Lexical Representation and Selection in Bilingual Memory as Evidenced by Negative and Positive Priming Effects

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By

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ABSRACT

Bilingual speakers present an intriguing puzzle for selective attention research because of the co-existence of two languages in the brain. Research (e.g., Marian & Spivey, 2003) shows that both languages of the bilingual are activated in parallel when bilinguals intend to use one language alone. What are the cognitive mechanisms that enable bilinguals to select one language for use in the midst of competing languages in the brain? How do bilinguals regulate influences from the nontarget language when one language is in use? These are some of the major questions investigated by cognitive psychology and psycholinguistic researchers. To understand bilingual language processing, it is important to uncover the structure and organisation of language representations in memory, as well as the processes involved in coordinating the two different languages. This dissertation presents a series of studies that examine the cognitive mechanisms underlying bilingual lexical processing, using a priming technique, and further test predictions from the two rival theories of conceptual negative priming - the inhibition based and episodic retrieval accounts.

The tasks involved the presentation of pairs of items, one in uppercase letters and one lowercase letters. Those in lowercase letters served as targets and those in uppercase served as distractors. Participants were asked to ignore the uppercase items in prime-probe couplets, which comprised a trial. During presentation of the prime stimuli, participants were required to name the lowercase target word aloud, followed by the probe display, which required them to make a lexical decision (word/nonword judgement) to the lowercase item. The key relationships between prime and probe stimuli were manipulated in three ways. In the attended repetition (AR) condition the attended lowercase prime word was the same as, or the noncognate translation equivalent of the attended probe target item. In the control (CO) condition the prime word pairs had no relationship with the probe items, and in the ignored repetition (IR) condition the prime distractor word was the same as, or the noncognate

translation equivalent, of the attended probe item. Each word was used no more than twice in the experiments, and then only to satisfy either the AR or IR manipulations.

In the within-language experiments (all English stimuli, or all Twi stimuli), lexical decisions to probe target words were facilitated when the word was identical to the preceding prime target word, whereas delayed lexical decisions to probe target words occurred when the word was identical to the preceding prime distractor word. The within language experiments thus produced positive (facilitatory) and negative priming (NP) effects respectively. The NP effect that emerged in the within-language experiments showed that NP can occur with experimentally novel stimuli, that is, stimuli that are seen no more than twice in an experiment, once as the distractor and then as the target in the prime-probe couplet.

In the bilingual (Twi-English) experiments, between languages rather than within language priming manipulations were used. Ignored repetition NP effects were found across languages but cross-language AR positive priming effects disappeared. This dissociation of priming effects in the within and between-language priming conditions is inconsistent with episodic retrieval predictions. Instead, the results support inhibition-based accounts by showing that bilingual language selection is achieved by active inhibition and that inhibition can flexibly operate at both the local and global levels of abstraction. In the between-language (Twi-English) task where participants were categorised according to second language (L2 = English) less and more proficient bilinguals, the more proficient produced robust NP effects coupled with no positive priming. Less proficient bilinguals, however, showed a trend towards positive priming, but nonsignificant NP. These results indicate that more proficient bilinguals relied on inhibition of the Twi (first) language in order to perform the task in the English (second) language, thereby accounting for the elimination of AR positive priming and the preservation of IR NP. Less proficient participants, in contrast, seem to rely on the first (Twi) language as a form of crutch to perform the task in the second language.

Finally, in the between-language (English-Twi) experiment where participants were required to name prime targets in their L2 followed by making lexical decisions to letter strings in their L1, AR positive priming effects were obtained, but no IR NP effects. A plausible conclusion suggested that there is inhibition of the dominant (L1) language when bilinguals perform the prime task in the weaker (L2) language. However, the weaker (L2) language does not have to be inhibited to the same magnitude (or perhaps at all) in order to perform the subsequent probe task in the dominant (L1) language; hence accounting for the AR positive priming. Due to the relative weakness of the language used in the prime, the prime distractor also elicits comparatively weaker competition with the target, thus reducing the degree of inhibition applied to it, which could potentially account for the absence of NP. Taken together, the cross-language priming effects reported here seem to fit single-store models of bilingual language representation, wherein conceptual representations are deemed to be integrated across languages in bilinguals. Because of the processing mechanisms involved in juggling the languages and words within them, however, they operate *as if* they were functionally separated (Neumann, McCloskey, & Felio, 1999).

Chapter 1

1.1. Introduction

On a daily basis, a myriad of information vies for our attention. A basic question is how individual responses are controlled by specific stimuli in the presence of competing input. Another question is what happens to the information derived from the competing or distractor stimulus during execution of a response to a target stimulus? Selective attention is the generic term for those mechanisms that allow us to tune out unimportant information and focus on what really matters at a given moment. Selective attention mechanisms may also be relevant in helping to explain how bilinguals manage to select one language for use in the midst of a competing language in the mind. Cognitive scientists and neuroscientists have come to the understanding that the way bilinguals negotiate the presence of two languages may reveal processes that will otherwise be enshrouded in mystery if research is restricted to speakers of a single language (Kroll, Dussias, Bogulski & Kroff, 2012). Currently, there is an explosion of studies addressing the language and cognitive processing of bilinguals. These studies employ various paradigms, different tasks, and report varied findings. What is clear, however, is the convergence on the hypothesis that the two languages are active when the bilingual intends to use one language alone (e.g., Marian & Spivey, 2003; Martin, Macizo & Bajo, 2010). What mechanisms enable bilinguals to recruit one language in the face of competing languages continues to be a matter of debate.

One of the experimental techniques employed to study selective attention involves priming manipulations (e.g., Botella, Barriopedro, & Joula, 2002; Frings, Schneider, & Fox, 2015; Loula, Kourtzi, & Shiffrar, 2000; Milliken et al. 1998). Such a priming technique is employed in this dissertation to investigate the mechanism underlying bilingual language selection and processes. The term bilingual is used here to denote people who "use two or more languages (or dialects) in their everyday lives" (Grosjean, 2010, p.4). Because all of the experiments in this dissertation entail both negative and positive priming manipulations, the next section provides an overview of different theories of priming.

1.2. A brief overview of three existing negative priming theories

Priming involves increased sensitivity to a stimulus due to prior exposure. It is believed to often occur outside of conscious awareness, and therefore differs from explicit memory that relies on conscious retrieval of information. Technically described, priming is an implicit memory effect of a previously encountered stimulus (e.g., word, picture, or letter) on the response to a similar, identical or related stimulus. In one type of priming study, participants engage in a selective attention task in which two displays, a prime display followed by a probe display, are presented in succession. Each attentional display consists of a relevant target and an irrelevant distractor, with the target requiring a response. The target is usually defined by some physical feature such as colour or shape. The priming effect is measured by contrasting response latency and accuracy of related and unrelated trials. Positive priming manifests in faster response to an object that is similar, identical or semantically related to a previously encountered object compared with an unrelated object. Negative priming (NP) results in a slowdown of reaction in response to an object that is similar, identical, or semantically related to a previously encountered *but* ignored object compared with an unrelated object. Since the NP effect was first reported (e.g., Dalrymple-Alford & Budyar 1966) three main theories have been proposed to explain the phenomenon: distractor inhibition (Houghton & Tipper, 1994; Tipper, 1985; Tipper, 2001), episodic retrieval (Neill & Valdes, 1992), and temporal discrimination (Milliken, Joordens, Merikle & Seiffert, 1998).

The distractor inhibition theory assumes that successful selective attention is the result of an interplay of target activation and distractor inhibition. By this account, the initial exposure to a stimulus activates internal categorical representations for targets and distractors concurrently (Neumann & DeSchepper, 1991; Tipper, 1985). For successful goal-directed behaviour to occur, an excitatory mechanism acts to enhance target information while an inhibitory mechanism simultaneously suppresses the activation levels of the distractor information. Thus, at the initial encounter with the prime stimuli, the abstract mental representations of the target stimulus are activated whereas those of the nontarget (distractor) stimulus are actively inhibited by mechanisms of selective attention. Activation of the prime target facilitates or accelerates the processing of the same, or related, stimulus on a subsequent encounter. However, if the nontarget distractor from the prime trial becomes the probe target, the recently inhibited representation has to be time consumingly re-activated, or overcome in some way, for a response to be accomplished, and thus NP occurs.

By contrast, the episodic retrieval model contends that perceiving a target activates memory traces associated with a previous processing episode containing that particular, or highly similar, stimulus. Priming reflects the consequence relating to the retrieval of a memory trace containing specific prior response information that is compatible or incompatible with a current correct response (e.g., Neill, 1997). Positive priming is as a result of access to an episodic representation that contains response information (a response tag, "respond") that is identical or similar and thus facilitates the needed probe response (i.e. respond, "respond"). Negative priming here is caused by the incompatible response tag generated, when a stimulus that was 'ignored' in a preceding episode becomes relevant in a subsequent encounter. As such, delayed response in the ignored repetition (IR) condition is attributed to the retrieval of an episodic representation which contains prime response information (i.e., “do not respond”) that conflicts with the contradictory response required by the probe (i.e., “respond”). Resolving this conflict takes time, resulting in NP.

The temporal discrimination theory (Milliken et al., 1998) maintains that an attentional system differentiates between a stimulus whose response is already known (and can be recovered from memory) and a stimulus whose response has to be newly computed. If a probe is identified as old, response is expedited as there is an immediate integration and retrieval of an episodic history accompanying that stimulus, thus producing a positive priming effect. Negative priming within this framework, is generated at the instance of response formation during the IR probe trial. When a probe target is identified as new, a moderately fast response is generated on the basis of perceptual analysis. However, a probe target in an IR trial is ambiguous due to its familiarity because it had appeared at the prime display. This prevents a quick categorization as new, and yet as a stimulus recently unattended, it is not familiar to be classified as old. The time taken to resolve this ambiguity results in NP.

