe is controlled, the time delay between the prime and the previous probe is variable due to random presentation of RSIs with the result that sometimes the delay before the prime will be short and sometimes long.

According to this account, retrieval of the current prime trial (at the time of the current probe trial) will depend on how close in time prime and probe are. The closer a current prime trial is to the current probe trial (a short RSI) and the greater the temporal distance from the probe trial which preceded the current prime (a long PRSI), the greater the likelihood of the current prime being retrieved by the current probe and the greater the negative priming. On the other hand, the greater the temporal distance between the current prime and the current probe trial (a long RSI) and the shorter the temporal distance between the current prime and the preceding probe trial (a short PRSI), the less chance of the prime being retrieved by the current probe and the less negative priming.

Neill et al. (1992) investigated this hypothesis by manipulating PRSI/RSI with all possible combinations of 500 and 4000 ms. Negative priming was found to be greatest when PRSI was 4000 and RSI was 500 in agreement with the hypothesis. In addition negative priming did not differ for trial-pairs in which the RSI was equal to the PRSI, indicating no significant decay of negative priming between RSIs of 500 and 4000 ms.

Hasher et al. (1996) challenged the proposal that negative priming decays when RSI is manipulated within groups but not when negative priming is manipulated between groups. Participants performed a location task in a within subjects randomized design. RSIs of 500 and 2500 were used but PRSI was fixed. No evidence of significant decay of negative priming was found.

To summarize, Neill and colleagues in several experiments have found that if a within subjects randomized design is implemented, and PRSI and RSI are not equal, there is a decay of negative priming over RSIs. However, if PRSI and RSI are equal, there is no decay. Several other researchers, however, have found that negative priming does not decay over RSI even if RSI and PRSI are not equal (Hasher et al., 1996; Conway, 1999). It is important therefore, if investigating the persistence of negative priming, to equate the RSI and PRSI to ensure that any decay of negative priming found is not due to a difference between the PRSI and RSI.

Although some between language research has previously been carried out with negative priming and bilinguals (Neumann et al., 1999; Fox, 1996), it would be interesting to extend this research to investigate how the ability to inhibit irrelevant information and activate relevant information within each language is reflected in the difference between first and second language fluency. By comparing the time course of negative priming in first and second languages it may be possible to examine the extent to which a slowdown in reading speed is affected by the timing and duration of the underlying cognitive mechanisms of inhibition and activation.

The Purpose of the Present Studies

The purpose of the present series of studies was to determine whether the ability to inhibit irrelevant information and activate relevant information in a second language could be two of the mechanisms underlying the development of fluent reading in a second language.

Although some studies have documented the presence of both between and within language interference encountered by second language learners, very little research to date has investigated within language interference and suppression as a function of fluency in reading a second language.

The first experiment in this thesis employed the negative priming paradigm to study the efficiency of inhibitory mechanisms in bilinguals and used a modified version of the negative priming task used by MacDonald et al. (1999). Participants were presented with two words respresenting unit of time on the prime trial and asked to decide which of these two represented the longer unit of time. If, for example, the words *decade* and *year* were presented, the participant would be required to press the key on the keyboard corresponding to the position of the word *decade*. A positive priming version of the size-selection task was also implemented to study the efficiency of facilitatory mechanisms.

The second experiment investigated whether the time course of *inhibition* is different in L1 than in L2. In this experiment the intention was to investigate the time course of negative priming in relation to first and second language reading. Questions asked were whether the onset of inhibition would be later in L2 than in L1, if levels of negative priming would be lower in L2 than in L1 across time delays (RSIs) or if similar levels of inhibition would be attained but at later time delays. A third question asked was whether inhibition would persist as long in L2 as in L1.

The third experiment explored the time course of *activation* in the first and second languages of participants and whether there were in fact any differences between L1 and L2. More specifically, the time course of positive priming was examined in L1 and L2.

Based on the positive priming results of Experiment 1 and research by Gernsbacher it was expected that positive priming would show similar levels of activation across RSIs although it is possible that onset would be later.

These experiments were originally designed to look at the role of inhibition in second language reading but the results were examined in light of some of the alternative explanations for negative priming results reviewed earlier.

General Methodological Considerations

Extensive counterbalancing, both in the construction of *sets of trial-pairs* and in the organization of the overall lists, was implemented both to maximize the probability that inhibition was the mechanism responsible for negative priming effects in this experiment and to disable strategic processing by participants as much as possible.

Design Issues Related to Inhibition vs Episodic Retrieval

As discussed previously, a major issue is whether negative priming effects are the result of an inhibitory mechanism or episodic retrieval. May et al. (1995) argue that in fact negative priming may be a result of inhibition in some situations and episodic retrieval in others and have set out certain criteria to maximize the possibility that inhibition is operating in a given situation. They suggest that inhibition is more likely to be operating if (1) test stimuli are easy to process and therefore stimulus display times should be sufficiently long to permit full identification of the target, (2) if the retrieval of the prime trial does not help current target identification - in other words a condition with repeated targets should not be included in the same experiment and (3) postlexical processing should be avoided - in other words lexical decision-type tasks that may encourage strategic processing should not be used.

Therefore in this set of experiments we took the following steps to optimize the possibility that inhibition was the mechanism responsible for the results.

Stimulus Presentation

For all experiments, all stimuli were clearly presented on the screen until the participant responded.

No Repeated Targets

In the first experiment both negative priming trial-pairs and positive priming trial-pairs (repeated targets) were presented. However this was done in separate blocks so that no repeated target trial-pairs were used in the negative priming block of trials. There was the very occasional repeated target item between one trial-pair and the next one if the second trial-pair was a non-critical trial-pair. This was done so that participants would not assume that every repeat was a negative priming trial-pair.

Techniques Adopted to Avoid Postlexical or Strategic Processing

Stringent counterbalancing techniques were employed to avoid strategic processing as much as possible and were implemented in the following manner. First of all, it was important to ensure that the participant could *not* respond to a probe trial on the basis of an *expectation* formed during the prime trial. Thus it was critical that the participant be unaware of the relationship between prime and probe.

This goal was achieved in part by presenting trials in a continuous manner and by counterbalancing, as much as possible, trial-pairs in both descending and ascending order. Descending order refers to the progression from longer units of time in the prime trial to shorter units of time in the probe trial (e.g. prime: *century-decad*e, probe: *season-year*). Ascending order refers to the progression from shorter units of time in the prime trial to longer units of time in the probe trial (e.g. prime: *season-year*, probe: *century-decade*). Negative priming trial-pairs had to be constructed in descending order due to the inherent nature of the task. However, prime and probe trials for both neutral and positive priming trial-pairs were counterbalanced in both ascending and descending order.

Secondly, twice as many neutral as negative priming trial-pairs were presented and twice as many neutral as positive priming trial-pairs were presented. This was done to ensure that participants were not able to respond on the basis of expectation.

Techniques Employed to Avoid Other Strategic Artifacts

As discussed above, as much care as possible was taken to minimize strategic processing by participants. Therefore, although all of the words listed above were presented to participants, only trials that could ***not*** be responded to in a strategic manner were retained for analysis. First of all, it was recognized that participants could quickly learn that the words *second, seconde* were always the shortest unit of time and that *century, siècle* were always the longest unit of time and could be responded to on the basis of that knowledge after a number of trials. This knowledge could affect response time on those trials and thereby create strategic artifacts that could compromise interpretation of the results. Therefore, those trial-pairs which included the smallest or the longest unit of time were not identified as critical trial-pairs to be submitted for analysis.

Secondly, sets of trials were constructed such that words were seen equally often as targets and distractors and as primes and probes. Trial-pairs which included words that could not be presented equally often as targets and distractors and as primes and probes were not considered critical trial-pairs (*minute, minute* and *decade, décennie*). Consequently only trial-pairs in which the words *morning, hour, day, week, month, season, year* and the corresponding words in French, *matin, heure, jour, semaine, mois, saison, année*, were considered as critical trial-pairs to be included in the analysis. This meant that of the 45 negative priming trial-pairs, only 25 trial-pairs were employed as critical trial-pairs to be submitted for analysis (for all trial-pairs described here and below, only probe trials were submitted for analysis). Similarly, of the 90 neutral trial-pairs, only 24 trials were considered critical trial-pairs to be submitted for analysis (12 in descending order and 12 in ascending order). The balance of the neutral trial-pairs were either non-critical trial-pairs as discussed above or fillers. In similar fashion, of the 54 positive priming trial-pairs, only 24 trial-pairs were considered critical trial-pairs. Of the 108 neutral trial-pairs, only 24 trial-pairs were designated to be submitted for analysis, the rest being non-critical trial-pairs or fillers. It should be noted that Macdonald et al., (1999) did not counterbalance to avoid these strategic effects even though they could still be present in the naming task. For example they apparently analyzed all of the trials even though some of their stimuli could only be presented as targets or distractors but not both and therefore were not seen equally often.

Thirdly, the difficulty of decision between units of time was kept constant so that no results could be attributed to differences in the difficulty of particular decisions. For negative priming and neutral trial-pairs, for the most part, there was a one-step difference in unit of time between target and distractor and between prime and probe. However due to the difficulty imposed by all of the above counterbalancing constraints, there were in fact three instances in each set of neutral trials where there was more than a one step difference in unit of time between prime and probe.

For positive priming trial-pairs there was either a one- or-two step difference in unit of time between targets and distractors. This was counterbalanced between prime and probe trials so that on half of the trial-pairs there was a one-step difference in unit of time on prime trials and a two step difference on probe trials. On the other half of the trial-pairs the reverse was true.

Fourthly, to ensure that there were no artifactual effects due to the difficulty of a particular word-pair decision, the items in probe trials were counterbalanced for occurrence on negative priming and neutral trial-pairs and on positive priming and neutral trial-pairs.

Equality of PRSI and RSI

Experiment 2 examined the time course of negative priming in a situation in which most previous first language studies had found negative priming to persist over several seconds. Thus although RSI was randomized within subjects, the PRSI and the RSI were equal for any one trial-pair. With this procedure it is possible to attribute any differential decay of negative priming to between language differences.

Experiment 1

The goal of this first study was to investigate the relationship between the efficiency of inhibitory processing and reading proficiency in a first and second language. Participants were tested in both their first and second languages.

Most previous studies have found that negative priming is dependent on stimulus repetition (Malley & Strayer, 1995 but see Neumann et al., 1999) and therefore it was important to select a negative priming task with a small set of stimuli. In addition, it was essential to ensure that any differences found between L1 and L2 could not be attributed to language-based differences in perceptual fluency (ease of word recognition) and therefore it was necessary for the stimuli to be easily recognized words in both L1 and L2. By using a small set of words repeatedly, we were able to ensure that perceptual fluency would not be a factor responsible for performance differences in L1 versus L2. Thus the present task using units of time was selected.

Previous research by MacDonald et al. (1999) using the task that was used in the present experiments, has produced enhanced negative priming as compared to most previous studies that have found effects ranging from approximately 15 to 25 ms (review by Fox, 1995). For example Hasher et al. (1996) examining the time course of negative priming with a location task, found effects ranging from 9 to 23 ms. Conway (1999; Experiments 3 and 4) with an identity task and also manipulating RSI, found effects ranging from 33 ms of negative priming to 8 ms of positive priming. The enhanced effects as found by Macdonald et al. have much practical value for the study of bilingual processing. The greater amount of negative priming found with this task may allow for more sensitivity in assessing the magnitude of negative priming effects in a second language, where the effect may be reduced. Typical negative priming experiments in which the effects are quite small may not be sensitive enough to detect small between-language differences. For this reason, the task used by MacDonald et al. was chosen as likely to yield large enough effects to permit L1-L2 comparisons.

As described previously, on this task participants were asked to make judgments to time-related words, one indicating a longer duration than the other. Thus on each trial subjects had to decide what was the longer unit of time. For negative priming trial-pairs, the distractor in the prime trial was the same as the target in the probe trial. For neutral trial-pairs, neither of the words presented in the prime trial was presented in the probe trial and so there was no relation between the two words presented in the prime trial and the two words presented in the probe trial. For the positive priming trial-pairs the target in the prime trial was the same as the target on the probe trial. In each case the various counterbalancing procedures were followed as described in the previous chapter, to remove the possibility of artifactual results due to strategic responding or other forms of bias.

Experiment 1 consists of two parts, Experiment 1A and 1B. In Experiment 1A, participants were given one block of trials which included both negative priming and neutral trial-pairs. In Experiment 1B another block of trial-pairs included both positive priming and neutral trial-pairs. All individuals participated in both Experiments 1A and 1B.

Experiment 1A tested the factors of Language (first vs second) and Type of Trial (neutral, negative priming). It was expected that when participants performed the task in their first language that they would demonstrate significant negative priming indicating that they were able to suppress irrelevant information efficiently. On the other hand, when participants performed the task in their second language they were expected to exhibit less negative priming indicating less efficient inhibitory processing.

Experiment 1B tested the factors of Language (first vs second) and Type of Trial (neutral, positive priming). Participants may exhibit similar levels of positive priming in their second language as compared to their first indicating that in both languages individuals are able to activate relevant information efficiently.

Method

Participants

Twenty Anglophones (16 women and 4 men with a mean age of 24) and with French as their second language participated in this experiment. These participants were recruited as volunteers from courses at Concordia University and were paid $20.00 for their participation. Participants had normal or corrected-to-normal vision.

Potential participants were given a reading proficiency test in English and French to determine reading time and accuracy in both languages. This reading test consisted of eight standardized texts, presented in each language, and taken from a collection of TOEFL (Davy & Davy, 1992) practice tests with slight modifications. These texts were translated into French by a professional translator, who preserved the overall style and register of the original texts, which had been constructed as suitable for a university readership. Participants saw eight texts in English and eight different texts in French. The texts were randomly selected for each subject from a pool of sixteen texts. The texts were modified slightly to ensure that the vocabulary was appropriate for second language readers (including the situation where the second language was English) although in the present research all subjects were L1 readers of English and L2 readers of French. In addition to the sixteen texts described above, one practice text was given at the beginning of each language testing session. Participants read instructions in English and then in French. Individuals were asked to read the texts as quickly as possible without sacrificing comprehension. These texts were then presented one paragraph at a time on the computer screen and participants pressed a button on a keypad to move to the next paragraph. Reading times were calculated as the amount of time between each button press. Although the main purpose of the reading proficiency test was to determine reading speed, it was necessary to ensure that comprehension was relatively constant across participants. Therefore, after each text was read, participants were asked to answer one 3-item multiple choice question that tested knowledge for gist. Only participants who correctly answered 75% of the multiple choice questions in both L1 and L2 were included in the main part of the experiment.