The inhibition based and episodic retrieval models are the two theories of priming that have survived empirical testing, according to Mayr and Buchner (2007). Hence, researchers continue to question whether priming effects are based on attentional inhibition or episodic retrieval, or both processes (Tipper, 2001). In this dissertation a clear distinction is drawn between these two theories. The results show that the priming effects in the present study are largely driven by inhibition processes, rather than episodic retrieval. The findings in this dissertation thus present a challenge to the episodic retrieval model and add to the body of research that questions the exclusion of inhibitory processes in NP interpretations (e.g., Grison, Tipper, & Hewitt, 2005; Tipper, 2001). Although episodic retrieval may be involved in other NP paradigms, the inhibition-based processing mechanisms uncovered in the current experiments appear to be able to override any potential episodic retrieval effects, and accommodate the full range of findings better.

1.3. Organisation of the dissertation

The dissertation begins with a general introduction (Chapter 1) and ends with a general conclusion (Chapter 6). The main body of the dissertation comprises three self-contained chapters (2, 3, and 4) each with its own literature review, experiments, findings and conclusions. However, the format has been adjusted to conform to a dissertation. All references for the dissertation have been grouped together and follow after Chapter 6. Word stimuli and questionnaire come after references as appendices. Chapter 5 involves a new manipulation and the findings are discussed in the context of how they relate to the previous experiment chapters. Chapter 3 was submitted for publication and an invitation to revise and re-submit the paper has been received from the editor of the *Journal of Cognitive Psychology*. Chapters 2 and 4 have been submitted as manuscripts for publication and are currently being reviewed in *Language and Cognition* and the *Quarterly Journal of Experimental Psychology*, respectively.

Chapter 2 attempts to reconcile divergent findings regarding the manifestation of NP with nonrecycled words. Chapter 3 distinguishes and tests differing predictions between the episodic retrieval and inhibition based theories of NP when cross-language priming tasks are used, and examines the nature of bilingual language representation and processing. Chapter 4 explores the mechanism that regulates language selection and processing in the bilingual lexicon, and further examines how this system is influenced by different levels of L2 proficiency. In contrast to the two previous chapters wherein the prime was in L1 and probe in L2, Chapter 5 investigates priming effects when bilinguals respond to the task from L2 to L1. A brief synopsis of each chapter is provided below.

1.4. Chapter 2: Identity based positive and negative priming effects

Excitatory and Inhibitory Priming by Attended and Ignored Nonrecycled Words

Research Aim: To investigate negative and positive priming effects using a large pool of nonrecycled words and to further assess whether these are expressed differently in bilinguals from monolinguals.

Foreword: Until recently, it was widely assumed that NP effects while consistently found with recycled word situations with small pools of words, are not found with experimentally novel stimuli (e.g., Grison & Strayer, 2001; Malley & Strayer, 1995). However, this assumption is questioned by findings in Neumann et al. (1999) who reported NP effects in experiments that employed a large pool of words in which a particular word was encountered maximally twice in the experiment, and only within a given prime-probe couplet. Thus, there is a disparity among extant reports on whether NP can be obtained with nonrecycled words. Chapter 2 attempts to re-affirm whether IR NP effects can indeed be obtained when words are presented once and only once as a prime distractor.

1.5. Chapter 3: Cross-language negative and positive priming effects

Cross-language negative priming remains intact, while positive priming disappears: Evidence for two sources of selective inhibition

Research Aim. To draw theoretical and empirical parallels and differences between the mechanisms of excitation and inhibition and to isolate the different circumstances in which these mechanisms operate in bilingual language processing. In addition, to test predictions stemming from episodic retrieval and inhibition-based models to determine if one provides a better account of the cross-language findings than the other.

Foreword. The traditional account of NP is a reflection of an inhibitory mechanism of attention. However, the episodic retrieval model contends that NP does not reflect inhibitory mechanisms, instead, the delayed reaction times on NP trials are due to the retrieval of incongruent response tags. Other authors contend that inhibitory mechanisms and/or episodic retrieval processes can be the source of NP effects depending on the contextual variables of the task (e.g., Kane, May, Hasher, Rahhal, & Stoltzfus, 1997). Chapter 3 reports within and between language priming experiments that attempt to dissociate the predictions from inhibition-based and episodic retrieval theories of priming. The early years of bilingual memory research addressed many questions that remain relevant to current research in this field. One of such is whether bilinguals have two separate lexicons, one for each language, or a single big 'bilingual' lexicon. This question has produced few conclusive answers (French & Jacquet, 2004). As a consequence, the cross-language priming effects also provide implications regarding the nature of bilingual language representation and processing.

1.6. Chapter 4: Language proficiency and language control in bilingual lexical processing

Bilingual cross-language positive and negative priming effects as a function of L2 proficiency

Research Aim. To examine the system that regulates the activation and suspension of target and nontarget languages (as well as the words within them) during bilingual language processing and to determine how this system is influenced by different levels of L2 proficiency.

Foreword. Bilinguals are able to communicate in either of their two languages seemingly shielded from constant interference from the nonresponse language. Yet, research shows that both languages are active when a bilingual identifies a word or plans to speak in one of the languages (e.g., Blumenfeld & Marian, 2013; Colomé, 2001). If the two languages are active and compete for selection, then there must be a system in place that regulates this activity so that random errors of language do not happen (Kroll, 2008). Currently, there is an ongoing debate about how the control mechanism operates (e.g., Green, 1998), and how this might change with different levels of L2 proficiency (e.g., Costa & Santesteban, 2004). These issues are explored in Chapter 4.

1.7. Chapter 5: Effects of reversing prime-probe language dominance and its influence on negative and positive priming

Cross-language positive and negative priming effects reverse when priming manipulations proceed from L2 to L1, compared to L1 to L2

Research Aim: To examine whether priming effects obtained in cross-language experiments are influenced by the order of prime-probe language manipulations.

Foreword. There is evidence that when bilinguals speak in their first language (L1), not much inhibition is needed to suppress the less dominant second language (L2) because the baseline level of activation of L2 lexical items is lower than that of L1 lexical candidates. When speaking in the L2 however, L1 representations have to be actively suppressed or inhibited to enable selection of L2 lexical candidates (e.g., Filippi, Karaminis & Thomas, 2014; Meuter & Allport, 1999). Chapter 5 examines the priming effects produced when participants respond to a naming task in their L2 followed by making lexical decisions in their L1. Chapter 5 aims to determine whether the same pattern of AR positive priming and IR NP effects obtained in the cross-language experiments of chapters 3 would again be observed. Or, alternatively, whether the different language dominance factors described above would alter the pattern of findings.

Chapter 2

Excitatory and Inhibitory Priming by Attended and Ignored Nonrecycled Words

2.1. Abstract

Two experiments examining identity priming from attended and ignored words in a lexical decision task are reported. Experiment 1 tested English monolinguals whereas Experiment 2 tested Twi-English bilinguals. Participants were presented with sequential pairs of displays, a prime followed by a probe display, with each containing two items. They were required to name the target word in the prime display, and to make a lexical decision to the target item in the probe display. On attended repetition (AR) trials the probe target item was identical to the target word on the preceding attentional display. On ignored repetition (IR) trials the probe target item was the same as the distractor word in the preceding attentional display. Relative to a control condition (CO) where prime and probe stimuli had no relationship, the experiments produced *facilitated (positive) priming in* the AR trials *and delayed (negative) priming in the* IR trials. This pattern of results is at odds with studies that claim that negative priming cannot be obtained with experimentally novel (nonrecycled) words encountered only once as a distractor prior to becoming a target. Our results demonstrate that negative priming effects can, in fact, be produced under these circumstances. The positive and negative priming effects were found in both monolingual and bilingual groups of participants, despite the fact that the bilinguals responded to the task in their non-dominant language.

2.2. Introduction

Visual selective attention is the ability to respond to a segment of information while ignoring irrelevant information. Determining how relevant information is selected from among distractors in the stimulus environment remains an imperative issue in cognitive psychology. Arguably, such information is initially activated in parallel, and then relevant information targeted and irrelevant information actively suppressed. To explore the suppression of irrelevant information, Tipper (1985) presented participants with sequential pairs of trials, a prime followed by a probe, with each trial consisting of two superimposed objects printed in green and red. The task was to name the green object while ignoring the red one. In contrast to neutral control conditions, *positive* (facilitation) identity and semantic priming effects occurred, the former when the target objects in the prime and probe trials were the same, and the latter when they were semantically related. However, response times (RTs) were considerably longer, compared to control conditions, when the ignored object on the prime display was the same as, or semantically related to, the subsequent probe target. These latter effects thus ensued in both identity and semantic conditions and were dubbed *negative priming* (NP).

Negative and positive priming effects have been extensively researched (e.g., Frings, Wentura & Wuhr, 2012; MacLeod, Chiappe & Fox, 2002; Neumann & DeSchepper, 1991; Ortells & Tudela, 1996). One of the inconsistencies in the NP literature provides the focus of the present investigation. The inconsistency relates to whether NP can be produced with experimentally novel words (i.e., words that are encountered maximally twice in an experiment). In the seminal study, Malley and Strayer (1995) reported a series of experiments that investigated the effects of stimulus repetition on NP. Participants were presented with displays consisting of two different words and were asked to name the target word (printed in red) while ignoring a distractor word (printed in white). Prime and probe words appeared only once in the experiments except to fulfil attended repetition (AR) and ignored repetition (IR) manipulations. They observed AR positive priming in the conditions where prime and probe target words were the same, but IR NP did not occur in conditions where the prime distractor word was the same as the probe target item. In further experiments they used prime-probe couplets with a limited stimulus pool of words, and the words were repeatedly used as both targets and distractors. In this case, they observed NP with IR trials, but no positive priming on AR trials.

Intriguingly, Malley and Strayer (1995, Experiment 5) reported positive priming in experimentally novel word IR conditions, and claimed that low activation levels can lead to positive priming, irrespective of whether an item is attended or ignored in the prime display (see also, Grison & Strayer, 2001; Strayer & Grison, 1999). To account for their mixture of findings, Malley and Strayer proposed an activation model to explain that NP effects occur when two highly activated items are presented in tandem and compete for a response, as would be the case with a small pool of recycled words. From their perspective, word activation levels would be high due to the repetition, and NP then occurs because selection difficulty in the prime display is high. That is, when the distractor is highly activated, it is more likely to compete or interfere with responding to the target, and it is in such situations that the conditions for producing NP are engaged. However, with experimentally novel (nonrecycled) words their activation levels are relatively low and thus NP does not occur. Moreover, as seen above, it may even revert to positive priming in the IR condition when selection difficulty is low. Under such circumstances, an experimentally novel distractor in the prime display is less likely to compete strongly with response to the target, and hence the conditions necessary for NP to emerge are unmet.

A departure from the generalisation that NP effects with words depend on stimulus repetition comes from a study by Neumann, McCloskey and Felio (1999, Experiment 1).

They employed a large pool of words in an experiment where a word was displayed just once except to fulfill AR and IR manipulations. Their participants were presented with displays consisting of two words and were required to name the prime target and make a lexical decision to the probe target item. Positive priming effects occurred when the prime target was identical to the following probe target, whereas NP was observed when the prime distractor was the same as the following probe target. DeSchepper and Treisman (1996) have also reported NP in experiments that employed a large set of shapes presented only once as the unattended distractor followed by becoming the attended target. However, when they conducted a similar experiment with a large pool of experimentally novel words, Treisman and DeSchepper (1996) did not obtain NP. Hence, it remains elusive whether NP is obtained with experimentally novel *words* (i.e., words that are seen maximally twice in an experiment, once as a distractor and then as a target). This issue is pursued in the present study because of its implications for the use of stimuli with the wide ranging flexibility of words in NP tasks.

In light of the prevailing counterevidence, the main objective of Experiment 1was to determine whether AR positive and IR negative priming effects can be observed when using a large pool of nonrecycled words. The aim of Experiment 2 was to investigate whether the same findings would emerge when the stimuli were in the non-dominant language of a group of bilinguals.

Traditionally, research in psycholinguistics and cognitive psychology has predominantly been conducted in English, typically with English monolingual speakers, and the results were assumed to apply to bilinguals. However, the cognitive and linguistic processes engaged in the acquisition and use of two languages are different from those involved in monolingual language use (Bialystok, 2010). Questions about how two or more languages are represented in memory, how people manage to select one language for use amidst other languages in the mind, and the system that enable people to switch back-and-forth between languages in different circumstances without constant errors, are enduring issues that confront bilingual researchers but do not arise in monolingual discussions. Clearly, the presence of two languages in the mind creates an important distinction between bilinguals and monolinguals. The present study discusses a somewhat different issue from the regular bilingual-monolingual debate over the superiority of one group in a specific cognitive task. Instead, the current study investigates whether priming effects produced by attended and ignored experimentally novel words are expressed differently in bilinguals than in monolinguals when bilinguals engage in the task using responses based on their second language (L2). In particular, Experiment 2 explores the issue of whether the additional processing complexity involved when bilinguals perform selective attention tasks in their L2 impacts positive or negative priming results differently from the pattern of effects produced in Experiment 1.

2.3. Experiment 1

Previous research appears equivocal on whether NP could occur in an experimentally novel *word* IR condition. Extrapolating from the assertion of Strayer and his colleague's (Grison & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999) and from Malley and Strayer's activation model, NP is contingent on stimulus repetition when *words* are used as stimuli. Contrary to this generalisation, Neumann et al.'s (1999) study with a large pool of words that were displayed maximally twice in a prime-probe couplet, produced robust NP effects. If Neumann et al.'s (1999) findings are corroborated, then a prime distractor encountered once should be impaired in response latency if that distractor becomes the next probe target requiring a lexical decision. Experiment 1 examined identity negative and positive priming effects using experimentally novel words, with 'pure' English monolingual respondents. If NP is conditional on stimulus repetition then no NP should be obtained in this circumstance, otherwise a significant NP should be observed.

2.3.1. Method

2.3.1.1. Participants

The participants were thirty-nine English monolingual students (29 men and 10 women) from the University of Canterbury, New Zealand. Their ages ranged from 18 to 28, with a mean age of 22 years. Self-reports indicated that none of the participants could speak more than a few words in another language and they all reported normal or corrected-to-normal vision.

2.3.1.2. Stimuli and Apparatus

The stimuli consisted of 620 three-to-thirteen letter words from the word norms of Francis and Kucera (1982). Word frequencies ranged between 32 to 50 uses per million. One hundred and sixty-eight words were randomly selected to act as targets and the remaining as filler words. Ninety-six English pronounceable nonwords were also created (e.g., *pawdar* - instead of *powder*) for the nonword condition. The nonwords were verified to ensure that they did not form legitimate words in another language. String length for “word” and “nonword” stimuli were kept similar so there was no predictive relationship between string length and the word versus nonword category.

Two hundred and fourteen words were randomly selected and assigned to one of the three groups (72 each) of nontarget primes, nontarget probes and probe targets. The 72 probe target words were randomly distributed into sets 1, 2 and 3, with 24 words in each of the three conditions of interest: attended repetition (AR), ignored repetition (IR), and control (CO). Participants were assigned at random to one of the three groups for the purpose of counterbalancing. Participants in Group 1 had Set 1 as AR trials, Set 2 as IR trials and Set 3 as CO trials; for Group 2 it was Set 1 as CO trials, Set 2 as AR Trials and Set 3 as IR trials; and for Group 3 it was Set 1 as IR trials, Set 2 as CO trials and Set 3 as AR trials. The entire trial sets of 72 word and 72 nonword trials (nonword trials were the same for all groups) were arranged in random order and the same order was employed for all participants irrespective of the group. This was done to ensure that each probe target was paired with the same distractor word and in the same position in the trial sequence for all participants regardless of counterbalancing group and condition. For instance, if the probe target word "*bird*" was presented on the 20th trial for Group 1 in the AR condition, it was also presented on the 20th trial for Groups 2 and 3 in the IR and CO conditions, respectively.

The task was designed with a small proportion of AR trials (16.7% of the total trial couplets) in order to induce an uncontaminated estimate of priming effects, because evidence shows that participants are apt to form expectancies and improve performance as relatedness ratio increases (e.g., Neely, 1991; Neely, O'Connor & Calabrese, 2010). Similarly, there were equal proportions of 'word' and 'nonword' trials, because if the nonword ratio is less than half of the total trial couplets participants may be biased to produce a word response when a nonword is presented (Altarriba & Basnight-Brown, 2007). The experiment consisted of 144 prime-probe trial couplets (72 word and 72 nonword), 50 percent of the trials required a "word" response and the remaining 50 percent required a "nonword" response, in an unpredictable random fashion. Each individual target or distractor item appeared only once in a prime-probe display except to fulfil AR or IR conditions. The experiment was preceded by 24 practice trials similar to those in the main experiment. No practice word was used in the main study.

Each trial consisted of a black fixation cross, followed by a target word (lowercase letters) and then a distractor word (uppercase letters) printed in black (Calibri, font size 11) on a white background. The width of the words covered the computer screen of approximately 1.4cm (1.6 degrees of visual angle) for the shortest to 5cm (5.7 degrees of visual angle) for the longest. The distance between the closest edges of the top and bottom letter strings was 1 pixel width. Target and distractor items were presented one above the other pseudorandomly, such that half of the time the target was on top and on the remaining half on the bottom, across all conditions. This presentation style reduces participants' ability to focus attention in advance on the location of the target word. Prime words were displayed either in the middle, or marginally towards the left or right of centre, and each position was used 1/3 of the time for each condition. Langley, Overmier, Knopman and Prod'Homme (1998) have shown that alternating stimulus position augments the magnitude of NP by taxing attentional selectivity better than when stagnant stimulus locations are held. Probe stimuli were centred on the screen at all times.

The experiment was performed on a 15.6 inch Hewlett-Packard (HP) laptop computer. All programming was done with E-Prime 2.0 software programme (Psychology Software Tool, Inc.). A 5-button PST Chronos response box which features milliseconds accuracy across machines, was used for registering lexical decision reaction times (Psychology Software Tools, Inc., 2012). A response sheet with all the prime target words listed was generated before the experiment. It was used for the experimenter to monitor the participants' naming of primes.

2.3.1.3. Design and Procedure

A within-subjects design was employed in which the prime-probe relationship constituted the independent variable. The three levels of the variable were AR, IR, and CO. In the AR condition, the target word in the probe trial was identical to the target word in the prime trial (e.g., comb ~ comb). In the IR condition, the distractor word in the prime trial was identical to the target word in the probe trial (SACK ~ sack) and in the CO condition, the prime and probe stimuli had no relationships (e.g., fish ~ computer).

Participants were examined individually in a session lasting about 45minutes, and the viewing distance in all cases was approximately 50cm. They were tested in a special room optimized for low noise and dimly-lit conditions. The order of list presentation was randomised across participants. Participants underwent 24 practice trials prior to the main experiment and they could repeat the practice run up, if necessary, to familiarise with the task. They were instructed to verbally name the lowercase target word in the prime stimulus display. When the probe display appeared, they made a lexical decision as to whether the lowercase target item was a correct English word or not. Speed and accuracy were emphasized and participants were encouraged to ignore the uppercase distractors as best as they could. Once the main experiment began, the experimenter stayed away from the participant to avoid distractions. Prime naming was collected by the experimenter by ticking the correct responses on the response sheet. On each pair of trials, before the prime trial, there was a 500ms fixation cross in black at the centre of the screen. This was immediately replaced by the two prime words, exposed for 250ms while the participant named the lowercase target word. The word pair disappeared after 250ms and the screen went blank for 1000ms. This was followed by the probe trial consisting of two words, which remained on the screen until the participant made a word or nonword decision to the lowercase target item. This sequence recurred throughout the experiment. A sample of the trial couplet sequence is displayed in Figure 2.1.