Several additional criteria were established for the inclusion of participants in this experiment in order to obtain a sample that demonstrated a threshold level of skilled reading in the first language and strong but less skilled reading in the second language. These criteria were that (a) reading time in L1 (English) was not more than 350 milliseconds per word (or less than 171 wpm (words per minute)) (This criterion was established as it was important to find participants who were skilled readers of English. The number chosen was somewhat arbitrary but was based on previous pilot testing in the lab which had suggested that the vast majority of participants would pass screening based on this test, in this format and in this lab.) (b) reading time in L2 (French) was at least 20% slower than reading time in L1 (c) reading time in L2 was not more than twice as slow as reading time in L1. Although a total of 43 participants performed both the reading and priming sections of the experiment, the data of only 20 of these participants were retained for analysis. Twenty-one subjects' reading data did not meet the criteria as discussed above and two subjects were not included due to computer failure.

Stimuli

Stimuli were chosen from the category "unit of time" and presented in the first and second languages (French) of Anglophone participants. Stimuli presented in English were the words: *second, minute, hour, morning, day, week, month, season, year, decade* and *century* and the corresponding items in French were: *seconde, minute, heure, matin, jour, semaine, mois, saison, année, décennie, siècle*. The English and French words did not differ significantly on the basis of letter length (English, M = 5.273, French, M = 5.727 ; $\underline{t}$ (20) = - .813, $\underline{p}$ > .10.

Each trial-pair consisted of a prime trial (two words) and a probe trial (two words). These two words were presented one above the other on the computer screen. Negative priming trial-pairs were constructed so that the word presented as a distractor in the prime trial was presented again in the probe trial as a target (e.g., prime: *month season*; probe: *week month*). Neutral trial-pairs were constructed so that none of the words presented in the prime trial were repeated in the probe trial (e.g. prime: *month season*; probe: *week day*). Positive priming trial-pairs were constructed so that the word presented as a target in the prime trial was repeated again in the probe trial as a target (e.g., prime: *month season*, probe: *week season*). Four different lists were created for blocks of *experimental trial-pairs* (English negative priming & neutral, French negative priming & neutral, English positive priming & neutral and French positive priming &

neutral).

The methodological considerations discussed previously resulted in prime-probe pairs being constructed in sets of nine. Each negative priming trial-pair was presented five times for a total of 45 negative priming trial-pairs (5 x 9). Of the 90 neutral trial-pairs presented, 35 were in descending order (the progression from longer units of time on the prime trial to shorter units of time on the probe trial) and 55 were in ascending order (the progression from shorter units of time on the prime trial to longer units of time on the probe trial). In total, in the blocks containing negative priming trial-pairs there were 135 trial-pairs (45 negative priming trial-pairs and 90 neutral trial-pairs).

For positive priming and the corresponding neutral trial-pairs, prime and probe trials were counterbalanced equally in both descending and ascending order. Thus half of the trial-pairs in the block were in descending order and half were in ascending order. In the positive priming blocks there were 162 experimental trial-pairs (54 positive priming trial-pairs and 108 neutral trial-pairs).

As discussed previously only probe trials in which the words *morning, hour, day, week, month, season, year* and the corresponding words in French *matin, heure, jour, semaine, mois, saison, année*, were considered as critical trials to be included in the analysis. This meant that of the 45 negative priming probe trials, only 25 probe trials were employed as critical trials to be submitted for analysis. Similarly, of the 90 neutral probe trials, only 24 probe trials were considered critical trials to be submitted for analysis (12 in descending order and 12 in ascending order). The balance of the neutral trial-pairs were either non-critical trials as discussed above or fillers. In similar fashion. of the 54 positive priming probe trials, only 24 probe trials were considered critical trials. Of the 108 neutral probe trials, only 24 probe trials were designated to be submitted for analysis. the rest being non-critical trials or fillers.

Lists for Experimental Trials

Neutral and experimental trial-pairs were presented in pseudorandom fashion with the constraints that not more than one negative or positive priming trial-pair was presented in a row (depending on whether it was a positive priming or negative priming block) and not more than three neutral trial-pairs were presented consecutively. In addition. none of the words used on a probe trial was repeated on the following prime trial unless the following trial-pair was not a critical trial-pair (a trial-pair which contained the words designated above as not-critical) or was a filler trial-pair. There were no trials which were direct repeats of the previous trial.

Target and distractor position was also determined pseudorandomly with the constraints that (1) approximately 50 % of the time the target appeared as the upper word and 50% of the time the target appeared as the lower word and (2) targets and distractors did not appear in the same position (upper or lower) more than five times in a row.

Lists for Practice and Warm-up trials

Eight different lists with 14 trial-pairs in each list were constructed for practice and warmup (four English and four French). These trial-pairs were neutral in that none of the words used in the prime trial were repeated in the probe trial. For all practice and warm-up trials there was a three-step difference in unit of time between targets and distractors (e.g. Prime trial - *month morning*: Probe trial: *hour week*).

These lists were constructed so that (1) there were not more than three trial-pairs of ascending or descending order in a row and (2) there were no repeated presentations within 3 trials (at least 2 presentations between duplicates).

Apparatus

Stimuli were presented on a Macintosh Quadra 630 computer. The software package used to write the programs for the experiment was Hypercard 2.3. A software patch permitted reaction time measurement accuracy to about 5 milliseconds as compared to screen frame time which is 16.67 milliseconds.

Design

The effects of negative priming and positive priming were examined separately (Experiment 1A and 1B respectively). For negative priming trials, the experiment employed a design with Language (first vs second language) and Type of Trial (neutral vs negative priming) as within subjects factors. Similarly, the experiment employed a corresponding within design for positive priming with Language (first vs second language) and Type of Trial (neutral vs positive priming) being within subjects factors.

Procedure

Participants were tested in L1 and L2 on two different days, with blocks of negative and positive priming trial-pairs being presented on the same day. These constraints resulted in the generation of four different counterbalanced orders of testing. Five participants were assigned to each order of testing.

On the first day of testing participants were asked to complete a consent form (please refer to Appendix A) and a language background questionnaire (please refer to Appendix B). On each day of testing, general instructions were presented to the participant, outlining the general structure of the testing session (refer to Appendix C). Subsequently, participants read instructions specific to the experiment (refer to Appendix D). These instructions stated that two words would be presented on the computer screen, one above the other, and that participants should indicate which of the two words was the longer unit of time by pressing an arrow on a keypad corresponding to the position of the correct item. Participants were requested to respond by pressing the designated top button with the index finger of their preferred hand and the designated bottom button with the index finger of the other hand. Participants were encouraged to respond as quickly and accurately as possible.

Following the presentation of instructions, participants were shown a vocabulary list of the words that were included in the experiment, in English and in French, and asked to state if they were familiar with all of the words (Please refer to Appendix E). If participants were not familiar with any of the words, they were reminded of the meaning. This happened on very few occasions. The occasions when this did occur were constrained to the non-critical word "décennie".

After presentation of the vocabulary list, participants were given a set of practice trial-pairs and a 3-4 minute break. Then an additional block of practice trial-pairs (warm-ups) was presented, directly followed by a block of experimental trials (either a positive or negative priming block of trial-pairs). After completion of this block of experimental trials, participants were given the reading proficiency test in whichever language they were being tested that day (four of the participants had already been tested on the reading proficiency test and therefore were presented with another short experiment in the language of testing for that day. This experiment involved reading sentences and making pronoun inference judgements. The details of this experiment are not relevant to this study and will not be discussed further). This was followed by practice, warm-up trials and the other block of experimental trials.

The events occurring during presentation of a typical trial-pair were as follows. The words in the prime trial were first of all presented in lowercase letters in the centre of the screen until the subject responded or for a maximum of 6000 ms. Following this, a blank screen was presented for approximately 1400 ms and then the probe trial was presented for 6000 ms or until the subject responded. This was followed by a blank screen for 1400 ms and then the presentation of a new trial-pair began.

Reaction time was calculated from the onset of the probe stimulus until the subject responded. If the subject did not respond within 6000 milliseconds, this was counted as an incorrect response. Percent error was also measured.

If errors were made on critical trial-pairs, those trial-pairs were represented at the end of the experiment. If an error preceded a critical trial-pair, then a buffer trial was inserted at that point. This buffer trial would include either the word-pair *second, minute* or *decade, century* or the corresponding words in French, if participants were being tested in that language. An error on a buffer trial resulted in the presentation of another buffer trial. Two buffer trials were also inserted between each re-presented critical trial-pair to ensure that on these trial-pairs there was no overlap with the preceding trial-pair. The re-presentation of critical trials on which there were errors and the presentation of buffer trials was the reason that counterbalancing of position could only be approximate.

On completion of 30 correct trial-pairs, feedback was presented to participants. This feedback included information regarding speed of responding and error rate. At this time participants were encouraged to take a short rest. Feedback was also presented at the end of each block of trials, informing participants of their mean reaction time and error rate over the whole block of trials.

Results

The primary focus of this experiment was to investigate the contribution of inhibitory mechanisms to first and second language fluency by examining differences in first and second language readers' ability to suppress or ignore irrelevant information and to put them in the light of first and second language readers ability to facilitate or activate relevant information.

The reading proficiency data are presented first. This is followed by the results of negative priming blocks of trial-pairs then the positive priming blocks of trial-pairs.

Reading Proficiency Data

The mean reading rate for each participant in L1 and L2 was submitted to a planned comparison that, as expected, revealed a significant difference between the reading rate times for the two languages, $t\ (19) = -20.792$, $p < .0001$, with the mean reading time in L1 being 228 mpw (milliseconds per word) and the mean reading rate in L2 being 346 mpw. The range of reading times in L1 was 173 mpw and in L2 was 139 mpw.

Negative and Positive Priming Data

As discussed previously, only responses to trials involving the words *hour, morning, day, week, month, season, and year* were included in the L1 analysis.

Reaction times were analyzed only for correct responses on probe trials which followed correct responses on the immediately preceding prime trials. Less than .025 %

of trials were discarded because of technical difficulties or coding discrepancies.

Due to the specificity of the hypotheses, planned comparisons (one-tailed t-tests for Paired Samples) were carried out on the reaction time data. Negative priming and positive priming data were analyzed separately. The reaction times entered into the analyses were each participant's mean RT (MRT) for the selected trials described above. Data were trimmed across subjects to two standard deviations above the mean. The MRT and standard errors (SE) are displayed in Table 1.

Negative Priming(Experiment 1A)

To verify that there were between language differences in response times and that the negative priming manipulation had worked, mean reaction times for correct responses were submitted to a two-way (2 x 2) repeated measures analysis of variance (ANOVA) in which the factors were LANGUAGE (first vs second language) and TYPE OF TRIAL (neutral vs negative priming). The main effect of LANGUAGE was significant with MRTs of 1350 and 1452 ms for first (L1) and second (L2) languages respectively, [$F(1, 19) = 5.05$, $MSE = 41,278.11$, $p < .05$], indicating that, overall, participants responded more quickly in their first language than in their second. There was also a main effect of TYPE OF TRIAL where the MRT was 1375 ms and 1426 ms for neutral and negative priming trials respectively, [$F(1, 19) = 11.20$, $MSE = 4649.96$, $p < .01$], indicating that negative priming probe trials were responded to significantly more slowly than neutral trials overall. The interaction of LANGUAGE and TYPE OF TRIAL was not

Table 1.

Mean Reaction Times (MRT) (in Milliseconds) and Mean Standard Errors (MSE) for Correct Responses on Probe Trials as a Function of Experiment, Language and Type of Trial.

Experiment 1A	L1	L1	L2	L2
Type of Trial	MRT	SE	MRT	SE
Neutral	1313	65.04	1437	72.05
Negative Priming	1386	72.19	1466	66.87
Difference	- 73**		- 29	
Experiment 1B				
Type of Trial				
Neutral	1237	60.41	1295	50.42
Positive Priming	1171	54.02	1253	41.07
Difference	66**		42	

Note. * indicates significance at p <= .05.
** " " " p <= .01.

significant, [$F(1, 19) = 1.54$, $p > .10$]. Please refer to Figure 1.

Planned comparisons (one-tailed Paired-Samples T-tests) revealed that, for the L1 data, the difference between response times for neutral and negative priming probe trials was significant $t(19) = -3.29$, $p = .002$. Response times were not significantly slower in the negative priming condition as compared to the neutral condition for L2 responses, $t(19) = -1.23$, $p > .10$. A third comparison was carried out which investigated whether there was a significant difference between the amount of negative priming in L1 and the amount of negative priming in L2. Difference scores were calculated for each subject by subtracting individual means for the negative priming condition from individual means for the neutral condition. Subsequently, these difference scores for L1 and L2 were submitted to a one-tailed t-test for correlated means. The difference was not significant, $t(19) = -1.24$, $p > .10$, although the amount of negative priming in L1 was 73 ms and, in L2, 29 ms for a difference of 44 ms.

Error Percentages

Error percentages were calculated by two different methods because of the difference in the total number of correct responses depending on whether or not re-presented items at the end of the experiment are included in the calculation. First of all, errors were calculated as the total number of possible responses (without re-presentations) less the total number of correct responses (includes re-presentations). This gives a measure of how many trials were actually included in the analyses.

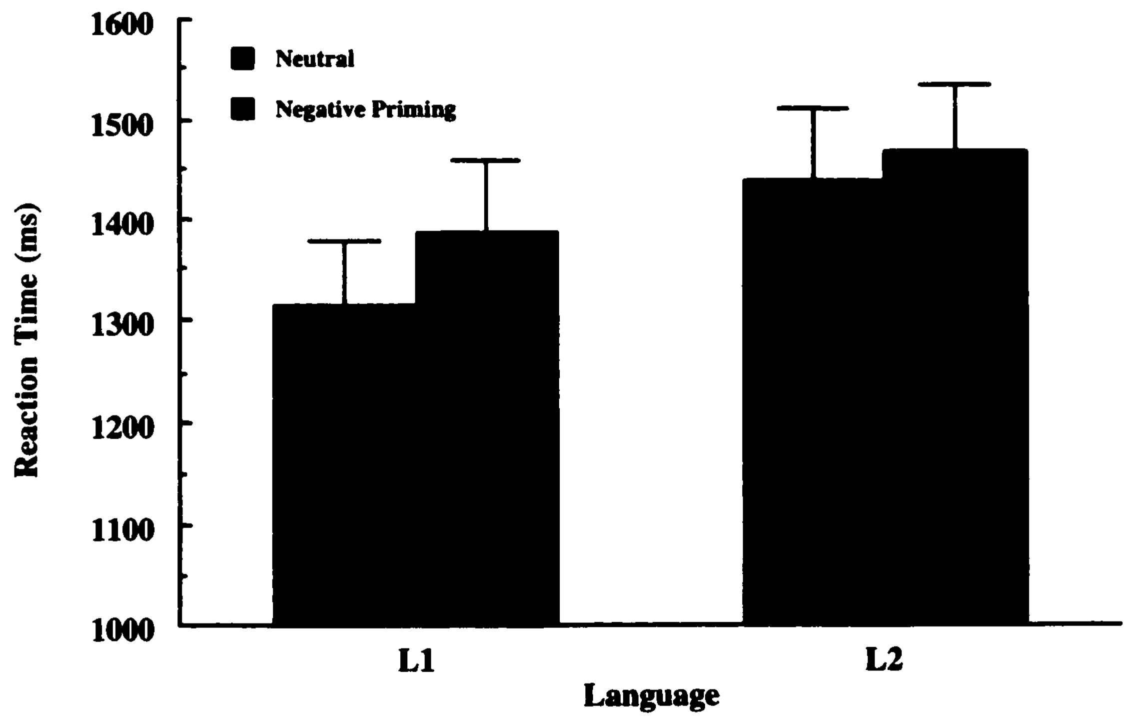

Figure 1. Mean reaction time (in milliseconds) as a function of language and type of trial in Experiment 1A. Error bars indicate standard errors.