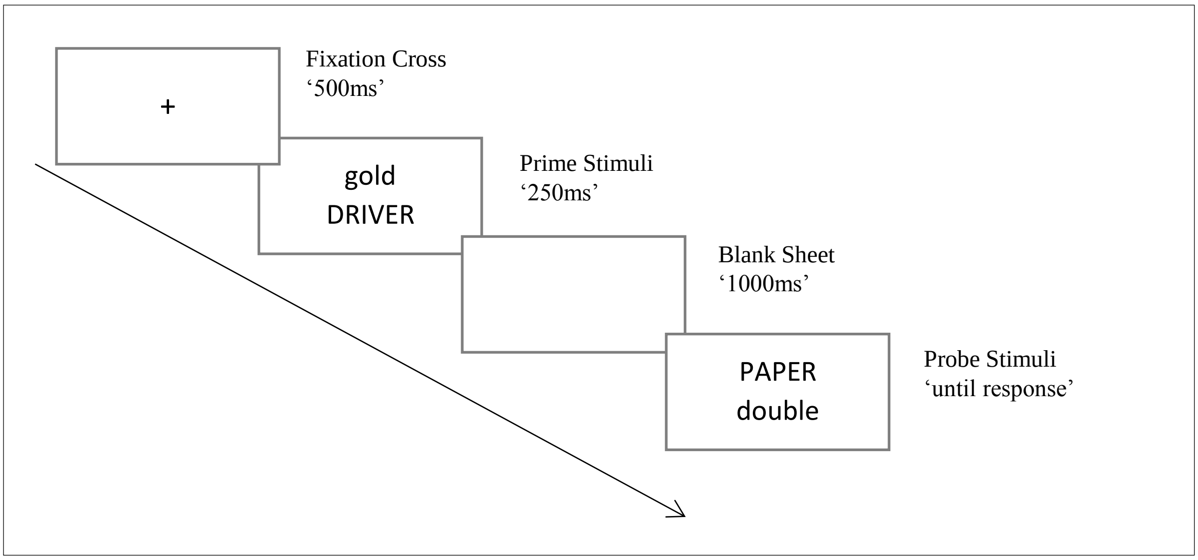

Figure 2.1. Sequence of stimuli presentation for Experiment 1. Note that the distance between the closest edges of the top and bottom item in each display was 1 pixel width

2.3.2. Results

Individual data sets that contained 30% or above naming errors, or lexical decision response errors, were excluded from analysis. Two participants were removed from further analysis based on this criterion. Nonword data were not analysed. The mean reaction time (RT) data are shown in Figure 2.2. A repeated-measures analysis of variance (ANOVA) was conducted on the RTs data. A significant effect of priming was found F (2, 72) = 29.69, MSE = 14430, p < .001, $\eta_p^{2 =}$ .45. Owing to the specificity of the hypothesis being tested, two paired samples t-tests were conducted to establish whether in contrast with the CO condition, AR produced a significant facilitation effect and IR produced a significant delay. The results show that the AR condition (M = 993, SD = 325.89) produced significantly faster RTs than the CO condition (M = 1148, SD = 420.22), t (36) = 5.25, p < .001, d = .86; whereas the IR condition (M = 1200, SD = 455.12) produced significantly slower RTs than the CO condition (M = 1148, SD = 420.22), t (36) = 2.56, p = .02, d = .42.

Error rates were analysed in a similar way. The priming effect was significant [*F* (2, 72) = 5.01, *MSE* = 16.68, *p* = .01, η_p^{2} = .12]. Planned t-tests further showed that relative to the CO condition (*M* = 3.54, *SD* = 3.48), the participants made fewer errors in the AR condition (*M* = 1.78, SD = 4.03), *t* (36) = 1.88, *p* = .03, *d* = .31 and marginally more errors in the IR condition (*M* = 4.76, *SD* = 4.90), *t* (36) = 1.34, *p* = .09, *d* = .22. This pattern of data shows no evidence of speed-accuracy trade-offs.

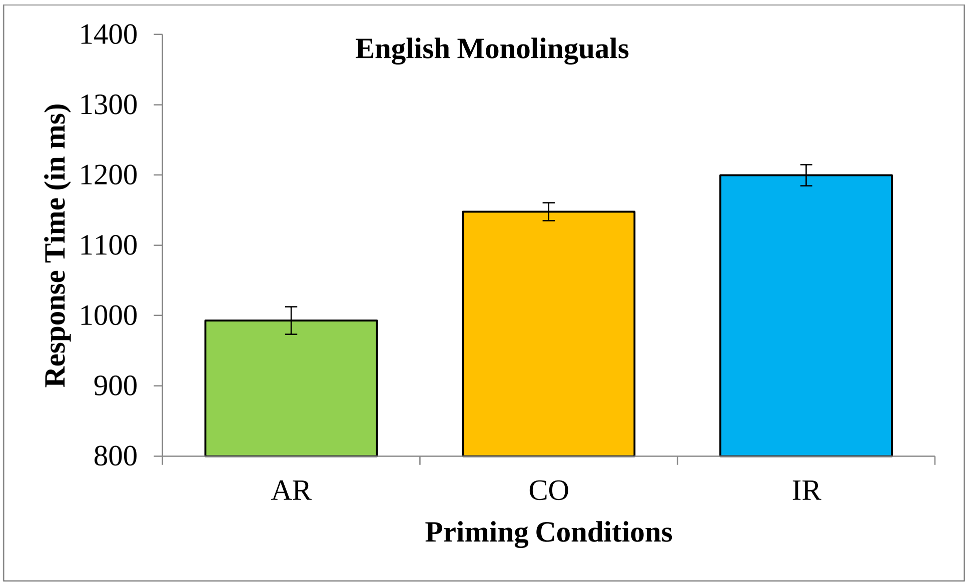

Figure 2.2. Mean response latency (in milliseconds) as a function of Attended Repetition (AR), Control (CO), and Ignored Repetition (IR) conditions in Experiment 1. Error bars indicate standard errors.

2.3.3. Discussion

Experiment 1 revealed substantial negative and positive priming effects in the IR and AR conditions, respectively. These observations challenge the assumption that when words are used NP occurs only under conditions of stimulus-repetition. Instead, the results corroborate Neumann et al.'s (1999) findings. It appears that NP effects can prevail in conditions where prime and probe stimuli are displayed maximally twice. This conclusion would be considerably strengthened, however, if the same pattern of results was obtained with a uniquely different group of participants. Given that monolinguals differ from bilinguals on many cognitive and linguistic tasks (e.g., Bialystok & Craik, 2010), it is possible that the results obtained in the first experiment were mediated by the characteristics of monolingual information processing involving the only language known by the participants.

2.4. Experiment 2

Experiment 2 was designed to be a unique attempt to extend the results in Experiment 1 using Twi-English bilinguals. Contemporary research has broadened our understanding that being bilingual influences not only language but also cognition more generally and the brain networks that maintain language and cognition (Kroll, Bobb & Hoshino, 2014). The cognitive processes involved in bilingual language use are different from those engaged by monolinguals (e.g., Bialystok, 2010). It is thus unclear whether the priming effects produced in Experiment 1 would generalise to a bilingual group of participants who engage in the same task, but in their L2, rather than their dominant language. If similar patterns of results were observed, it can be concluded that NP is not dependent on stimulus repetition regardless of the language characteristics of respondents, and even regardless of whether responding involves a dominant or non-dominant language.

2.4.1. Method

2.4.1.1. Participants

Forty Twi-English bilinguals (15 men and 25 women) from the University of Cape Coast, Ghana volunteered to participate in the experiment. Their ages ranged from 17 to 28 years with a mean age of 21 years. All the participants reported having normal or corrected to normal colour vision. Self-reports also showed that they all acquired their second language before age 6 and are reasonably proficient in their second (English) language. All the participants reported frequent, intentional switches of spoken language in English and Twi as an everyday occurrence.

2.4.1.2. Stimuli and Apparatus

The word stimuli, apparatus (laptop, response box) and stimuli preparation and presentation were the same as described in Experiment 1.

2.4.1.3. Design and Procedure

Each participant participated in an approximately 60-minute session consisting of 24 practice trials and 144 experiment-proper trials. All the other aspects of the design and procedure were identical to those in Experiment 1.

2.4.2. Results

No individual participant's data set contained 30% or above naming errors, or lexical decision response errors. Hence the analyses were conducted on all the 40 respondents. Nonword data were not analysed. The mean RT data are shown in Figure 2.3. A repeated-measures ANOVA was conducted on the mean RT. A significant effect of priming was found F (2, 78) = 10.14, *MSE* = 162658, $p < .001$, $\eta_p^2 = .21$. As in Experiment 1, planned t-tests were further performed to establish whether in contrast with the CO condition, AR produced a significant facilitation effect and IR produced a significant delay. The AR condition (*M* = 2373, *SD* = 1290.37) produced significantly faster RTs than the CO condition (*M* = 2603, *SD* = 1187.84), *t* (39) = 2.20, *p* = .02, *d* = .35; and the IR condition (*M* = 2778, *SD* = 1294.76) produced significantly slower RTs, than the CO condition, *t* (39) = 2.73, *p* = .01, *d* = .44. Error rates were analysed in a similar way. The effect of priming was not significant [*F* (2,

78) = 1.47, *MSE* = 10.33, *p* = .24, $_{p}^{2}$ = .04]. Thus there was no evidence of speed-accuracy trade-offs.

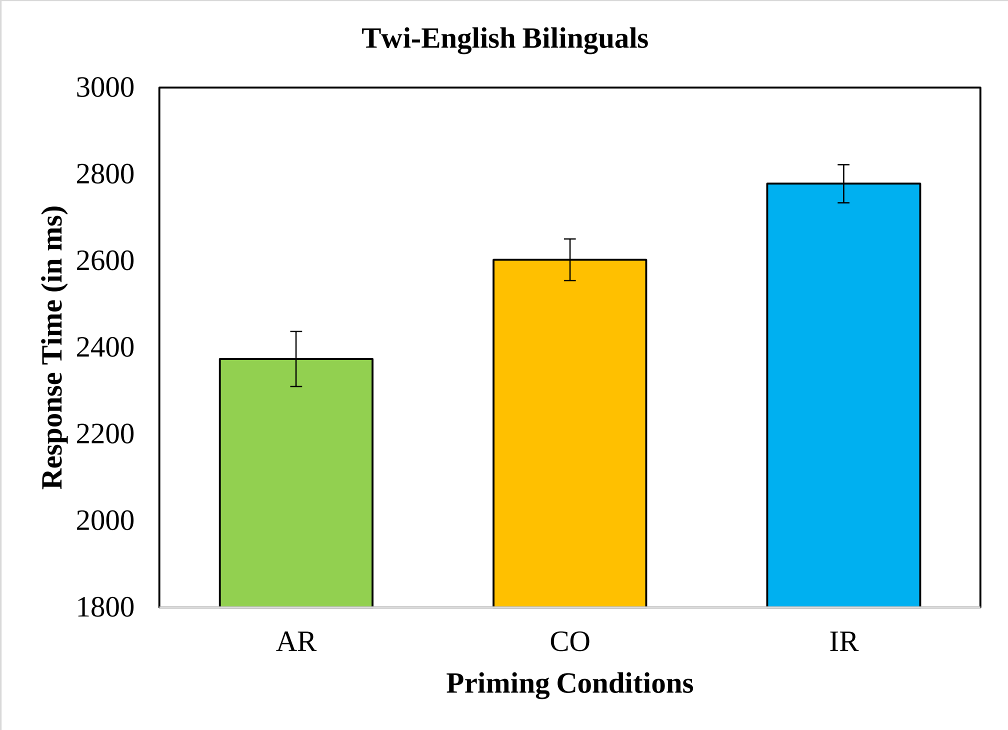

Figure 2.3. Mean response latency (in milliseconds) as a function of Attended Repetition (AR), Control (CO), and Ignored Repetition (IR) conditions in Experiment 2. Error bars indicate standard errors.

2.4.3. Discussion

Consistent with Experiment 1, Experiment 2 also produced substantial negative and positive priming effects in the IR and AR conditions, respectively. Thus despite presenting the task in the non-dominant language of the bilinguals, NP effects were again observed. This suggests a universality in the way languages are modulated that can override language-specific or cultural differences. An interesting feature of the results is that the overall RTs were more than double those of Experiment 1. Nonetheless, the pattern of the results in Experiments 1 and 2 was nearly identical, despite the longer RTs in Experiment 2. In addition to the processing delay that might be expected when bilinguals perform a task in their non-dominant language, it is also possible that the participants in Experiment 2 were comparatively unfamiliar with computerised tasks or may have been affected by different socio-cultural values that could have contributed to overall slower RTs.

2.5. General Discussion

In the present paradigm, two experiments were conducted with large pools of words to test negative and positive priming effects. Each word appeared once in the experiments except to fulfil the AR and IR manipulations. Both experiments recorded robust NP effects in the IR conditions where the ignored prime word was the same as the target probe word, and positive priming in the AR conditions where the attended prime target word was the same as the subsequent probe target word. Based on these findings we contend that a word encountered once as a prime distractor, but never as a prior target, can nevertheless elicit a cost in subsequent processing if it appears as a target in a following probe trial. Because it can emerge with just one encounter as the prime distractor, we conclude that NP with words is not conditional on stimulus repetition.

The present results are consistent with Neumann et al.'s (1999) study with large pools of nonrecycled words, but inconsistent with Strayer and his colleagues' (e.g., Grison & Strayer, 2001; Kramer & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999) claim that NP only occurs with repeated stimulus presentations involving a small pool of words. Strayer and his colleagues argued that experimentally novel distractors fail to strongly interfere with responding to the target item because the activation levels of novel words are low, hence the inhibition-based modulation mechanism is not engaged to the degree required for producing NP. Although our results differ from theirs, we agree with their proposal that the activation level of the prime distractor is an important factor in the manifestation of NP effects.

One possible explanation for the observed difference between the present results and those of Strayer and his colleagues relates to the methodological manipulations employed in each study. All word stimuli presented in their experiments were printed in different colours for targets (red colour) and distractors (white colour) and these colours served as selection cues. In the present paradigm however, targets and distractors were printed in black and differentiated by lettercase, which can make selection between the target and distractor more difficult due to inherently greater competition. Because colour is a very salient object feature, it should be comparatively easy for participants to distinguish between the target and distractor. If a target stimulus is distinguishable from distractors by a unique feature such as colour, the ease of selection is almost guaranteed due to 'pop-out effects' (e.g., Treisman & Gormican, 1988), which can accommodate the absence of NP when experimentally novel words are used. Ruthruff and Miller (1995) even go so far as to say that in very easy selection conditions distractor stimuli are not processed, and consequently not identified in prime trials. In any event, ease of selection is undoubtedly a factor which can determine if NP is observed in experiments involving words.

Previous studies have shown that the magnitude of NP tends to increase when attentional state is heightened (e.g., Moore, 1994; Pritchard & Neumann, 2011; Tipper & Cranston, 1985). In the present study, there was an initial change in response requirement from naming in the prime display to a lexical decision in the probe display to tax attentional demand. Second, word presentation varied such that no static stimulus positions were held for targets and distractors. Presenting words in close proximity to one another, along with spatial uncertainty, augments attentional selection difficulty, and using uppercase and lowercase words that share the same colour jettisons the propensity for pop-out. These factors made the target selection difficult, by inducing a heightened selective state in an experiment-wide manner, resulting in the NP effect. Our results are thus consistent with the notion that, a high degree of competition between target and distractor words is required to induce significant NP effects in the absence of stimulus repetition.

Consistent selection difficulty increases the chances of obtaining significant NP effects because more conflicting distractors require a greater degree of inhibition (Pritchard & Neumann, 2011). For instance, it has been shown that NP is only observed in children when anticipation of conflict in target selection is present throughout the experiment (Pritchard & Neumann, 2011). Other studies have demonstrated the significant role of conflict difficulty in target selection for eliciting NP effects (e.g., Frings & Wühr, 2007; Gamboz, Russo & Fox, 2000; Pritchard & Neumann, 2009). Such conjectures are usually expressed as reflecting inhibitory based assumptions. However, May, Kane, and Hasher (1995) have claimed that, although a single mechanism of NP is parsimonious, NP is not always a manifestation of inhibition. They argue that NP involves a dual process just as positive priming and support the view that episodic retrieval is also involved.

2.5.1. Implications for Episodic retrieval and Inhibition based theories of negative and positive priming

One enduring debate in cognitive psychology is whether NP effects are driven by episodic (memory) retrieval mechanisms or distractor inhibition processes. However, information derived from the present experiments are insufficient to dissociate these two opposing views. In a repetition priming experiment, such as those employed here, both theories predict positive priming when a prime target concept is identical to the subsequent probe target, and NP effects when a prime distractor concept is identical with the subsequent probe target because the probe elicits the relevant response tags associated with the items in the prime display. However, the theories differ with regards to what is emphasised in the sequence of processes engaged in the entire prime-probe event (Tipper, 2001).

From the distractor inhibition perspective, the fact of attending to a target stimulus activates the mental representation of that stimulus as well as those of its semantic neighbours (e.g., room and building). This accelerates the processing of that stimulus on a subsequent encounter relative to a neutral stimulus that has not been encountered before (e.g., Houghton & Tipper, 1994; Neumann, Cherau, Hood, & Steinnagel, 1993; Neumann & DeSchepper, 1991, 1992; Tipper, 1985). In addition, selecting for target information is associated with the suppression of the nontarget stimuli. When the prime is encountered the mental representations of both the target and nontarget items are concurrently activated, and the nontarget item is then inhibited in order to select the target. The inhibition applied to the nontarget is assumed to persist and impair response latency to that item (as well as those of its semantic relations) when it appears as the probe target requiring a response. To account for positive priming in the present paradigm, the distractor inhibition theory purports that the presentation of the target word on the prime trial (e.g., stick) activated the mental representations of that word, and this activation lingered and facilitated the response to that word when subsequently encountered owing to preactivation. Similarly, the internal representations of the ignored prime distractor word (e.g., GOAT) was inhibited during selection of the target, and this inhibition persisted and delayed the response to the word "goat" when it appeared as the probe target requiring a lexical decision, hence NP.

The episodic retrieval account argues that the presentation of a stimulus automatically induces the retrieval of the most current episode connected with that stimulus (Neill & Valdes, 1992; Neill, Valdes, Terry & Gorfein, 1992). Positive priming is conditional on the matching congruence ("respond" "respond") between the processing information present at the probe display and at the prime display (e.g., Fox & De Fockert, 1998; Neill, 1997). Regarding NP, the previous distractor and its tag ("do not respond") are automatically retrieved once the target probe is encountered which generates conflict because of the incongruous requirement for the target probe (“respond”). The cost of resolving this conflict results in NP. The episodic retrieval account of the positive priming observed in the present paradigm, is that the congruence between the current requirement to attend and respond to the probe target (e.g., shoe) on AR trials, and the retrieved prime response information for that same item (shoe) which facilitated response to the probe target. However, the mismatch between the current requirement to attend and respond to the probe target (e.g., shoe) on IR trials, and the retrieved response information for that same item (“ignore” SHOE) inflicts conflict due to the competing, incompatible response tags to the same item, hence NP.