According to this calculation, error percentages for the neutral and negative priming conditions were 2.3 % and 3.2 % respectively in L1 and 2.90 % and 2.6% respectively in L2.

In addition, errors were calculated as the total number of errors on probe trials for neutral and negative priming trials (includes all presentations and re-presentations). For the negative priming data error percentages were submitted to a two-way 2 x 2 repeated measures analysis of variance (ANOVA) in which the factors were LANGUAGE (first vs second language) and TYPE OF TRIAL (neutral vs negative priming). None of the effects were significant (all $p > .10$). According to this calculation, error percentages for the neutral and negative priming trials were 6.30 % and 7.86 % respectively in L1 and 5.88 % and 6.32 % in L2. Thus although errors were greater in the negative priming condition than in the neutral condition, in agreement with previous research, the difference was not significant.

Positive Priming (Experiment 1B)

Mean reaction times for correct responses were submitted to a two-way (2 x 2) repeated measures analysis of variance (ANOVA) in which the factors were LANGUAGE (first vs second language) and TYPE OF TRIAL (neutral vs positive priming). A main effect of LANGUAGE approached significance with MRTs of 1204 and 1274 ms for first (L1) and second (L2) languages respectively, [$F(1,19) = 3.71$, *MSE* = 26,382.75, $p = .069$], indicating that participants tended to respond more quickly in their first language than in their second. There was a main effect of TYPE OF TRIAL where the MRT was 1266 ms and 1212 ms for neutral and positive priming trials respectively. [$F(1, 19) = 6.26$, $MSE = 9252.19$, $p < .05$], indicating that, overall, positive priming trials were responded to significantly more quickly than neutral trials. The interaction of LANGUAGE and TYPE OF TRIAL was not significant $p > .10$. Please refer to Figure 2.

Planned comparisons revealed that for the L1 data, positive priming responses were faster than neutral responses, $t(19) = 2.69$, $p < .01$. Planned comparisons carried out on the L2 reaction times revealed that the difference between positive priming and neutral conditions approached significance, $t(19) = 1.69$, $p = .054$. A third planned comparison was performed which investigated whether there was a significant difference between the amount of positive priming in L1 and the amount of positive priming in L2. Similar to the negative priming analysis, difference scores were calculated for each subject by subtracting individual means for the positive priming condition from individual means for the neutral condition both in L1 and in L2. Subsequently these difference scores for L1 and L2 were submitted to a planned comparison. The results were not significant $t(19) = 1.01$, ($p > .10$). To summarize, positive priming responses were found to be significantly faster than neutral responses in L1 and approached significance in L2.

Error Percentages

Error percentages were again calculated by the two different methods for the

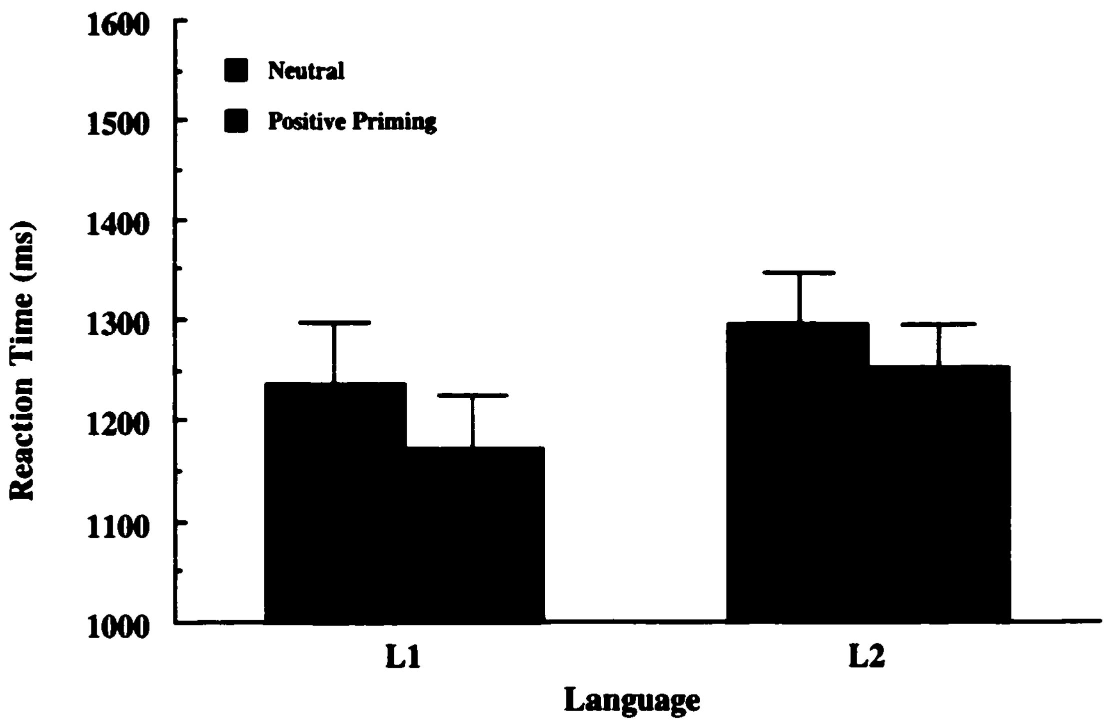

Figure 2. Mean reaction time (in milliseconds) as a function of language and type of trial in Experiment 1B. Error bars indicate standard errors.

positive priming data. When errors were calculated as the total number of possible responses (without re-presentations) less the total number of correct responses error percentages for the neutral and positive priming conditions were 1.05 % and 1.47 % respectively in L1 and 2.3 % and 2.1 % respectively in L2.

Errors were again calculated as the total number of errors on probe trials for neutral and negative priming probe trials (includes all presentations and re-presentations). Error percentages were then submitted to a two-way 2 x 2 repeated measures analysis of variance (ANOVA) in which the factors were LANGUAGE (first vs second language) and TYPE OF TRIAL (neutral vs positive priming). None of the effects were significant (all $p > .10$ ns.). According to this calculation, error percentages for the neutral and positive priming probe trials were 5.36 % and 5.21 % respectively in L1 and 6.79 % and 6.94 % in L2. Thus there is no evidence that faster RTs in the positive priming condition were associated with a greater number of errors in that condition.

Correlations

Correlations were also calculated between English and French reading times and the amount of negative and positive priming (two-tailed tests). English and French reading times (mpw) correlated strongly, $r = .8237$, $p < .0001$ indicating that fast reading times in L1 are associated with fast reading times in L2. English reading times did not correlate significantly with either negative or positive priming scores but French reading time correlated with French positive priming scores, $r = -.4929$, $p < .05$ indicating that faster readers in L2 demonstrated greater positive priming. An odd result was that French reading times tended to correlate with English negative priming scores, $r = -.4062$, $p = .076$ indicating that faster readers in French demonstrated less negative priming in English.

Discussion

One of the questions addressed in this experiment was whether readers would demonstrate significant negative priming in their first language but not in their second. This was indeed the result found. Participants demonstrated significant negative priming of 73 ms in L1 but only 29 ms of negative priming in L2. This result suggests that while readers in L1 demonstrate efficient inhibition, participants who read more slowly in their second language than their first do not demonstrate evidence of efficient inhibitory mechanisms. In the sense that by comparing L1 and L2 readers, we are comparing more and less proficient readers, this result is in agreement with Neumann et al. (1999) who found that more proficient readers in a second language demonstrated significant negative priming while less proficient readers in a second language did not. This result is also in agreement with Gernsbacher et al. (1990) who found evidence that less proficient readers in L1 are less able to inhibit irrelevant information than more proficient readers in L1.

The amount of negative priming in L1 in this experiment was less than that found by MacDonald et al. (1999) who found 91 ms of negative priming with a very similar task and the same sample size. However, there were several differences between the task as implemented by MacDonald et al. and the one used in this study. First of all the mode of response was different. In the MacDonald et al. study participants were asked to *name* the larger unit of time rather than to respond with a button press. Secondly there were a larger number of trials in the MacDonald et al. study. The number of trials in the study was not provided but an approximation of 48 trials in each condition can be made from the information given.

Thirdly, the timing of the various events in this experiment over a trial-pair differed from that found in the MacDonald et al. study. In that study a focal point was presented for 250 ms followed by a blank screen, also for 250 ms prior to the onset of the prime. A mask was presented between prime and probe trials for 250 ms. In the present study no focal point or mask was presented between prime and probe but a blank screen was presented for approximately 1400 ms.

Previous pilot testing had led us to believe that this was the optimal time delay to obtain negative priming with this particular task and mode of response. Nonetheless, in view of the fact that the negative priming found in this study was somewhat less than that obtained in the MacDonald et al. study it is possible that the delay between prime and probe was not the optimal one for the detection of negative priming. In other words, perhaps greater negative priming would have been obtained in L1 if the delay between the prime and probe trials had been shorter or longer, thus catching inhibition before it began to dissipate or allowing more time for inhibition to accrue.

Most research on the time course of negative priming indicates that, in a within subjects randomized design with the delay before the prime and probe (RSI) being equal to the delay between the prime and the previous probe trial (PRSI), that negative priming could persist for up to 6600 ms (Tipper et al., 1991). In other words it is uncertain where in the time course of negative priming the optimum time delay between prime and probe would occur. As the time delay was relatively long (1400 ms) it is possible that negative priming was already dissipating to some extent, but it is also possible that, because of the strong semantic nature of the task, it had not yet accrued to full strength. To summarize, in view of the results of Experiment 1, it is reasonable to ask whether perhaps in this particular testing situation, negative priming took longer than 1400 ms to accrue fully in L1 and in L2 or perhaps dissipated somewhat before this time delay.

The second question addressed in this experiment was whether readers would demonstrate similar positive priming in L2 as in L1 or whether there would be diminished positive priming in L2. Significant positive priming of 66 ms was found in L1 and significant positive priming of 42 ms was also found in L2 indicating that readers in both languages activated relevant information. This result, to the extent that positive priming in both L1 and L2 was significant agrees somewhat with Gernsbacher and Faust (1991). She and her colleagues, however, found that less skilled comprehenders actually demonstrated significantly more activation of relevant information than more skilled comprehenders. However, there was a difference in subject populations between this experiment and that of Gernsbacher in that although our participants read L2 more slowly than L1, their comprehension in L2 matched that in L1. In Gernsbacher's study her participants were chosen on the basis of comprehension scores rather than reading speed with participants divided into a group of high comprehenders and low comprehenders. Thus, although the group of high comprehenders in Gernsbacher's study may have been quite similar to our L1 group, our group of L2 readers may differ from her low comprehenders. In addition the correlation of reading times in L2 and positive priming scores suggests that in this study and for this group of participants, faster reading times were associated with greater positive priming and by extension greater facilitation.

The positive priming results are somewhat at odds with those of Neumann et al., (1999; Experiment 2). In that experiment a propensity towards positive priming was found for less proficient but not for more proficient L2 readers. Thus both Gernsbacher and Neumann found greater positive priming for less proficient readers. In the current experiment the lower positive priming for L2 readers may be because there was a wider range of proficiency in our second language group as both more and less proficient L2 readers were included or because our L2 group was performing in their second language and thus performance was qualitatively different from Gernsbacher's L1 group of low comprehenders.

In summary, as expected, this experiment found significant negative priming in L1 but not in L2. These results suggest that when people read in their first language, they are able to suppress irrelevant information efficiently but when they read in their second language they are not able to suppress information efficiently. In addition, significant positive priming was found in both L1 and L2, indicating that people are able to activate relevant information efficiently when they read in both first and second languages.

The second and third experiments looked at bilinguals' ability to inhibit irrelevant and activate relevant information at several different time delays. Less proficient bilinguals have been found to take longer to perform some components of reading (Favreau et al., 1980) and so it is possible that participants may just take longer to inhibit irrelevant material. On this view, if a negative priming task is employed but additional time is allowed between presentation of the prime and probe, participants in L2 may indeed demonstrate significant negative priming.

Experiment 2

Experiment 2 investigated whether in fact the time course of negative priming varies as a function of the reading skill of the individual. Previous research has found that individuals reading in a second language take longer to carry out some components of reading (Favreau et al., 1980). Favreau et al. (1980) found that the top-down processing revealed by the word superiority effect appeared to be absent in L2 as compared to L1 (Experiment 1) but in a second experiment found that such effects were evident when a longer processing time was given. These experiments suggest that readers in L2 had the knowledge to enable them to make use of orthographic redundancies in L2, but that they were less efficient in doing so.

Similarly, it is possible that if more processing time is given and therefore longer delays are presented between the response to the prime trial and the presentation of the probe trial (varying the time course of negative priming), that readers in L2 will demonstrate negative priming effects.

Lowe (1985) found, with a Stroop task, that at a short delay of 50 ms between prime and probe trials, participants show a small amount of, or no, negative priming. In addition, when participants are asked to respond as quickly as possible, sacrificing accuracy, they also do not show negative priming (Neill & Westbury, 1987). This may indicate that it takes time for inhibition to build up (May et al., 1995) and that at longer delays greater negative priming in both L1 and L2 may be demonstrated. It is in fact possible that optimal negative priming will be demonstrated at shorter RSIs in L1 than in

L2. Thus in order to discover whether less skilled readers take longer to inhibit irrelevant information or whether they merely inhibit information to a lesser degree, the time between prime and probe was manipulated, so that a range of response-to-stimulus intervals (RSI) was tested.

Accordingly, the second experiment was identical to Experiment 1A (looking at negative priming) with the exception that the variable of RSI was manipulated in addition to Language and Type of Trial. Thus factors tested were Language (first vs second), Type of Trial (neutral, negative priming) and RSI (1150, 1400, 1650 and 1900 ms).

If there is less inhibition in the second language, it was expected that first language readers would (a) demonstrate greater negative priming at shorter and longer RSIs and that (b) readers in L2 would exhibit significant negative priming but at longer RSIs than in L1.

Method

Except where noted, the method for Experiment 2 was the same as that for Experiment 1.

Participants

Twenty-four Anglophones (17 females, 7 males with a mean age of 24.1) with French as their second language participated in this experiment. These participants were recruited either as volunteers from courses at Concordia University or in fulfillment of a course requirement to participate in a study. Participants were paid $6.00 for participation in the reading proficiency test or received recognition for fulfilling a course requirement. Individuals were paid $20.00 for their participation in the negative priming sessions. All participants had normal or corrected-to-normal vision. None of the participants had participated in Experiment 1.

Potential participants were given the same reading proficiency test as in Experiment 1. However, in Experiment 2 the reading proficiency test was given on a day previous to the negative priming sessions. The same criteria were implemented for the selection of participants, with the exception that participants were selected whose reading time in L2 was at least 15% slower than reading time in L1. In Experiment 1 participants were chosen whose reading time in L2 was at least 20% slower in L2 than in L1. This change was implemented because the 20% criterion was found to restrict our selection of participants to too great an extent.

Although 47 participants performed the reading proficiency test, twenty-one individuals were not asked to participate in the negative priming sessions as they did not meet the selection criteria discussed previously. A further two participants could not participate in the negative priming sessions due to computer failure during the reading proficiency test. In addition three participants discontinued the experiment after the first negative priming session for personal reasons.

Stimuli

For the present experiment two new lists were created, one in English and one in French. These lists were constructed by quadrupling each of the lists used in Experiment 1, resulting in two lists with a total of 540 trial-pairs each. Each previously counterbalanced quarter of the list (in English and French) was then assigned an approximate RSI of 1150, 1400, 1650 and 1900 ms (135 trials for each RSI). Each list was then re-randomized and counterbalanced in the same manner as for Experiment 1 with the exception that there could be as many as four neutral trial-pairs in a row but no more than three trial-pairs with the same RSI in a row. The interval between the prime and probe trials (RSI) and between the prime and the previous probe trials (PRSI) were equal. All buffer trials were presented with an RSI of 1650 ms.

The same lists as used in Experiment 1 for practice and warm-up trial-pairs were used (four out of the eight lists) but with the RSIs of 1150, 1400, 1650 and 1900 ms randomly assigned to the trial pairs.

Apparatus

The experiment was run on a Macintosh Quadra 630 for some subjects and a Power Macintosh 7200/90 for others.

Design

This experiment employed a design with Language (first vs second language), Type of Trial (neutral vs negative priming) and RSI (1150, 1400, 1650 and 1900 ms.) as within subjects factors.

Procedure

Participants were tested in L1 and L2 on two different days. This means that participants were asked to come for a total of three sessions (once for the reading proficiency test and twice for the negative priming sessions). Half of the participants performed the L1 session first and the other half performed the L2 session first. Four different counterbalanced orders of testing were set up with six participants assigned to each order of testing.

Participants completed the language background questionnaire and two separate consent forms. The first consent form was for the reading proficiency test only and was completed in the first session (Please refer to Appendix F). The second consent form, for the negative priming sessions, was completed at the start of the second session and was the same as the consent form for Experiment 1. Participants were also asked to complete the vocabulary checklist. As before only one word was ever unfamiliar to subjects and on the very few occasions this occurred it was the non-critical word "décennie".

The procedure was the same as for Experiment 1. The instructions presented to participants were basically the same as for Experiment 1 with the exception that participants were told that there would be one short block of trials and one long block of trials in each session and that the longer block would take approximately 1 hour or longer. In addition to being asked to respond as quickly and accurately as possible, participants were also verbally encouraged to keep their errors at or below 5 % and if their error rate was higher, to slow down a little or take a break.

Results

Reading Proficiency data

The mean optimal reading rate for each participant in L1 and L2 was submitted to a planned comparison that, as expected, revealed a significant difference between the L1 and L2 reading times, $t(23) = -11.96$, $p < .0001$, with the mean reading rate in L1 being 261 mpw (milliseconds per word) and the mean reading rate in L2 being 383 mpw. The range of reading times in L1 was 166 mpw and 278 mpw in L2.

Negative Priming Data

The primary focus of this experiment was to investigate the differences in the time course of negative priming between first and second language readers.

As in Experiment 1, only decisions involving the words *hour, morning, day, week, month, season,* and *year* were included in the L1 analysis. Similarly, only decisions involving the words *heure, jour, semaine, mois, saison,* and *année* were included in the L2 analysis.

This meant that, in the negative priming analysis, for both L1 and L2 data, there were a possible 25 negative priming trial-pairs and 24 neutral trial-pairs at each RSI to be submitted for analysis. Furthermore, reaction times were analyzed only for correct responses on probe trials which followed correct responses on prime trials. As in Experiment 1, less than 1 % of responses had to be discarded due to coding discrepancies or technical difficulties. Participants' mean reaction times and standard deviations were calculated for correct responses. As in Experiment 1, means were trimmed to two standard deviations above the mean. Reaction times reflect means in each language and condition and are displayed in Table 2.

Analyses of variance were conducted for both mean reaction times for correct probe trials and percent error.

Mean Reaction Times

Mean reaction times for correct responses were submitted to a three-way 2 x 2 x 4 repeated measures analysis of variance (ANOVA) in which the factors were LANGUAGE (first vs second language), TYPE OF TRIAL (neutral vs negative priming) and RSI (1150, 1400, 1650 and 1900).

There was a significant main effect of LANGUAGE, where the MRT was 1343 ms and 1515 ms for first and second languages respectively, [$F(1, 23) = 13.01$, MSE = 218,236.20, $p = .001$], indicating that participants responded more quickly in their first language than in their second. There was also a main effect of TYPE OF TRIAL where the MRT was 1400 ms and 1458 ms for neutral and negative priming probe trials respectively [$F(1, 23) = 14.99$, MSE = 21,850.61, $p = .001$] indicating that negative priming probe trials were responded to significantly more slowly than neutral probe trials. The main effect of RSI was not significant, [$F(3,69) = 2.26$, $p = .089$] and the interaction of LANGUAGE, RSI and TYPE was not significant [$F(3, 69) = 1.60$, $p > .10$]. None of the other interactions were significant, all $p > .10$. Please refer to

Figures 3, 4 and 5.

A series of a priori comparisons (one-tailed Paired-Samples T-tests) were conducted to explore whether there were significant differences between neutral and negative priming trials at each RSI. In L1, significant negative priming was found at the RSI of 1150 ms. $\underline{t}$ (23) = - 2.10, $\underline{p}$ < .05, but not at the RSI of 1400 ms, $\underline{t}$ (23) < 1.00, $\underline{p}$ > .10. Significant negative priming was found at the RSI of 1650 ms., $\underline{t}$ (23) = - 3.24, $\underline{p}$ < .01 and also at the RSI of 1900 ms. $\underline{t}$ (23) = - 2.31, $\underline{p}$ < .05.

For the L2 data, significant negative priming was found at the three shortest RSIs but not at the longest RSI. At the RSI of 1150 ms, the difference between neutral and negative priming trials almost reached significance, $\underline{t}$ (23) = - 1.71, $\underline{p}$ = .05. Significant negative priming was also found at the RSI of 1400 ms $\underline{t}$ (23) = - 2.10, p < .05. Negative priming was basically significant at the RSI of 1650, $\underline{t}$ (23) = - 1.71, $\underline{p}$ =.05 but not at the RSI of 1900, $\underline{t}$ (23) < 1.00, $\underline{p}$ > .10.

Thus to summarize so far, significant negative priming was found at the shortest RSIs in L2 as well as in L1 but the pattern differs across the two languages in that negative priming seems to decay more quickly in L2. Somewhat puzzling is the dip and rebound of negative priming at the RSI of 1400 ms in L1.

Visual inspection of the data suggested that there was greater negative priming across most RSIs (except for the RSI of 1400 ms) in L1 than in L2 and therefore, further analyses were carried out to investigate whether these differences were significant. Difference scores were calculated for each subject by subtracting individual means for the

Table 2.

Mean Reaction Times (MRT) (in Milliseconds) and Standard Errors For Correct Responses on Probe Trials as a Function of Language, Type of Trial and RSI

RSI	Neutral	Negative Priming	Difference
	L1		
1150	1294 (53.52)	1365 (60.33)	- 71 *
1400	1331 (57.41)	1317 (50.37)	+ 14
1650	1317 (58.35)	1412 (66.16)	- 95 **
1900	1312 (52.54)	1400 (67.18)	- 88 *
	L2		
1150	1463 (80.18)	1527 (80.21)	- 64 *
1400	1493 (73.60)	1557 (78.40)	- 64 *
1650	1499 (79.82)	1569 (89.25)	- 70 *
1900	1493 (79.97)	1521 (78.01)	- 28

Note. * indicates significance at p < = .05.
** " " " p <= .01.

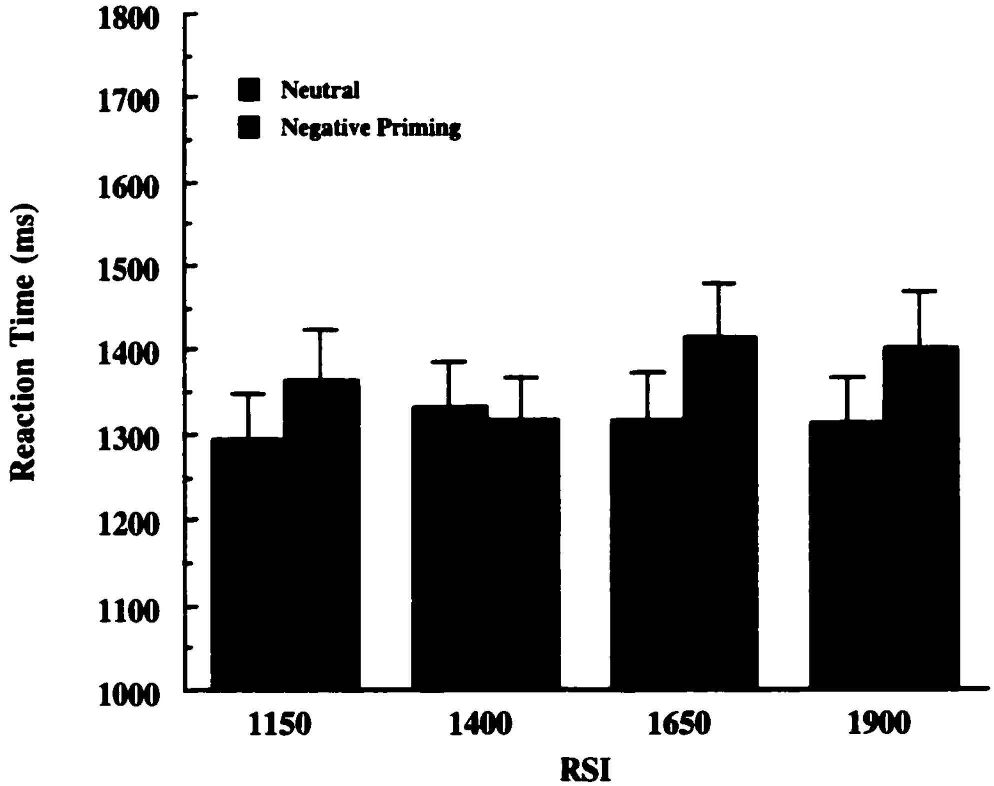

Figure 3. Mean reaction times (in milliseconds) in L1 as a function of type of trial and RSI for Experiment 2. Error bars indicate standard errors.

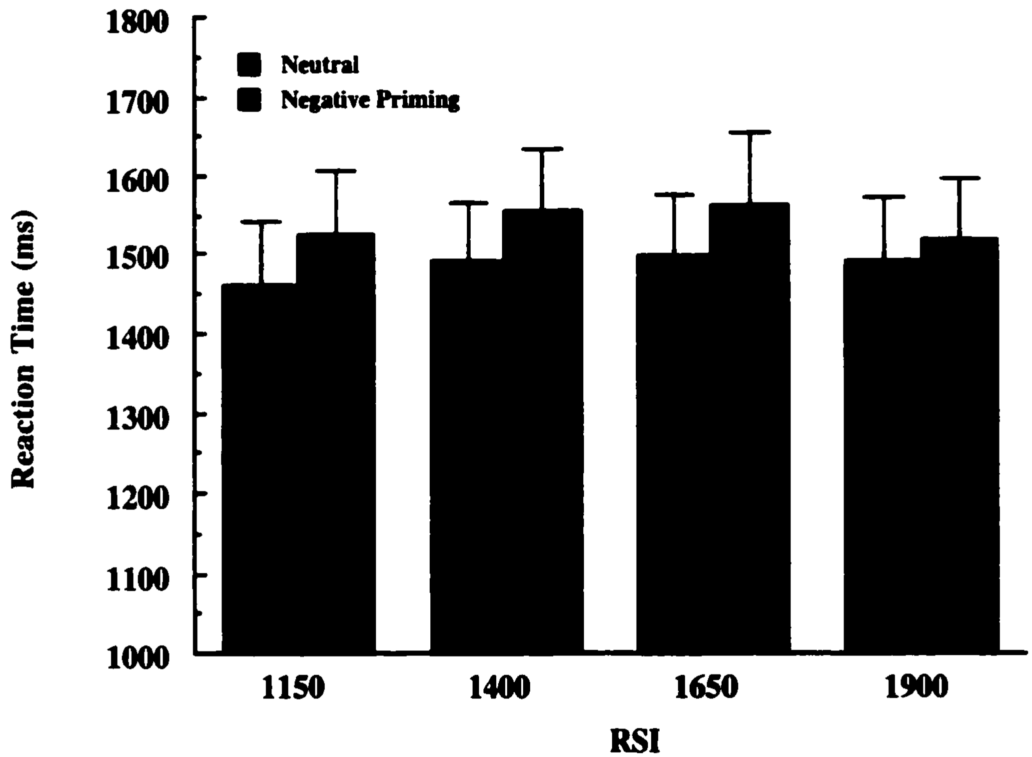

Figure 4. Mean reaction time (in milliseconds) in L2 as a function of type of trial and RSI for Experiment 2. Error bars indicate standard errors.