A clear difference between these two theories relates to the direction in which they each operate. The distractor inhibition theory works in a “forward” direction, beginning at the prime display and continuing to the subsequent probe trial (Tipper, 2001). The activation of the internal representation of the prime target item ‘carries forward’ and facilitates response when the same item or its semantic relation appears as the next probe target. Similarly, inhibition applied to the ignored prime ‘persists’ and impairs response when the same item or its semantic relation appears as a probe target. Although the distractor inhibition account contends that spreading activation and inhibition occurs with both identical and semantically related stimuli, there is evidence that semantic NP effects are usually smaller than identity NP effects (Fox, 1995). Further, some authors have reported no evidence of NP for semantically related *words*, which has triggered arguments on whether semantic NP really exists (Chiappe & MacLeod, 1995; MacLeod, Chiappe & Fox, 2002). Episodic retrieval theory on the other hand works in a “backward” direction with the probe trial target acting as a memory retrieval cue to access the prime ‘response tag’. Despite these differences both theories would make similar predictions for the within-language experiments reported here. Neumann et al. (1999, Experiment 2) have, however, provided differentiating predictions between the episodic retrieval and inhibition-based accounts, using a cross-language version of the present paradigm with bilinguals. Further tests of these predictions are currently being pursued with Twi-English bilinguals (see also Neumann, Rochford, Nkrumah, & Russell, 2016).

2.6. Conclusion

The present experiments reported negative and positive priming effects with large pools of nonrecycled words. These findings suggested that a word encountered only once as a distractor, but never as a target, can nonetheless be significantly impaired if it appears as a subsequent probe target, as evidenced by NP effects. For the first time, this was shown to be the case even when bilinguals perform the task in their non-dominant language. These findings extend the work of Neumann et al. (1999) and provide additional evidence that repeating words multiple times prior to becoming a distractor is not a necessary condition for obtaining NP with words.

Chapter 3

Cross-language negative priming remains intact, while positive priming disappears: Evidence for two sources of selective inhibition

3.1. Abstract

In the current experiments, within- and between-language primed lexical decision tasks with Twi-English bilinguals were used to explore the priming effects produced by attended and ignored words, in an effort to draw theoretical and empirical parallels and differences between the mechanisms of excitation and inhibition and to isolate the different circumstances in which these mechanisms operate in bilingual language processing. In the within-language (Twi) experiment, facilitatory (positive) priming resulted when a prime word and subsequent probe target words were identical, whereas delayed decisions to probe targets (negative priming) ensued when the ignored prime word was conceptually identical to the subsequent probe target word. In contrast, while the between-language (Twi-English) experiments replicated the ignored repetition negative priming effect, no hints of positive priming were observed. These between-language findings undermine episodic retrieval models of selective attention that discount inhibitory processes in negative priming paradigms. Instead, our findings substantiate inhibition-based accounts by showing that there are two sources of inhibition operating at the local word and global language levels of abstraction. The findings also support a single store model of bilingual language representation, in which the words of the two languages are integrated.

3.2. Introduction

Bilingualism is increasingly prevalent in many countries. In spite of this, the vast majority of psychological research on cognitive processing has focused on monolinguals. Recently however, there has been a proliferation of studies in bilingual cognitive processes. These studies examine how two or more language-bounded experiential systems operate in one brain. To appreciate bilingual language processing, it is fundamental to unearth the structure and organisation of these language representations in memory, as well as the processes involved in regulating two or more different languages. In this study, we began with a within-language experiment, where all stimuli for the task were sourced from a single language. The within-language experiment then served as a baseline with which to contrast the two subsequent between-language experiments. The bilingual version of the current selective attention study uses Twi (a native language of Ghana) – English bilinguals, and has three primary objectives: (1) to explore the nature of bilingual language representation and processing; (2) to investigate whether an inhibitory mechanism is central to the resolution of potential cross-language interference in bilingual lexical selection and processing; and (3) to attempt to elucidate and tease apart the two major rival theories of conceptual negative priming - the selective inhibition-based approach and the episodic retrieval account (for reviews see Frings, Schneider, & Fox, 2015; Mayr & Buchner, 2007; Tipper, 2001; Tipper & Weaver, 2008).

3.3. Overview of major issues

3.2.1. Language Selectivity: Separate or Shared Representations?

A number of researchers have shown that there is parallel activation of lexical items from both languages when a bilingual identifies a word or plans to speak (e.g., Blumenfeld & Marian, 2013; Colomé, 2001). Evidence for language non-selectivity has been shown in studies employing words with similar orthography and/or phonology (e.g., Gullifer, Kroll &

Dussias, 2013), words that overlapped in form across translation equivalents (cognate words) (e.g., Blumenfeld & Marian, 2007) and when words are presented in the context of a sentence (e.g., Rossmark, Hell, Groot, & Starreveld, 2014). Perhaps surprisingly, even distinct language scripts do not provide a satisfactory cue to prevent activation of the irrelevant language during processing of the target language (e.g., Moon & Jiang, 2012). It remains unclear, however, how the different languages of bilinguals are stored and represented in memory and what processes underpin the ultimate choice of the target language while preventing interference from the nontarget language.

These elusive issues are examined in the present study with a Lexical Decision Task (LDT) in which the relevance of each of two languages changes systematically in regularly alternating sequences between primes and probes, thereby inducing attentional selectivity between the two languages. Selective attention is warranted whenever only a subset of the total information presented is required for goal-directed behaviour. At a local exogenous level this may apply to the occurrence of a target stimulus in the presence of a concurrent nontarget, distractor stimulus. At an endogenous global level this may apply to accessing one language as opposed to another in bilinguals (Neumann, McCloskey, & Felio, 1999). Bilinguals provide an intriguing population to study because they must develop a control mechanism that enables them to resolve lexical competition and select the intended language for use (e.g., Abutalebi & Green, 2007; Green & Wei, 2014).

To explore this issue, Tzelgov, Henik, and Leiser (1990) exposed fluent Arabic-Hebrew bilinguals to Stroop stimuli in which the irrelevant color word was in either Arabic or Hebrew script and manipulated subjects' expectations regarding the language of the distractor word. Knowledge that the next distractor word would appear in Arabic enabled subjects to significantly reduce the amount of interference (when the response language was Hebrew) in comparison with conditions in which subjects could not predict the language of the distractor (or when the response language was in Arabic). To account for this decreased interference, the authors conjectured that subjects can control or modulate a whole language system by inhibiting or attenuating its global activation.

Most models of word production (e.g., Cutting & Ferreira, 1999; Levelt, Roelofs, & Meyer, 1999) suggest that word production begins with a concept, from which activation spreads to a range of lexical items, that convey semantic and syntactic information. As activation ‘spreads’ to the intended lemma, semantically related nodes are co-activated, and lexical selection has to overcome the influence of competing lemmas. Selection is thus, a competitive process (e.g., Ferreira, 2010). As such, bilingual lexical selection would seem to require avoiding lexical competition from semantically similar and identical items in another language. Nevertheless, a number of studies demonstrate that bilinguals initially activate both of their languages when they perform a linguistic task (e.g., Colomé, 2001; Costa, 2005; Kroll, Bobb, & Wodniecka, 2006). To deal with simultaneous activation, a cognitive mechanism underlying selection between competing languages in a single mind has been proposed in the Inhibitory Control Model (e.g., Green, 1998). This model suggests that the initial conflict between two languages is resolved by a mechanism of active inhibition. For example, when a Twi-English bilingual is required to name a picture of a spoon in English, the competing translation equivalent word ‘*atere’* in the nontarget Twi language would have to be inhibited to facilitate selection and articulation of the English target ‘*spoon’.* Selecting one language over another requires selective modulation. In addition to investigating such language modulation in cross-language experiments (Experiments 2 and 3), the present study also investigates exogenous selection of a target word in the presence of a conflicting nontarget word in a similar, but within-language priming task (Experiment 1).

3.3.2. Positive Priming and Lexical Decisions Within and Across Languages

The most commonly used laboratory technique for studying bilingual memory is an examination of cross-language priming using lexical decision and naming tasks (e.g., Altarriba & Basnight-Brown, 2007). In a lexical decision task (LDT) subjects make a speeded manual decision to a letter string on the computer screen as to whether it is a word (e.g., book) or a nonword (e.g., okbo). Subjects are typically faster and more accurate to process a word when it is preceded by the same word (e.g., chief preceded by chief) or a related word (e.g., queen preceded by chief) than an unrelated word (e.g., pen preceded by chief). Such findings of identity and semantic priming effects are interpreted by many theorists as a reflection of fundamental characteristics of the organisation of memory in the human cognitive system. Spreading activation theorists (e.g., Anderson, 1983; McNamara, 1992a, 1992b, 1994) posit that semantic memory is made up of a network of interconnected nodes, each representing a specific concept. Processing a word involves activating the concept node in semantic memory that matches its meaning, and this activation is assumed to "spread" to related concepts thereby facilitating the subsequent processing of those concepts.

In a within language LDT, subjects typically perform a task in one language, such as naming a prime target word in English (e.g., *heart*) and then deciding whether a letter string that follows is a correct word in English or not (e.g., *jeose*). In a cross-language LDT, on the other hand, bilingual subjects perform a task in their two different languages, such as naming a prime target word in Twi (e.g., *akoma*) and then deciding whether the letter string that follows is a correct word in English or not (e.g., *heart*). Researchers have generally shown that within-language priming yields more of the facilitation effect than cross-language priming. For instance, Travis, Cacoullos, and Kidd (2016) found both within-and-cross language priming effects using Spanish-English bilinguals, however, cross language priming from English-to-Spanish was weaker and more short-lived than within language Spanish-to-Spanish priming.

Cross-language positive priming is the product of the activation of a word in one language “spreading” to semantically related nodes in the other language (Fox, 1996). According to Kroll (1993), under conditions that require rapid access to meaning to obtain priming, cross-language priming should occur only if both languages access a common conceptual memory store. Put another way, if the positive priming occurs between languages (where the target probe item is the translation equivalent of the target prime word), then the two languages are shared and stored together in memory. On the other hand, the absence of positive priming between languages in such situations may be indicative of independent and separate memory systems for the two languages (DeGroot & Nas, 1991; Keatley & De Gelder, 1992; Keatley, Spinks & Gelder, 1994). Neumann et al. (1999), however, using cross-language prime target naming followed by a probe target lexical decision task, questions the assumption that the absence of cross-language positive priming discredits the single store model.

3.3.3. Negative Priming across Languages

Fox (1996) required English-Spanish bilinguals to categorise as odd or even a focally attended number, while ignoring flanking words in the prime display and further making lexical decisions about a letter string in the probe display. Fox reported that there was a response time delay when probe words were translation equivalents or translations of semantic associates of the previously ignored flanker words, indicating a negative priming effect. Of particular relevance to our study is Fox’s conclusion that it was indeterminate whether the negative priming observed was triggered by ‘spreading inhibition’ between languages (e.g., Neumann & DeSchepper, 1992) or episodic retrieval elicited by the probe stimulus (e.g., Neill & Valdes, 1992). Since one of our fundamental objectives is to tease apart the predictions emanating from these two competing theories of negative priming, we will initially provide brief appraisals of each of them and illuminate their predictions in the context of the current experiments.

3.3.4. Sources of Negative Priming: A Comparison of Inhibition and Episodic Retrieval Accounts

Negative priming is the impairment (slowing) of the response to a nontarget stimulus that has been previously ignored. Traditionally, the negative priming effect has been viewed as a consequence of the competing irrelevant, distracting information being *inhibited* as a function of target selection (e.g., Mayr & Buchner, 2007; Neumann & DeSchepper, 1991; Tipper, 1985). However, a non-inhibitory account, called episodic retrieval, has been posited by Neill and his colleagues (e.g., Neill & Valdes, 1992; Neill, Valdes, Terry & Gorfein, 1992), which rejects the notion that inhibitory selection mechanisms produce negative priming. From the episodic retrieval perspective, negative priming is a consequence of the incompatible 'response tag' produced when an item that was ignored (a distractor) in a prior episode becomes relevant (a target) in a subsequent encounter. In this account, it is the extra time required to resolve the conflict between the "do not respond" tag and subsequent "respond" tag that causes the response time impairment. The rationale underlying both theories requires that the probe accesses or retrieves the internal representations of the prime, or the processes engaged in the representation of the prime. Against this background, Tipper (2001) proposed that both theories are similar in that prior events are accessed (see also Neill, 2007, for a similar conclusion). Here we suggest that examining negative priming within and across languages provides a unique avenue for dissociating these two theories, because the bilingual version of the LDT elicits different predictions, than the within-language version (see Neumann et al., 1999).

3.3.5. Inhibition-Based Account of Positive and Negative Priming

In distractor inhibition accounts, selection is simultaneous and twofold: (1) excitatory processing of the target information, and (2) inhibitory processing of distractor information. In tasks involving attentional selectivity, inhibitory control can act on previously attended information that is no longer required but has the potential of being disruptive. In one demonstration of this, Macizo, Bajo, and Martin (2010) investigated how English-Spanish bilinguals select meanings of words that share the same orthography across languages but have different meanings (interlexical homographs such as *pie*, meaning *foot* in Spanish). Subjects were required to decide whether pairs of English words were related. The authors observed that subjects were slower to respond to homographs presented along with words related to the Spanish meaning of the homographs as compared to control words. More importantly, subjects were slower to respond when the English translation of the Spanish homograph meaning was presented in the subsequent pair of English words. The authors concluded that bilinguals inhibited the irrelevant homograph meaning to enable them to respond to the target task, hence bilingual language selection in comprehension tasks implies inhibitory control processes.

To further unravel the nature of dual-processing in inhibitory models, Neumann and DeSchepper (1992) surmised that, in situations that provoke attentional selectivity, an inhibitory mechanism operates on previously attended relevant information that is no longer needed and has the potential to become disruptive. They contended that such inhibitory mechanisms were similar to the distractor inhibition ostensibly producing negative priming effects, except that it was an endogenous form of such inhibition. Endogenous inhibition acts on internally represented information that is apt to interfere with responses to targeted information, whereas exogenous inhibition reflects suppression of distractors that are visible in the environment. Experimental indices of endogenous and exogenous inhibition are manifested by evidence of suppression of distracting nontarget information and should thereby have consequences for the subsequent accessibility of related information (Neumann, Cherau, Hood & Steinnagel, 1993; Neumann & DeSchepper, 1992). In the present bilingual experiments, it is conjectured that endogenous inhibition is applied to the *language* of the prime stimuli so that it does not interfere with the language required for processing the probe target. This should result in the reduction or elimination of cross-language positive priming effects. However, the suppression of the nontarget prime *word* should nonetheless produce negative priming if its translation equivalent becomes the next probe target, compared to an unrelated word. Because the prime language is inhibited at a global level and the prime distractor word is inhibited, but at the local word level, negative priming should remain intact, as opposed to positive priming, which should not remain intact (see Neumann et al., 1999).

3.3.6. The Episodic Retrieval Approach to Positive and Negative Priming

The episodic retrieval model explains positive priming effects between related prime and probe targets on the basis of spreading activation and compatible response tags ("*respond*" "*respond*"). As such, there are always two potential sources underpinning positive priming effects in selective attention tasks. On the other hand, the episodic retrieval account explains negative priming effects on the basis of the retrieval of incompatible tags automatically elicited by the target probe item ("*do not respond*" "*respond*"), rather than as a repercussion of inhibitory processes affecting the initial encoding of the nontarget prime distractor (Neill, 1997; Neill & Valdes, 1992). This account of negative priming stems from Logan's (1988, 1992) theory of automaticity which acknowledges the role of probe target stimuli as memory-retrieval cues. In Logan's view, as a rule of attention every encounter with a stimulus (typically called an episode) is encoded and separately stored in memory and each episode contains information about the stimulus and the given response. Successful performance upon encountering a subsequent task is achieved by either analytically computing a response or by retrieving the response from a previous encounter with the same stimulus from memory.

Expanding on Logan's work, Neill and his colleagues (Neill, 1997; Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992;) argued that negative priming is the result of retrieving the prime episode when exposed to the probe stimulus, and that a probe target that is similar or identical to the prime distractor serves as a retrieval cue for the prime episode. Part of the retrieved episode is the '*do not respond'* information tied to the prime distractor. This response information conflicts with the requirement to '*respond'* to the stimulus in the probe episode. Resolving this conflict is time consuming, resulting in a negative priming effect. As already mentioned, episodic retrieval and inhibition theories can both account for negative priming, which involves a response time delay that occurs when responding to a previously ignored stimulus. This phenomenon will first be examined in the *within-language* experiment of the present study (Experiment 1), in order to provide a base-line measure for the two subsequent *between-language* experiments (Experiment 2 and 3). While the two theories make the same predictions regarding the projected outcome of Experiment 1, they make distinctively different predictions regarding the outcomes of Experiments 2 and 3. The specific predictions hypothesised by each of these theories will follow after an overview of some important distinctions between the Twi and English languages used here in the cross-language experiments.

3.3.7. The Twi Language: Overview of Major differences with the English Language

Although the negative priming phenomenon is well known, there is a general paucity of priming research, including simple positive priming, conducted in an African context. In fact, as far as we are aware, the present series of experiments are the first studies involving priming that have been conducted in Africa. Studies involving priming have been conducted mostly in the Western world, Asia, or Oceania. The present study introduces a new group of bilinguals into the priming literature, Twi-English bilinguals from Ghana, Africa. Twi and English are the two prominent languages spoken in Ghana. The latter, besides being a major world language is the only official language, while Twi is the most prominent indigenous language with almost half of the Ghanaian population using it as their first language and many more using it as a lingua franca in various social, cultural, religious and economic contexts (Anyidoho & Kropp-Dakubu, 2008). Like many languages, Twi was spoken long before it was written. It started to be written in religious books, by Danish, German, and British missionaries during the 17th and 18th centuries. Twi has twenty-two letters, twenty of which are shared with the English alphabet. It has two distinct letters (ɔ, ɛ) and excludes the letters (c, q, j, v, x, z) of the English alphabet. Other significant areas of similarity and difference between Twi and the English language are:

i. Twi concepts that are borrowed from English only entail words established since colonial times, and mainly consist of objects and technology of foreign origin. Such words are indirectly derived from the original English concept, but expressed entirely differently. More specifically, the word in English is expressed as a phrase in Twi (but written and pronounced as a word). For example:

   aeroplane - [wie/mu/hyen] - (a van in the air),

   telephone -[nkra/toɔ/ahoma] - (message sending thread).

   Thus, whereas English has single words for these concepts, Twi uses phrases to describe them making the Twi translations longer to say. More importantly, Twi is agglutinative, so most Twi words convey different morphemes to determine their meaning. For example [hospital- (ayaresabea) has three morphemes; ayare/sa/bea-thus *ayare*-sickness/*sa*-treatment/*bea*-place] and each morpheme is a meaningful word; also bank, (meaning sikakorabea in Twi has three meaningful morphemes, *sika*-money/*kora*-keeping/*bea*-place).

ii. Twi is a tonal language; words are dependent on tone pitch. It has two level tones (low and high) which are part of the lexical entry of some morphemes (Hyman, 2001, inspired by Welmers, 1973). Tones, including tonal combinations play an important role in distinguishing words. For example the lexical meaning of the disyllabic word papa changes according to its tonal specification.