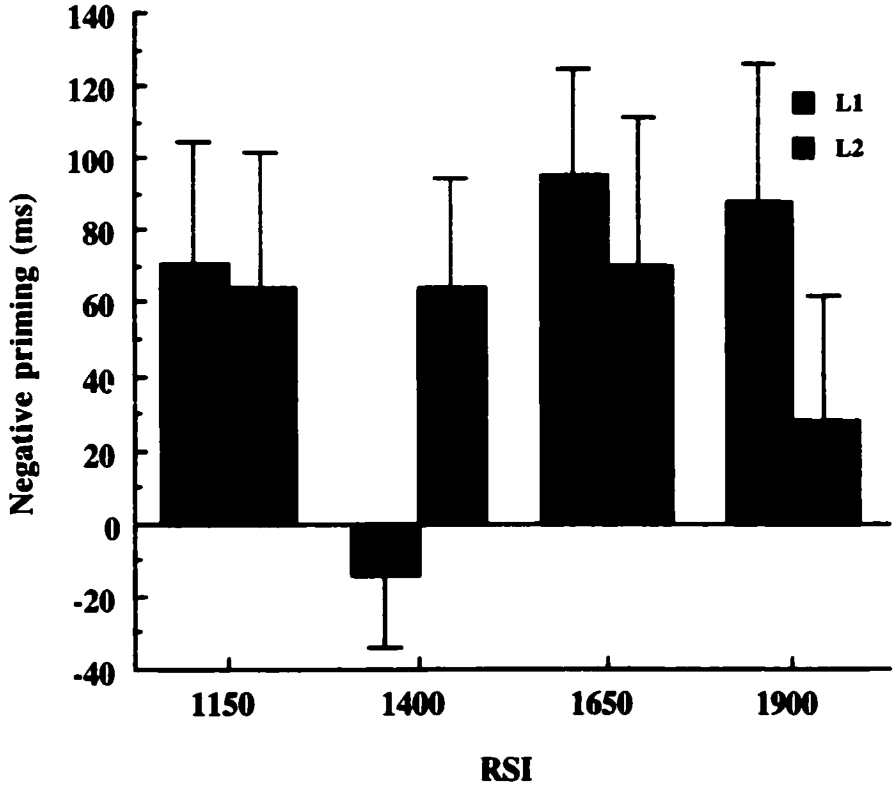

Figure 5. Negative Priming in reaction time (ms) as a function of language and RSI.

negative priming condition from individual means for the neutral condition. Subsequently, these difference scores for each RSI were used to compare the amount of negative priming in L1 and L2 and were then submitted to a priori t-tests. The only difference found to be significant was that between L1 and L2 at the RSI of 1400, $t(23) = 2.17$, $p < .05$ with 14 ms of positive priming in L1 and 64 ms of negative priming in L2 indicating greater negative priming in L2 at the RSI of 1400 ms.

Further t-tests (two-tailed Paired Sample T-tests with Bonferroni corrections) investigated the unexpected dissipation and rebound of negative priming in L1 across RSIs. As two comparisons were being made, the alpha level for these analyses was set at .025. The difference between the amount of negative priming at the RSIs of 1150 and 1400 in L1, was not significant $t(23) = -2.09$, $p = .048$, with 71 ms of negative priming at the RSI of 1150 ms and 14 ms of positive priming at the RSI of 1400 ms. However, the difference between the amount of negative priming at the RSIs of 1400 ms and 1650 ms was significant with 14 ms of positive priming at the RSI of 1400 ms and 95 ms of negative priming at the RSI of 1650 ms, $t(23) = 3.05$, $p < .01$.

A question that could be asked is whether the dissipation and rebound of negative priming in L1 was due to some idiosyncratic difference in stimuli presentation. T-tests (two-tailed) were therefore run to see if the response time for neutral responses differed between the RSI of 1400 and the other RSIs. None of the differences were significant (all $p > .10$).

Discussion of the apparent decay and rebound of negative priming at these RSIs is deferred to the discussion section.

Correlations

Correlations were calculated between English and French reading times and the amount of negative priming in each language. English and French reading times again correlated strongly, $r = .8022$, $p < .0001$. The only two other correlations which approached significance were between English reading time and negative priming at the RSI of 1150 ms, $r = .3542$, $p = .089$ and between English reading time and negative priming at the RSI of 1400 ms, $r = .3538$, $p = .09$. Both of these correlations suggest that better readers in L1 have a tendency towards greater negative priming at these shortest RSIs. None of the other correlations were significant.

In summary, the most important results of Experiment 2 showed that in L1, significant negative priming was found at RSIs of 1150, 1650 and 1900 ms indicating that participants demonstrated strong inhibition across these RSIs. In L2 significant negative priming was found only at the shortest RSIs of 1150, 1400 and 1650 ms, indicating that as far as the RSIs tested were concerned, inhibition accrued almost as quickly in L2 as in L1 but appeared to dissipate earlier in L2.

Percent error

Error percentages were again calculated by two different methods as in Experiments

1A and 1B. First of all, errors were calculated as the total number of possible responses less the total number of correct responses. According to this calculation, error percentages for the neutral trials for RSI's of 1150, 1400, 1650 and 1900 ms were .87 %, .70 %, .52 % and .5 % respectively and for the negative priming conditions were .5 %, 1.16 %, .5 % and .5 % respectively in L1. Similarly for L2, error percentages for the neutral trials for RSI's of 1150, 1400, 1650 and 1900 ms were 1.56 %, 2.43 %, 2.95 %, and 2.1 % respectively and for the negative priming conditions were 3.17 %, 3.17 %, 2.17 %, 2.67 % respectively. In addition errors were calculated as the total number of errors on probe trials for neutral and negative priming conditions. According to this calculation, error percentages for the neutral probe trials for RSI's of 1150, 1400, 1650 and 1900 ms in L1 were 1.98 %, 2.27 % , 1.22 % and 3.3 % respectively and for the negative priming conditions were 2.77 %, 3.41 %, 2.78 % and 2.33 %. Similarly for L2 error percentages for the neutral trials for RSI's of 1150, 1400, 1650 and 1900 ms were 2.68 %, 4.66 %, 3.21 % and 2.74 % respectively and for the negative priming conditions were 5.57 % and 4.11 %, 3.71 % and 4.70 % respectively.

Errors percentages were submitted to a three-way 2 x 2 x 4 repeated measures analysis of variance (ANOVA) in which the factors were LANGUAGE (first vs second language), TYPE OF TRIAL (neutral vs negative priming) and RSI (1150, 1400, 1650 and 1900).

The main effect of LANGUAGE was significant where the percent error was 2.51 % and 3.92 % for first and second languages respectively, $F(1, 23) = 8.36$, $MSE = .002$, $\underline{p} <$

.01. Thus as expected there was a greater number of errors in L2 than in L1. There was also a main effect of TYPE OF TRIAL where the percent error was 2.76 % for neutral trials and 3.67 % for negative priming trials, $F(1, 23) = 5.90$, $MSE = .001$, $p < .05$. As expected errors were greater on negative priming trials than on neutral trials overall. The interaction of LANGUAGE, RSI and TYPE OF TRIAL was almost significant, $F(3,69) = 2.73$, $MSE = .001$, $p = .051$. A series of a priori t-tests were carried out to investigate the nature of this interaction. In L1, a significant difference in percent error was found at the RSI of 1650 ms, $t(23) = -2.10$, $p < .05$ with means of 1.22 % and 2.78 % for neutral and negative priming trials respectively. In L1 there were no significant differences in percent error at all other RSIs. In L2 there was a significant difference at the RSI of 1150 ms, $t(23) = -2.61$, $p < .01$ with means of 2.68 % and 5.57 % percent for neutral and negative priming trials indicating that there were a significantly greater number of errors on negative priming than on neutral trials. The difference between neutral and negative priming trials was also significant in L2 at the RSI of 1900 ms with 2.74 % percent error for neutral trials and 4.70 % percent error for negative priming trials, $t(23) = -2.03$, $p < .05$. Thus at the RSI of 1900, although participants in L2 did not demonstrate negative priming of response times, they did demonstrate negative priming in their error patterns.

Discussion

The question addressed in this experiment was whether the time course of negative priming would differ for participants in their first language as compared to their second language. Two important findings with potential implications for first and second language research were found.

The most important finding in this experiment concerned the pattern of data between L1 and L2. This pattern differed for the two languages over the four RSIs tested, with participants demonstrating significant negative priming at three RSIs in L1 but only at the first three RSIs in L2. Visual inspection of the data at the longest RSI (1900 ms) showed negative priming in both languages but that negative priming only reached significance for the L1 data at this RSI. There was a significantly larger percentage of error in the negative priming trials than in the neutral trials in L2 at the RSI of 1900 ms, suggesting that the negative priming effect was present in errors if not in response time. However, the error rate was still below five per cent and it is unlikely that this percentage of error could account for the difference in negative priming between the two languages at this RSI. In particular, there was a 60 ms difference in the amount of negative priming between L1 and L2 at the longest RSI indicating that inhibition is present in both languages at the earliest RSI tested, but dissipates earlier in L2. For the most part, negative priming was greater in L1 than in L2 although the differences were not significant. Previous studies looking at the persistence of negative priming have found that in L1 negative priming can persist for up to 6600 ms (Tipper et al., 1991). In fact Lowe (1998) found that negative priming persisted over a five minute retention interval.

In terms of reading fluency, this could indicate that in L1, readers are able to maintain inhibition for a relatively long time to remove and prevent irrelevant items from entering working memory. However in L2, even in the simple well-practiced task implemented in this experiment, participants were unable to maintain inhibition after long time delays. Thus in L2 reading, one of the factors that may influence reading speed is the ability to maintain high levels of inhibition for the same time as in L1. Maintaining high levels of inhibition over several seconds may prevent working memory from being cluttered with irrelevant information that may interfere with the ongoing understanding of the text.

Surprisingly, significant negative priming was found at the earliest RSIs in L2 as well as in L1. This was contrary to expectation as pilot work had suggested that negative priming in L2 would be less at this RSI than in L1. This result suggests that negative priming builds up as quickly in L2 as in L1. However, it is very possible that the particular RSIs chosen were in fact too long and had shorter RSIs been selected, a difference in the onset of negative priming would have been detected between the two languages. A second reason for these unexpected results is suggested by the sample chosen for the experiment. As discussed previously, our sample of L2 readers had high comprehension skills. Although all of the participants read at least 15 % slower in L2, they did have high comprehension. Gernsbacher and Faust's (1991) less skilled participants were selected for their low comprehension.

Gernsbacher portrays suppression as a "general comprehension mechanism" which allows us to select information auditorily, in pictures and in text reading efficiently. She has found evidence of correlations in ability to suppress information across modalities. It is possible therefore that this general comprehension mechanism crosses languages so that high comprehenders in L1 and in L2 are able to suppress irrelevant information irrespective of how quickly they read. In other words, if comprehension is high, the ability to suppress irrelevant information may not be a factor in further skill development.

A puzzling result was the decay and rebound of negative priming found in the data for participants reading in the first language. In L1 there was significant negative priming at the shortest RSI, a rapid decay of negative priming by the RSI of 1400 ms and a strong rebound at the longer RSIs. This result in L1 is in contrast to the results found for the L2 data and will be discussed at length below.

At first glance the L1 data seem to be in sharp contrast to previous research which has found negative priming at early RSIs followed by a decay (Neill & Valdes, 1992) or no decay at all (Hasher et al., 1996; Conway, 1999). However, closer examination of the data of Neill and Valdes (1992) shows some support for these results. Neill and Valdes (1992, Experiments 1, 2 and 3) studied the persistence of negative priming by examining negative priming at RSIs of 500, 1000, 2000, 4000 and 8000 ms. In Experiment 1, participants were asked to decide whether the second and fourth letters of a display were the same or different. In the neutral trial-pairs, prime and probe letters had no relation to each other while in the negative priming trial-pairs, the letters to be targeted on the probe trial were the letters previously ignored on the prime trial (e.g. BGBGB followed by EBEBE). They found that negative priming decreased over RSIs with the sharpest drop between 500 and 1000 ms. However, they also found a rebound effect at the RSI of 2000 ms. This rebound effect was not statistically significant. A rebound also occurred in Experiment 3. Neill et al. proposed no explanation to account for this rebound, citing that there was no previously hypothesized mechanism to account for such an effect and emphasized that the rebound was not significant.

Recent research into the persistence of negative priming has not investigated this rebound phenomenon (Conway, 1999; Hasher et al., 1996; Neill & Valdes, 1992). Neill et al. (1992) found no decay, citing the reason as being that the PRSI (the time interval between the response to the previous probe trial and the onset of the current prime trial) and RSI were equal, but looked only at negative priming effects at RSI's of 500 and 4000 ms. Hasher et al. found no decay of negative priming at RSIs of 500 and 2500 ms and Conway (1999) also found no decay of negative priming at RSIs of 500 and 4000 ms.

The restriction of RSIs to the above values may have precluded the detection of decay and rebound effects by these researchers. The experiment reported here investigated the time course of negative priming in a more fine-grained fashion (by manipulating RSI's fairly close together) and in so doing, it was possible to detect this difference. In addition, our task, with typically large negative priming effects was probably more sensitive to the detection of the variability of negative priming effects across RSIs.

The question remains as to why there was a decay and then a rebound in L1. The question could be asked as to whether there was a methodological reason for the phenomenon. For example, could idiosyncratic differences between the stimuli sets used across RSIs have caused these effects. We can, most likely, rule out this explanation. The stimuli set for each RSI was composed of exactly the same stimuli although they were presented in a different pseudorandom order. The analyses run on neutral probe trials across RSIs showed no significant differences in response times across RSIs indicating that the lack of negative priming was not the result of longer responses on neutral trials. Response times were somewhat longer for neutral trials at the RSI of 1400 but the difference was not significant.

An alternative explanation could be that it was the result of subject strategies. However, stimuli were presented for the different RSIs randomly and it would be impossible for subjects to predict the upcoming timing of the next presentation.

A more plausible explanation is that these results reflect the operation of two distinct mechanisms. Both Kane, May, Hasher, Rahhal and Stolzfus (1997) and Tipper (2001) have proposed that in negative priming experiments two mechanisms may be operating so that both an inhibitory mechanism and episodic retrieval may contribute to negative priming effects. Kane et al. suggest that various experimental manipulations may encourage the operation of one or another mechanism in an experiment. Therefore in one type of experiment the operation of inhibition may occur while in another the results may be due to episodic retrieval. This dichotomy has been presented as an explanation for the many discrepant results found in the negative priming literature. For example, degraded stimuli may encourage the operation of episodic retrieval while very clearly presented stimuli may encourage the operation of inhibition.

Tipper (2001), on the other hand, suggests that both mechanisms may operate in a single experiment so that inhibition operates at the time of the prime trial as part of the encoding process in a forward-acting manner while episodic retrieval operates at the time of the probe trial as an automatic retrieval process.

As discussed previously, the theory of episodic retrieval does not assume that there is a forward-acting inhibitory mechanism. In contrast, this theory states that negative priming works backward from the probe trial. On this view, items presented in the prime trial are encoded in memory as a unique episodic trace. This episodic trace may include contextual information as well as response information. Thus prime targets may be tagged "respond" and prime distractors may be tagged "do not respond". On a negative priming trial-pair, when the probe stimuli are presented, an automatic retrieval process retrieves information from the prime trial which conflicts with the current information on the probe trial causing a slowdown in response times (a distractor on the prime trial coded "do not respond" becomes a target on the probe trial requiring a response). In the context of less efficient second language performance, this could mean that the automatic retrieval process was not as efficient in the second language, resulting in less conflict in response information and causing less of a disruption in response times. In support of this idea is research by Favreau and Segalowitz (1983) who found that there is significantly less automatic spreading activation in less fluent bilinguals than in bilinguals who speak both L1 and L2 equally well.

In summary, the dip and rebound of negative priming in the L1 data from Experiment 2 may indicate the presence of inhibition at the earliest RSI, the dissipation of that inhibition at the RSI of 1400 ms and the onset of episodic retrieval at the two longest RSIs.

An important question is why the pattern in the L1 data and the L2 data was so different. In other words why was there a dissipation and rebound in L1 but not in L2? Overall, the amount of negative priming in L2 was lower and this was expected. But why was there no decay and rebound of negative priming in L2 but rather a relatively consistent pattern of reduced negative priming?

We could assume that negative priming effects in L2 are on the whole lower than those in L1 and that any effects we see are therefore muted. There was an apparent dissipation of negative priming at the RSI of 1900 ms in L2. If longer RSIs had been presented, would there have been a rebound of negative priming in the L2 data or not? As the longest RSI tested was 1900 ms, it is not possible to differentiate between these two explanations.

Another influential theory of negative priming is the semantic mismatch theory discussed previously by MacDonald et al. (1999). According to this theory, negative priming is caused when there is a semantic mismatch between items in the prime trial and items in the probe trial as when an item like "turtle' is coded as "smaller" on the prime trial and "larger" on the probe trial. As far as second language fluency is concerned, given that significant negative priming was not found to persist at longer RSIs, this could indicate that in L2 some semantic codes are not activated as extensively, resulting in less of a mismatch effect. However, the results of Experiment 1 - demonstrating significant positive priming and those of Gernsbacher showing that less skilled readers are well able to activate relevant information would appear to rule out this explanation. In contrast to this research, however, is the study by Vasos (as cited in Segalowitz, 1986), who found that single words do not activate word meanings as strongly, or for as long a duration, for moderately skilled bilinguals in contrast to fluent bilinguals. Therefore if semantic codes are not activated as strongly in L2 then it is possible that there is less of a mismatch effect.

To summarize, the time course of negative priming differed between the two languages, with negative priming in L1 and L2 occurring at the earliest RSI. All in all, negative priming was found to persist longer and to achieve higher levels in L1 than in L2 although the differences between languages were not significant.

Experiment 3

Experiment 1B showed significant positive priming in L1 and in L2 with greater (but not significantly greater) positive priming in L1. This effect is in agreement with that of Gernsbacher and Faust (1991) who found that less skilled readers in a first language activate meanings as efficiently as more skilled readers. In fact Gernsbacher found that less skilled readers activated relevant information significantly more than more skilled readers.

Similar to the question asked in Experiment 2, a question that could be asked is whether the time course of activation, as opposed to inhibition, would differ between L1 and L2. Although positive priming in Experiment 1B was significant in both L1 and L2 it is not possible to tell whether this was the optimal time to detect positive priming in both L1 and L2 or whether the pattern of positive priming would differ across RSIs in the two languages. Would greater positive priming be found in L2 as compared to L1 at a later time delay? If so, this result would be in agreement with Gernsbacher and Faust (1991) if this is placed in the context of more and less skilled readers.

As discussed previously, research by Favreau et al. (1980) found that readers in L2 did not demonstrate the word superiority effect as did readers in L1. However, when readers in L2 were given longer processing time, they did demonstrate the word superiority effect. Thus it is possible that if longer processing time were allowed in a positive priming experiment with a manipulation of RSI, that even greater positive priming would be demonstrated.

Experiment 3 investigated whether the time course of activation, as opposed to inhibition, would differ between L1 and L2 - specifically by looking at the time course of positive priming at the same RSIs as used in Experiment 2. Accordingly, Experiment 3 tested the time course of positive priming in L1 and L2 at the same RSIs as were tested in Experiment 2.

Experiment 3 tested the factors of Language (first vs second). Type of Trial (neutral. positive priming) and RSI (1150. 1400, 1650 and 1900 ms). Individuals reading in a second language may exhibit similar levels of activation as demonstrated by positive priming at all RSIs as compared to individuals reading in a first language. On the other hand it is possible that at later RSIs positive priming will be greater in L2 than in L1.

Method

Except where noted, the method for Experiment 3 was the same as for Experiment 2.

Participants

Nineteen Anglophones (18 females and 1 male with a mean age of 25.4 years) with French as a second language participated in this experiment. These participants were recruited either as volunteers from courses at Concordia University or in fulfillment of a course requirement to participate in a study. Participants were paid $6.00 for participation in the reading proficiency test or received recognition for fulfilling a course requirement. They were paid $20.00 for their participation in the positive priming sessions. All participants had normal or corrected-to-normal vision. None of the participants had participated in Experiments 1 or 2.

Potential participants were given the same reading proficiency test as in Experiments 1 and 2. Fifty-two participants completed the reading proficiency test but only twenty individuals met the selection criteria and were included in the study. (The selection criteria were the same as for Experiment 2. However, one of the subjects included in the experiment had only a 12 % difference between L1 and L2 due to the difficulty of finding participants at that time). Of the fifty-two participants, three additional individuals did meet selection criteria but were not included as participant selection was by that time complete. Of these twenty individuals, one participant completed the three sessions but his data were discarded as they included over 1.5 % of responses under 250 ms whereas typically subjects had zero or only one or two responses under 250 ms.

Stimuli

For positive priming trials two new lists were created, in the same manner as for Experiment 2. These lists were constructed by quadrupling each of the lists used in Experiment 1B resulting in two lists with a total of 648 trial-pairs each. Each previously counterbalanced quarter of the list (in English and French) was then assigned an approximate RSI of 1150, 1400, 1650 and 1900 ms (162 trial-pairs for each RSI). Each list was then re-randomized and counterbalanced in the same manner as for Experiment 2. The RSI and PRSI were equal. All buffer trials were presented with an RSI of 1650 ms.

Apparatus

Stimuli were presented on a Power Macintosh 7200/90.

Design

This experiment employed a design with Language (first vs second language), Type of Trial (neutral vs positive priming) and RSI (1150, 1400, 1650 and 1900 ms) as within subjects factors.

Procedure

The procedure was exactly the same as for Experiment 2 except that participants were told that the longer block of trials would last an hour and a quarter or longer. As in Experiments 1 and 2, in a very few situations the non-critical word "décennie" had to be explained to participants. One participant had to be reminded of the meaning of the non-critical word "siècle".

Results

Reading Proficiency Data

The mean reading time for each participant in L1 and L2 was submitted to a planned comparison that, as expected, revealed a significant difference between the reading times for the two groups, $t(18) = -8.11$, $p < .0001$, with the mean reading rate in L1 being 266 mpw (milliseconds per word) and the mean reading rate in L2 being 402 mpw. The range of reading times in L1 was 175 mpw and in L2, 349 mpw.

Positive Priming Data

The primary focus of this experiment was to investigate the differences in the time course of positive priming between people reading in their first language and people reading in their second language.

As in Experiments 1 and 2, only decisions involving the words *hour, morning, day, week, month, season,* and *year* were included in the L1 analysis. Similarly, only decisions involving the words *heure, jour, semaine, mois, saison,* and *année* were included in the analysis.

This meant that, in the positive priming analyses, for both L1 and L2 data, there were a possible 24 positive priming probe trials and 24 neutral trials at each of the four RSIs to be submitted for analysis. Furthermore, reaction times were analyzed only for correct responses on probe trials which followed correct responses on prime trials. Less than 1 % percent of responses were discarded due to technical or coding difficulties.

Participants' mean reaction times and standard deviations were calculated for correct responses on probe trials. Reaction times were trimmed to two standard deviations. Analysis of variance were conducted for both mean reaction times for correct trials and percent error.

Mean Reaction Times

Mean reaction times for correct responses were submitted to a three-way 2 x 2 x 4 repeated measures analysis of variance (ANOVA) in which the factors were LANGUAGE (first vs second language), TYPE OF TRIAL (neutral vs positive priming) and RSI (1150, 1400, 1650 and 1900).

There was a significant main effect of LANGUAGE, where the MRT was 1268 ms and 1367 ms for first and second languages respectively [$F(1,18) = 12.66$, $MSE = 58{,}331.56$, $p < .01$], indicating that participants responded more quickly in their first language than in their second. There was also a main effect of TYPE OF TRIAL where the MRT was 1352 ms and 1282 ms for neutral and positive priming probe trials respectively, [$F(1,18) = 26.88$, $MSE = 13{,}819.25$, $p < .0001$], indicating that positive priming probe trials were responded to significantly more quickly than neutral probe trials. Please refer to Table 3.

The three-way interaction of LANGUAGE, TYPE OF TRIAL and RSI was not significant [$F(3, 54) = 1.10$, $p > .10$]. Please refer to Figures 6, 7 and 8. A series of

Table 3.

Mean Reaction Times (MRT) (in Milliseconds) and Standard Errors For Correct Responses on Probe Trials as a Function of Language, Type of Trial and RSI

RSI	Neutral	Positive Priming	Difference
		L1	
1150	1304 (72.77)	1236 (64.55)	+ 68 **
1400	1324 (69.59)	1227 (78.68)	+ 97 *
1650	1295 (72.33)	1188 (66.06)	+ 107 **
1900	1299 (71.88)	1272 (98.36)	+ 27
		L2	
1150	1419 (60.42)	1313 (56.27)	+ 106 **
1400	1354 (67.73)	1318 (53.51)	+ 36
1650	1434 (78.08)	1353 (70.30)	+81 *
1900	1390 (65.33)	1353 (66.55)	+ 37

Note. * indicates significance at $p <= .05$.
** " " " $p <= .01$.

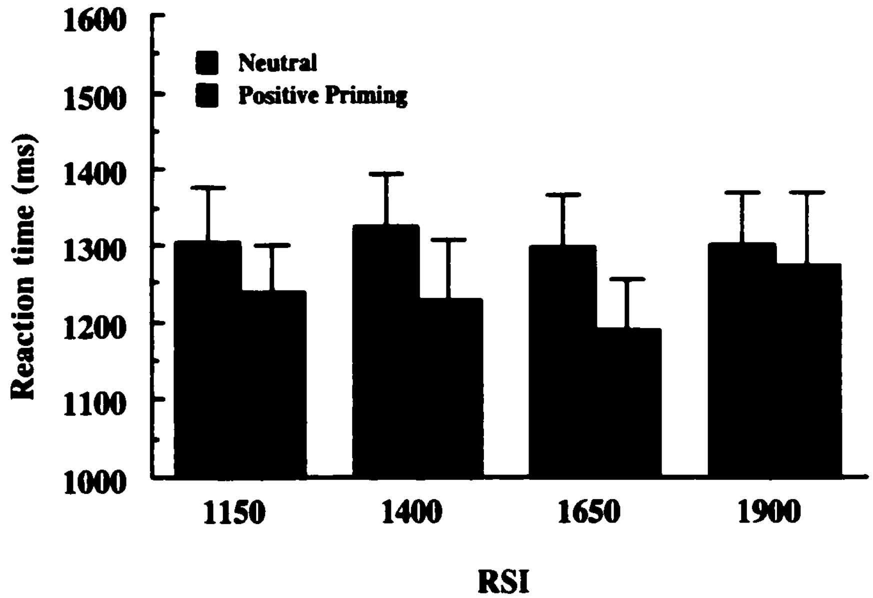

Figure 6. Reaction time (in milliseconds) in L1 as a function of type of trial and RSI for Experiment 3. Error bars indicate standard errors.

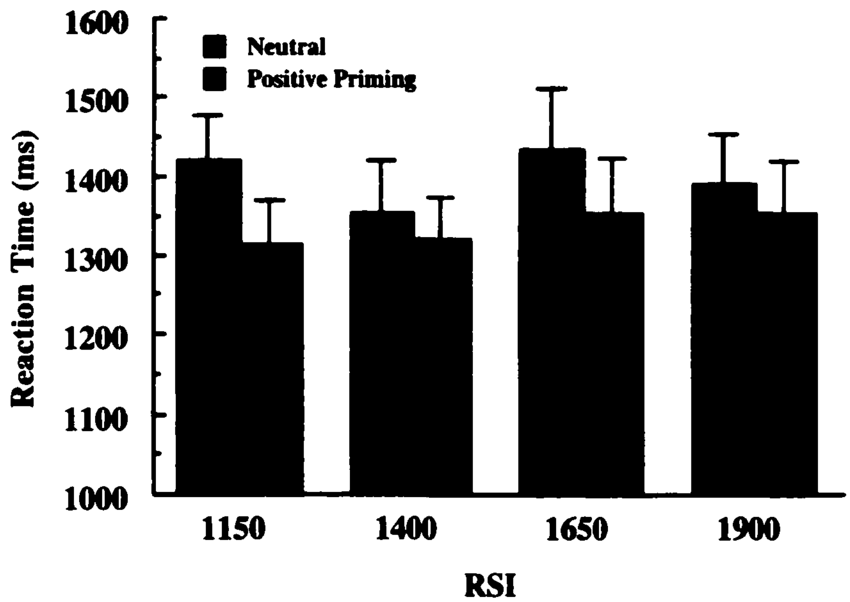

Figure 7. Reaction time (in milliseconds) in L2 as a function of type of trial and RSI for Experiment 3. Error bars indicate standard errors

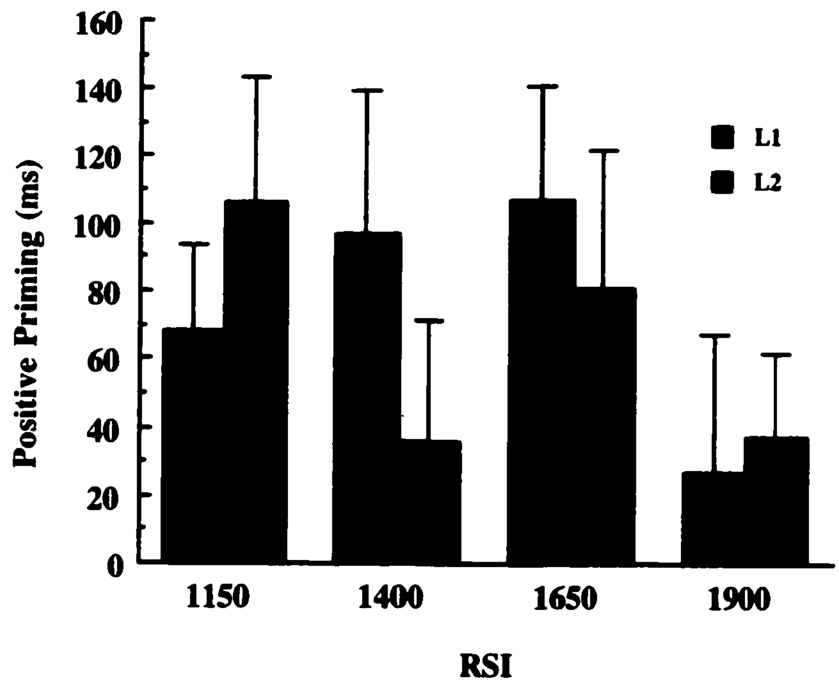

Figure 8. Positive priming in reaction time (ms) as a function of language and RSI. Error bars indicate standard errors.

planned comparisons (one-tailed Paired Samples T-tests) were conducted to investigate whether there were significant differences between neutral and positive priming conditions at each RSI. First of all, neutral and positive priming reaction times at each RSI in L1 were compared. Significant positive priming at the RSI of 1150 ms was found, $t\ (18) = 2.65,\ p < .01$. Significant positive priming at the RSI of 1400 was found $t\ (18) = 2.27,\ p < .05$ and also at the RSI of 1650 ms, $t\ (18) = 3.19,\ p < .01$. In contrast, significant positive priming was not found at the RSI of 1900 ms, $t\ (18) < 1.00,\ p > .10$.

In L2 significant positive priming was found at the RSI of 1150 ms, $t\ (18) = 2.85,\ p < .01$. Positive priming was not significant at the RSI of 1400 ms , $t\ (18) = 1.01,\ p > .10$. However, positive priming was significant at the RSI of 1650 ms, $t\ (18) = 1.98,\ p < .05$ and approached significance at the RSI of 1900 ms, $t\ (18) = 1.50,\ p = .076$.

The amount of positive priming at each RSI was calculated by subtracting the mean reaction times on positive priming trials from the mean reaction times on neutral trials to obtain difference scores for each participant. These difference scores were submitted to one-tailed Paired Samples t-tests to test for differences between the amount of positive priming obtained in each language at each RSI. No significant differences were found for any of these comparisons, $p > .10$.

As expected, significant positive priming was found across all RSIs in L2, with one exception - that of the drop in positive priming at the RSI of 1400. Further investigation of this unexpected drop was carried out as follows. T-tests (two-tailed t-tests for Paired Samples with Bonferroni corrections) were carried out to see if the drop in positive priming at the RSI of 1400 ms in L2 was significant. For this purpose comparisons were made between the amount of positive priming obtained at the RSI of 1150 ms and the amount obtained at the RSI of 1400 ms as well as the amount obtained at the RSI of 1400 ms and the amount obtained at the RSI of 1650 ms. Neither of these differences was significant. The difference in the amount of positive priming at the RSIs of 1150 and 1400 was not significant $t\ (18) = 1.18$, $p > .10$ with mean positive priming of 106 ms and 36 ms respectively. In comparing the RSIs of 1400 ms and 1650 ms, it was also found that the difference was not significant, $t\ (18) < 1.00$, $p > .10$, with means of 36 ms and 81 ms.

In addition, comparisons were made between neutral trials for each RSI to investigate whether the drop in positive priming could have been due to some anomalous difference between neutral trials. The difference between neutral trials at RSIs of 1150 and 1400 ms was not significant with a Bonferroni correction and with means of 1419 and 1354 ms, $t\ (18) = 2.01$, $p = .06$. The difference between neutral trials at RSIs of 1400 and 1650 ms was significant, where the mean at 1400 ms was 1354 and at 1650, 1434, $t\ (18) = -2.76$, $p < .025$. This suggests that the drop in positive priming may have been due to faster responding on neutral trials rather than slower responding on positive priming trials. Further discussion of this result follows in the discussion section.

Correlations

The only significant correlation for Experiment 3 was between English and French reading times, $r = .6981$, $p = .001$.

To summarize, in L1 significant positive priming was found at RSIs of 1150, 1400 and 1650 ms. In L2 significant positive priming was found at RSIs of 1150 and 1650 ms with positive priming approaching significance at the RSI of 1900 ms.

Percent error

Error percentages were calculated by two different methods because errors were re-presented at the end of the experiment. First of all, errors were calculated as the total number of possible responses less the total number of correct responses. According to this calculation, error percentages for the neutral trials for RSI's of 1150, 1400, 1650 and 1900 ms were 3.07 %, 5.05 %, 3.73 %, 3.29 % respectively and for the positive priming conditions were 2.42 %, 2.2 %, 2.63 %, 1.77 % respectively in L1. Similarly for L2 error percentages for the neutral trials for RSI's of 1150, 1400, 1650 and 1900 ms were .44 %, .44 %, 1.1 %, .66 % respectively and for the positive priming conditions were . 44 %, .88 %, .22 %, .88 % respectively. In addition errors were calculated as the total number of errors on probe trials for neutral and positive priming trials. According to this calculation, error percentages for the neutral trials for RSI's of 1150, 1400, 1650 and 1900 ms in L1 were 3.68 %, 5.53 %, 2.43 % and 3.31 %, respectively and for the positive priming conditions were 3.38 %, 3.84 %, 4.25 % and 2.65 %. Similarly, for L2, error percentages for the neutral trials for RSI's of 1150, 1400, 1650 and 1900 ms were 1.88 %, 1.89 %, 3.75 % and 2.89 % respectively and for the positive priming conditions were 1.86 %, 3.28 %, 3.90 % and 3.32 % respectively.

Error percentages were submitted to a three-way 2 x 2 x 4 repeated measures analysis of variance (ANOVA) in which the factors were LANGUAGE (first vs second language), TYPE OF TRIAL (neutral vs positive priming) and RSI (1150, 1400, 1650 and 1900).

There were no significant main effects or interactions (all $p > .10$) suggesting that errors were not greater in the positive priming conditions than in the neutral conditions. Percentage of error was not investigated further.

Discussion

The question investigated in the third experiment was whether the time course of positive priming would differ between the L1 and L2 of bilingual participants. For the most part the results of this experiment indicated that, across RSIs, positive priming was demonstrated in both L1 and in L2. These results are in agreement with those of Gernsbacher who found that in a sentence task both more and less skilled readers were able to enhance relevant information and that in fact less skilled readers demonstrated greater activation at both immediate and delayed times. Of particular interest was the finding that, in the current study, positive priming was greater at the earliest RSI in L2 than in L1 although the difference was not significant.

Contrary to expectation, at the time delay of 1400 ms there was a puzzling dissipation and later rebound of positive priming. Should it be argued, as in Experiment 2, that this was the result of the presence of two different mechanisms or could there be another reason?

In the context of this experiment it is of course possible that the dip in positive priming at the RSI of 1400 in L2 is in fact the dissipation of transient activation and that the rebound is the onset of episodic retrieval. This same dip would also have occurred in L1 but possibly at an earlier RSI than presented in our study. While this explanation is plausible it may not be, in this case, the correct one.

In Experiment 3, the reason for the drop in positive priming is most likely a methodological one. As discussed above, the mean for the neutral probe trials at the RSI of 1400 ms appears to be much shorter than that of the neutral probe trials at the other RSIs. In other words the lack of positive priming at this RSI is apparently the result of faster responses to neutral probe trials rather than slower responses on positive priming trials. In the present experiment there was no apparent reason for the speed-up in responses to neutral probe trials. The stimuli presented at each RSI were in fact the same as stimuli presented at every other RSI, albeit they were presented in different pseudorandom orders. It is possible that the dip observed at the RSI of 1400 ms is not, after all, very meaningful and was due to chance.

In summary, significant positive priming was found in L1 at the three shortest RSIs but not at the longest RSI of 1900 ms indicating that activation of relevant information is present across the three shortest RSIs but has dissipated by the longest RSI. The pattern of positive priming in L2 differed to some extent. Similar to the results found in the L1 data, significant positive priming was found at the RSIs of 1150 and 1650 ms. In contrast to the L1 data, however, positive priming approached significance at the RSI of 1900 ms, indicating that relevant information is still active at this RSI in L2. In addition, a dip in positive priming was found at the RSI of 1400 ms in L2.

General Discussion

In Experiment 1 it was found that although positive priming was significant both in L1 and L2, negative priming was significant only in L1. If we look at this from the perspective of the balance of positive and negative priming, and by extension activation and inhibition, we can see the repercussions this could have for second language reading. If activation is almost as strong in L2 as in L1, as indicated by the data, but inhibition is not as strong, then the consequences for L2 reading are apparent. It is well-known that we activate more information when reading than is necessary (Coltheart et al., 1977; van Orden, 1987). If superfluous information is activated but cannot be inhibited efficiently, then working memory may be cluttered with irrelevant or no longer relevant information.

Hasher, Zacks and May (1999) propose that inhibition has three functions in relation to working memory: access, restraint and deletion. Inhibition serves to limit access to working memory by preventing activated but irrelevant information from gaining access to it. This enables goal-relevant information to enter working memory with decreased cross-talk from irrelevant information. A second function is that of restraint wherein the dominant meaning or response is restrained so that other possible meanings can be considered. This function allows modification of response in the situation where there is more than one possible meaning even if one of them is dominant.

According to Hasher et al. a third function of inhibition is that of deletion. Deletion functions to inhibit or suppress information which is already active in working memory. Thus deletion operates to inhibit the activation of information which is irrelevant, marginally irrelevant or no longer relevant, from working memory. Information may become irrelevant because, to use an example from the reading literature, the topic changes, because goals have changed or because there has been a misunderstanding. Gernsbacher et al. (1990) and Gernsbacher and Faust (1991) have proposed a similar idea with their "structure-building framework". They suggest that while skilled comprehenders may quickly dampen interference from ambiguous words, less skilled comprehenders do not, resulting in the cluttering of working memory with off-goal and irrelevant information. They propose further that when reading we create a mental representation of what we are currently reading. However, if incoming information is irrelevant - such as the inappropriate meaning of an ambiguous word, the skilled comprehender dampens the meaning of this word quickly while the less skilled reader does not.

In the task used in Experiment 1, deletion would be the most appropriate function of inhibition. As both targets and distractors were attended, the function here was not to prevent access to working memory but to remove items that had been activated, that had gained access to working memory, but that were no longer relevant. In terms of second language fluency, the results of Experiment 1 could indicate that while L2 readers have no difficulty activating information, they may have difficulty deleting items that are no longer relevant. By carrying this reasoning one step further, one could suggest that one factor contributing to less fluent second language reading is the inefficient (or slow) removal of no-longer relevant items from working memory.

The delete function also serves to block information which has been recently suppressed, from becoming reactivated, thus facilitating the current on-line reading process by maintaining the distinction between currently relevant information and no-longer-relevant information. According to this view, the maintenance of inhibition over several seconds plays an important role in keeping recently suppressed information from becoming reactivated.

Experiment 2 investigated the onset and maintenance of inhibition through examination of the time course of negative priming in L1 and in L2. Significant negative priming was found in L1 at all RSIs except that of 1400 ms, indicating that, irrespective of mechanism in place, negative priming is relatively persistent across the RSIs tested. In L2 significant negative priming was found at the shortest RSIs but appeared to taper off at the longest RSIs. Visual inspection of the data reveals that at all RSIs, except the RSI of 1400, negative priming was greater in L1 than in L2 although these differences were not significant. It should be noted that these differences were still present even though participants received four times as much practice in Experiment 2 as in Experiment 1.

Of particular interest is the differing pattern of results between L1 and L2 at the longest time delay. Negative priming persisted through the longest RSI in L1 but had dissipated in L2 at this RSI, indicating that at longer time delays, inhibition is still present in L1 to inhibit no longer relevant information, but this is not the case in L2. Previous research has found that in L1 negative priming persists longer than six seconds and in some cases longer than five minutes (Lowe, 1998). In a situation where negative priming does not persist, as in the L2 condition in Experiment 2, it may mean that these individuals are not as efficient at maintaining inhibition and thus recently suppressed information may become reactivated, causing cross-talk with current task performance. In terms of second language reading this could indicate that not only do readers in L2 have difficulty removing information from working memory, but there could also be a problem related to keeping information which has already been suppressed from becoming reactivated.

The results of Experiment 3, for the most part, were in agreement with previous research which has found that less skilled readers are able to activate relevant information to the same extent as skilled readers (Gernsbacher & Faust, 1991). In L1 significant positive priming was found at all but the longest RSI. It is assumed, that, at the longest RSI, positive priming has dissipated and that activation has been reduced. However, significant positive priming was found at all but the RSI of 1400 ms in L2. Leaving aside for the moment the dip in positive priming at the RSI of 1400 ms, we can see that L2 participants still exhibit fairly strong positive priming at the longest RSI, indicating that activation of information is persisting longer in L2 than in L1.

At this point it is important to look again at the balance of positive and negative priming in Experiments 2 and 3 - and what this balance may mean in terms of interference and second language reading. Examination of the negative priming data from Experiment 2 indicates that while negative priming is still significant in L1 at the longest RSI, it has dissipated a great deal in L2. Thus in L1, at the longest delay, positive priming has dissipated and negative priming has not, indicating that extraneous and no-longer relevant information is still being inhibited at this longest delay. Consequently, in L1 previously relevant information is no longer activated and irrelevant information has not only been suppressed but the suppression of irrelevant information has been maintained, preventing irrelevant information from interfering with the ongoing reading process. However, in L2 positive priming is still evident but negative priming is not. By looking at the balance of positive and negative priming it is possible to see the possible repercussions for second language reading in that while facilitatory mechanisms are maintaining activation of information, inhibition has not been maintained and cannot prevent irrelevant information from regaining access to working memory. Thus, one factor that may differentiate fluent reading in a first language from the less fluent reading in a second language may be the ability to inhibit irrelevant information at the appropriate time.

Another interesting finding was the positive relationship between first language reading times and negative priming at the two earliest RSIs in Experiment 2. This indicates that faster readers in L1 tend towards greater negative priming than slower readers at these earliest RSIs, even though all of the readers in L1 had high comprehension. This agrees with the results by Gernsbacher et al (1990) and Gernsbacher and Faust (1991) which showed that more skilled comprehenders in a first language were able to suppress the extraneous meanings of ambiguous words at delays of 850 and 1000 ms respectively but that less skilled comprehenders were not. This suggests that at these time delays for that task, inhibition was a factor which affected reading fluency in L1.

On the other hand, there was no relationship between L1 reading times and negative priming at the later RSIs, indicating that by the longest delays all individuals were equally efficient at inhibiting information and that inhibition is no longer a factor which separates low and high skill L1 readers. However, no correlation was found between L2 reading times and L2 negative priming at any of the RSIs. In addition, negative priming was significant in both L1 and L2 at the earliest RSIs. An interesting question is why there was a relationship between reading times and negative priming at the earliest RSIs in L1 but not in L2.

A secondary but at the same time interesting result, was the apparently anomalous dip and rebound of negative priming in L1 in Experiment 2 and of positive priming in L2 at the RSI of 1400 milliseconds. While it is likely that the dip and rebound of negative priming in Experiment 2 was the result of two distinct mechanisms, the dip and rebound of positive priming in L2 may have occurred for very different reasons. As discussed previously, longer response times on neutral trials is the most likely reason for the apparent dip in positive priming and this may in fact be an effect obtained by chance.

The approach taken in this thesis is that the positive and negative priming found in these experiments is the result of activation and inhibition of information and that the relative strength and balance of these two mechanisms in L1 and L2 is reflected in the skilled performance of first and second language readers. However it is possible, as previously mentioned that other mechanisms are working in concert with these selection mechanisms or perhaps instead of them. First of all, it is possible, that although much care was taken to discourage the use of episodic retrieval, that in fact it did occur either concurrently with inhibition or by itself. If episodic retrieval was the mechanism responsible for the speeded responses in the positive priming experiments, it could indicate that, positive priming being almost equal in L1 and in L2, retrieval of past processing episodes was as automatic in L2 as in L1. However in those situations in which negative priming was strong in L1 but not L2, it is possible to speculate that possibly, although retrieval was automatic, the "ignore it tag" was lost.

Another theoretical possibility is offered by the "selection-feature mismatch theory" (MacDonald & Joordens, 2000). According to this theory, negative priming is the result of a mismatch between the classification of an item on the prime display as compared to the probe display. Thus an item which is classified as "smaller" on the prime trial is now classified as "longer" on the probe trial. In terms of bilingual processing, it could mean that in the situation where the classification stays the same, as in positive priming, there is very little difference between L1 and L2 due to the small size of the stimulus set and the amount of practice. However, when the classification changes, as it does in the negative priming task, it could mean that readers in L2 do not classify items as strongly on the prime trial as being smaller or larger due to reduced resources available and therefore do not encounter as much of a conflict on the probe trial. It is also possible to postulate the operation of two mechanisms here - an inhibitory mechanism at the earlier time delays and semantic mismatch at the later time delays. Note that it is impossible at this point to differentiate among the three possible mechanisms.

Limitations and Future Directions

One of the hypotheses in this thesis was that participants would not demonstrate negative priming at the earliest time delays (Experiment 2) when they were being tested in their L2. This hypothesis was not upheld as readers in L2 displayed almost as much negative priming as readers in L1 at the earliest time delays tested. This could indicate that in fact second language readers do inhibit irrelevant information as quickly as first language readers. Most likely, however, the time delays chosen in this experiment were too long, and if earlier time delays had been chosen, differences between first and second language readers would have been found.

Another factor which may have contributed to the similarity of negative priming in both languages at the earliest RSI was the fact that readers demonstrated significantly longer response times in L2 than in L1. This may have extended processing time in L2, allowing inhibition to build up to a greater extent than would have been possible had response times been similar to those in L1.

It is also possible that practice diminished differences between L1 and L2. Only eleven different words were used in these experiments and even by the time the practice sessions were finished, individuals would have responded to each word approximately ten times. Thus it is possible that although practice did not seem to remove all of the differences between L1 and L2, that it did ameliorate the effects somewhat. In support of this are the results of Experiment 1, which was much shorter and in which participants did not demonstrate significant negative priming in L2.

Future research should explore in detail the balance between activation and inhibition at various time delays and with different tasks in relation to skill in L1 and L2. Thus the onset, peak and offset of positive and negative priming at earlier and later time delays should be explored.

The task used in this experiment employed a very small set of stimuli, which became well-practiced after a very short time. It would be interesting to investigate the time course of positive and negative priming with a more complex, resource-demanding task that would involve minimal repetition of stimuli. In this way the relation of activation and inhibition to level of fluency could be assessed without concern for practice effects.

Another approach would be to explore the role of practice. As discussed previously, consistent practice has been found to bring about a qualitative change in the blend of automatic and controlled components contributing to various types of performance (Schneider et al., 1984; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Could inhibition become more efficient through the role of practice?

While some researchers refer to inhibition as a controlled mechanism (Hasher et al., 1999) and claim that inhibition/suppression can be affected by probability (Gernsbacher & Faust, 1995) it is possible that practice and in particular, consistent practice, may place inhibitory processing somewhat closer to the automatic end of the controlled-automatic continuum. Lowe (1998) investigated how consistent practice may affect the amount of negative priming in three experiments. All experiments were divided into practice and test phases. These phases were separated by a five minute retention interval. As in a typical consistent practice experiment, words could appear as targets or distractors but not both. Words were presented in different ink colours and participants named the words in the target colour and ignored the words presented in the non-target colour. Word pairs were displayed one, three, six or nine times and both negative priming and positive priming conditions were included. In Experiment 1, probe distractors in the test phase were new words. Other new word-pairs not related to practice were also included. Progressive positive priming was found for repeated items both in the positive priming and negative priming conditions.

In the second experiment a change was made to the test phase, so that new word-pairs were *not* included (an increase in general consistency). In the third experiment, the test phase was changed so that there was an increase in specific consistency (the same target-distractor pairs were included as used in the practice phase - in other words no new probe distractor words were used). In both experiments Lowe found that with increases in the number of presentations, progressively slower RTs were found in the negative priming condition. In addition, positive priming also increased with number of presentations.

These results suggest that the efficiency of inhibition could be improved with consistent practice. Lowe proposed that because negative priming persisted over the five minute retention interval, the mechanism in place was most likely episodic retrieval, and this is a possibility. However, it may be reasonable to suggest that if skill does play a role in the efficiency with which we inhibit extraneous information, consistent learning would lead to improved performance. For example, in the normal reading situation, if consistent practice were given in which one learned to suppress the inappropriate meaning of ambiguous words in particular contexts, would the time needed to suppress those words be shorter?

Lastly, further research could explore how the time course of activation and inhibition would generalize to the normal reading situation in L1 and L2. Experiments testing inhibition and activation at the sentence level, similar to those performed by Gernsbacher, could be carried out which would look at situations particular to second language learning. For example, "false friends" (words which are spelled the same in two languages but which mean two entirely different things (e.g. *four* which means an *oven* in French and a *number* in English) could be employed instead of homographs. Experiments could further investigate not only how fluency affects the ability to suppress the inappropriate meaning of a "false friend" but how timing and practice interact to improve second language fluency. An interesting question, for example, would be whether the amount of time required to inhibit the inappropriate meaning of a "false friend" or homograph (a word such as *pêche* in French that can be defined as either a *peach* or *fishing*) would be shortened with consistent practice in reading these words in the appropriate context.

To our knowledge this has been the first group of studies to investigate individual differences in second language reading fluency by examining the underlying mechanisms of facilitation and inhibition in a within language task and with the negative priming paradigm. A further contribution was made by measuring the time course of facilitation and inhibition in L1 as compared to L2. Overall, the studies reported here indicated that the role of inhibition and facilitation in L2 fluency can be profitably studied using the negative priming paradigm.

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Appendix A

Instructions for the Reading Proficiency Task

In a moment you will be shown some short passages, to be read to yourself, one paragraph at a time. Please read the text quickly, as you normally would when reading a magazine article. It is not necessary to study and remember every detail of the text.

After reading each paragraph, press a key to bring the next paragraph onto the screen.

After the last paragraph of each story, you will be shown a sentence that makes a general statement about the passage with three possible ways to complete the sentence.

Please choose the correct ending - first, second or third - by pressing the key marked 1, 2 or 3.

Please read the paragraphs as quickly as possible without sacrificing comprehension. We are interested in how quickly people can read while maintaining full comprehension. To ensure that you can respond quickly, please keep your fingers resting lightly on the keys at all time.

Appendix B

CONSENT FORM TO PARTICIPATE IN RESEARCH

This is to state that I agree to participate in a program of research being conducted by Dr. N. Segalowitz of the Department of Psychology at Concordia University.

PURPOSE

I have been informed that the purpose of the research is to further our understanding of the nature of skilled reading.

PROCEDURES

I understand that the research will be conducted at Concordia University in the laboratory of Dr. N. Segalowitz. I also understand that I will be asked to look at material on a computer screen and make judgments about the material. I understand that testing will take approximately 3 hours, divided into two sessions. In addition, I understand that, upon completing the second session, I will receive payment of $20.00.

CONDITIONS OF PARTICIPATION

- I understand that I am free to withdraw my consent and discontinue my participation at any time without negative consequences

- I understand that my participation in this study is confidential.

- I understand that the data from this study may be published.

- I understand the purpose of this study and know that there is no hidden motive of which I have not been informed.

- I understand that I may have a copy of this agreement and I may contact Prof. Segalowitz for a written copy of the report. Write to Prof. Norman Segalowitz, Psychology Department, Concordia University, 7141 Sherbrooke Street West, Montreal, Quebec H4B 1R6. Please allow several months for completion of the study and write-up.

I HAVE CAREFULLY STUDIED THE ABOVE AND UNDERSTAND THIS AGREEMENT. I FREELY CONSENT AND AGREE TO PARTICIPATE IN THIS STUDY.

Name (please print) ______________________________

Signature ______________________________

Researcher Signature ______________________________

Date ______________

Appendix C

Participant Questionnaire

PARTICIPANT QUESTIONNAIRE

Name : ______________________

Age : ______________________ Sex: M F

Field of study: ______________________

1. Where were you born? (city, country) ______________________
2. What do you consider to be your first language? English French Other_______
3. What do you consider to be your second language? English French Other_______
4. What language do you consider your dominant language? English French Other_______
5. At what age did you learn your second language? ______________________
6. What language do you speak at home now? ______________________
7. What is the first language of your mother: ____________ and father: ____________
8. In what language did you attend school (Please circle the appropriate one):
   - elementary school: English French Other ________
   - high school: English French Other ________
   - CEGEP: English French Other ________
   - University: English French Other ________
9. Do you have a known visual impairment that is NOT corrected by wearing glasses or contact lenses? yes no
10. Do you have a known reading disability (eg. dyslexia)? yes no
11. Please rate your level of ability for each of the three skills listed below by using the following rating scheme and circling the appropriate number in the boxes below:

1 = no ability at all **2** = very little **3** = moderate **4** = very good **5** = native-like ability

Language	Speaking	Reading	Writing
English	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
French	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Other	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Other	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

12. Please fill out Column 1 first. Then rate the time spent each week using each language. Use the following rating scheme and circle the appropriate number in the boxes:

1 = never/almost never
2 = one to three times/week
3 = four to six times/week
4 = more than six times but less than my main language
5 = main language used

Language	Speaking	Reading	Writing
First language:	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Second language:	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Other:	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Other:	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Appendix D

General Instructions

As indicated on the consent form, testing will take place on two different days, one day in English and one day in French.

Each day there will be two short blocks of trials and two longer blocks. An opportunity to take breaks will be given during each block and will be signalled by the presentation of feedback and a request to "Press any key when you are ready to continue." You may take as much time as you need during these breaks and continue only when you are ready.

The end of each block will be indicated by a statement saying that you have now completed this part of the study. There will be feedback giving your final cumulative scores for that block. Please advise the experimenter when the block has ended so that she may start the next part of the experiment.

Appendix E

Instructions

English Session

Two words, which represent units of time, will be shown in the center of the screen, one above the other. You are asked to select the word which refers to the longer unit of time.

If the word referring to the longer unit of time is on the top, then press the upper key (|). However, if the word referring to the longer unit of time is on the bottom, then press the lower key (|).

For example, if the words

century

decade

are presented, you should press the upper key (|) for "century". Please be prepared to respond at all times by placing the index finger of your preferred hand on the upper key (|) and the index finger of the other hand on the lower key (|).

If you make an error during the short blocks of trials , you will hear the sound of a short "beep". If you make an error during the longer blocks of trials you will not hear a "beep".

When making your decision, please use the everyday meaning of the words rather than attaching elaborate personal significance to them.

Please respond as quickly and accurately as possible. Feedback regarding your speed and accuracy will appear on the screen at various times. You may take a break at this time, if you wish.

If you have any questions, please ask now. Please press any key when you are ready to begin.

Appendix F

Vocabulary List

Name:____________________________

The following is a list of words that are going to be presented on the computer as part of the study in which you are about to participate, in English and in French. Please place an " X" beside any word(s) with which you are not familiar.

English

second __
minute __
hour __
morning __
day __
week __
month __
season __
year __
decade __
century __

French

seconde __
minute __
heure __
matin __
jour __
semaine __
mois __
saison __
année __
décennie __
siècle __

Appendix G

CONSENT FORM TO PARTICIPATE IN RESEARCH

This is to state that I agree to participate in a program of research being conducted by Dr. Norman segalowitz of the Department of Psychology at concordia University.

A. PURPOSE

I have been informed that the purpose of this research is to study reading ability.

B. PROCEDURES

I have been informed that this study will take place at Concordia University, in the laboratory of Dr. Segalowitz. I have been informed that the task I will be asked to accomplish consists of reading short stories on a computer, and then answering multiple choice questions. I am also aware that I will be timed. The total testing time will be of approximately 45 minutes.

C. CONDITIONS OF PARTICIPATION

- I understand that I am free to decline to participate in the experiment without negative consequences.
- I understand that I am free to withdraw my consent and discontinue my participation at any time without negative consequences.
- I understand that my participation in this study is confidential (i.e., the researcher will know but will not disclose my identity).
- I understand that the data from this study will be published.
- I understand the purpose of this study and know that there is no hidden motive of which I have not been informed.
- I will be paid six dollars per hour upon completion of my participation.

I HAVE CAREFULLY STUDIED THE ABOVE AND UNDERSTAND THIS AGREEMENT. I FREELY CONSENT AND AGREE TO PARTICIPATE IN THIS STUDY.

NAME (please print):____
SIGNATURE:____
RESEARCHER SIGNATURE:_______________________________________
DATE: ____________________2000.