Pápá (high-high) means good.

Pàpá (low-high) means father

Pàpà (low-low) means fan.

English, on the other hand, is considered a stressed language because important words are stressed, relative to other words in a sentence.

iii. While English allows both open and closed syllables, Twi has only open syllables and hence Twi is more syllabic than English. For example, in English, two or three sequential vowels appearing in a word can be pronounced as one (e.g., air, bureau), but in Twi each vowel in a word constitutes a syllable. For this reason, Twi has more syllables in words, making pronunciation longer, than in English (e.g., *daabi*, meaning *no* in English) is pronounced as da/a/bi and constitutes three syllables.

iv. In English, vowels preceding nasal consonants are nasalized, but there is no phonemic distinction between nasal and oral vowels (and all vowels are considered phonemically oral). In Twi, however, all vowels are nasalized. They are not nasalized because they follow nasal letters (m, n), rather, speakers of the language spontaneously nasalize all vowels. It takes a longer time to pronounce words with nasals, adding to the several reasons why Twi words generally take longer to pronounce (Manyah, 2011).

3.4. Experiment 1

Experiment 1 investigated whether attended repetition (AR) positive priming and ignored repetition (IR) negative priming would be observed, in contrast to a neutral Control condition. Target and nontarget items were presented simultaneously in each prime display and each probe display. Selection was cued by letter case. Items in lowercase were the designated target stimuli and uppercase words were nontarget distractors. This was a within-language experiment, because all stimuli were presented in the Twi language. Subjects first named the prime target word and then made word/nonword decisions to the probe target item. The selective inhibition and episodic retrieval theories both make the same predictions regarding the outcome.

The episodic retrieval theory asserts that a target stimulus cues the retrieval of past processing episodes involving similar stimuli (e.g., Neill, 1997; Neill & Valdes, 1992). The AR manipulation should therefore produce positive priming because the response tag elicited by the attended probe target word is compatible with that associated with the attended prime target word ("*respond*" "*respond*"). In contrast, the IR manipulation should produce negative priming, because the response tag elicited by the probe target word ("*respond*") is incompatible with the nontarget prime distractor word that it elicits ("*do not respond*"). The impaired response to the probe is due to the extra time it takes to resolve this conflict between incompatible response tags. Hence, the episodic retrieval theory predicts AR condition positive priming, compared to the neutral control condition, whereas the IR condition should result in negative priming, compared to the control condition. The rival inhibition-based theory (e.g., Neumann & DeSchepper, 1992; Tipper, 1985) makes the same predictions, but on the basis of different mechanisms. In their view AR positive priming is provoked by excitatory influences on the prime target word, and IR negative priming is the outcome of inhibition of the prime distractor word. Experiment 1 provides a conceptual replication of earlier studies involving both positive and negative priming manipulations (e.g., Neumann et al., 1999, Experiment 1; Schooler, Neumann, Caplan, & Roberts, 1997; Tipper, 1985), but uses an unstudied language group, Twi-English bilinguals. Experiment 1 also provides a baseline comparison for the outcome of Experiments 2 and 3, which involve cross-language priming manipulations and different predictions based on the two theories.

3.4.1. Method

3.4.1.1. Subjects

Twenty male and eighteen female students from the University of Cape Coast voluntarily participated. They ranged in age from 19 to 28, with a mean age of 22.4 years. Self-reports showed that all subjects had normal or corrected to normal vision and were all native speakers of the Twi language. The present experiment met the approval and requirements of the Ethics Committee of the University of Cape Coast, Ghana, concerning experimental studies with human subjects.

3.4.1.2. Stimuli and Apparatus

Six hundred and twenty words were chosen from the word norms of Francis and Kucera (1982) for stimuli construction. Word frequencies ranged between 32 and 50 uses per million. Their equivalent Twi words were sought from the Twi-English, English-Twi *Hippocrene Concise Dictionary* (Kotey, 2007). The Twi and English word lists were subjected to reliability testing at the University of Education, Winneba, Ghana. No student from the University of Winneba participated in any of the experiments because of the possibility of carry-over effects for having been exposed to the wordlists. Thirty-two items were removed from the word lists after pilot testing for not being commonly used words in Twi (e.g., *abakanye, meaning heron in English*), having spelling inconsistencies in the Twi language (e.g., *ɛnne/ nne meaning voice in English*), or having no noncognate translation equivalent in the Twi language (e.g., computer). The reliability co-efficients of the word lists from a two week test-retest interval were α = .89 and α = .86 for the Twi and English sets respectively (see Appendix B for the stimuli). Another set of 192 pronounceable nonwords were created for use in the nonword conditions, 96 were Twi nonwords [e.g., *ɛbɔfuɔ* - instead of *ɔbɔfoɔ* -(hunter)] for Experiment 1, and the other 96 were English nonwords (e.g., *agple* - instead of *apple*) for the cross-language experiments (Experiment 2 and 3). All nonwords were double-checked to ensure that they did not form legal words in the other language. The number of letters in letter strings was similar for words and nonwords, so there was no predictive relationship between string length and the word versus nonword category. The Twi nonwords were then given to seven high school language teachers in the Central Region of Ghana for content validation.

We developed a Twi version of a task that was modelled after Neumann et al. (1999, Experiment 1). The three conditions of interest were: attended repetition (AR) – wherein the target prime was the same as the target probe (e.g., *adowa-adowa*), control (CO) – wherein the prime and probe stimuli had no relationships (e.g., *sika-mpaboa*), and ignored repetition (IR) – wherein the nontarget prime word became the target probe (e.g., *KASAKOA-kasakoa*). Seventy-two nonword trials were also included, as is typical in lexical decision tasks. This ensured that half of the trials in the experiment required a “nonword” response and the remaining half required a “word” response in an unpredictable random fashion. One hundred and sixty-eight words were randomly selected to act as targets and the remaining 452 served as filler words. Seventy-two words from the stimulus pool were chosen randomly to act as prime distractors, 72 as probe distractors, and 72 words as probe targets. The 72 probe target words were randomly assigned into sets A, B and C, with 24 words in each of the three conditions of interest in each of these sets. Subjects were assigned at random to one of three groups for the purpose of counterbalancing. Subjects in Group 1 had Set A as AR trials, Set B as IR trials and Set C as CO trials; for Group 2 it was Set A as CO trials, Set B as AR Trials and Set C as IR trials; and for Group 3 it was Set A as IR trials, Set B as CO trials and Set C as AR trials. The entire trial sets of 72 word and 72 nonword trials (nonword trials were the same for all groups) were arranged in random order and the same order was employed for all subjects irrespective of the group. This helped to ensure that each probe target was paired with the same distractor word and in the same position in the trial sequence for all subjects regardless of counterbalancing group and condition. For instance, if the probe target word "*kuruwa*" was presented on the 20th trial for Group 1 in the AR condition, it was also presented on the 20th trial for Groups 2 and 3 in the IR and CO conditions.

Each individual target or distractor word appeared only once in a prime-probe display except to fulfil AR or IR conditions. This was done to eliminate any potential carry-over effects from the repetition of words and thus capture pure priming effects. The task was designed with a low proportion of AR trials (1/6th of the total trial couplets) in order to obtain an accurate estimate of priming effects. It has been shown that as relatedness proportion increases, participants are inclined to devise expectancies and benefit by improved performance when repetition is anticipated (e.g., Neely, 1991). Similarly, there were an equal number of nonword trials (72 couplets) to match the number of word trials in order to minimize any bias to respond word or nonword, because evidence has shown that when the nonword ratio is below 0.5 subjects may be biased to give a word response when a nonword is presented (Altarriba & Basnight-Brown, 2007). Preceding the experiment proper were 24 practice trials comprising twelve nonword trials and twelve word trials. Practice words were selected randomly from the pool of 620 words for the experiment, and no practice word was repeated in the actual experiment.

Stimuli were presented on a 15.6 inch Hewlett-Packard (HP) laptop computer. Prime displays were presented either centred, or slightly to the left or right of centre, in equal proportions, on the computer screen, since research shows that varying stimulus position helps to increase the magnitude of negative priming by taxing attentional selectivity more than when static stimulus positions are held (Langley, Overmier, Knopman, & Prod'Homme, 1998). Probe stimuli were displayed centred on the screen at all times. Word length for the Twi stimuli ranged from three to thirteen letters. The shortest words were 1.4cm wide, whereas the longest words were 5cm wide. On average, the distance between the closest edges of items appearing in the centre and those appearing to the right was about 1.5cm. Similarly, the distance between the closest edges of items appearing in the centre and to the left was also about 1.5cm. Black letters in Calibri font size 11 were used and were presented on a white background. Target items were presented in lowercase letters and distractor words in uppercase letters, displayed one above the other pseudorandomly such that they each appeared on top 50% of the time and at the bottom 50% of the time across all conditions. The distance between the closest edges between the top and bottom letter strings was 1 pixel width. Experiment generation was controlled using the E-Prime 2.0 software programme (Psychology Software Tool, Inc.). A 5-button PST Chronos response box was used for recording lexical decision reaction times. The PST Chronos features milliseconds accuracy across machines (Psychology Software Tools, Inc., 2012). The two leftmost buttons were activated and designated "word" and "nonword". A response sheet was also created with prime target words to enable the experimenter to monitor the naming of primes.

3.4.1.3. Design

A within-subject design was adopted. Priming condition (Attended Repetition vs. Control vs. Ignored Repetition) was manipulated in order to track participants' reaction time and accuracy rates on responding to the probe target stimulus. From here on these conditions are referred to as AR, CO, and IR, respectively. The nonword lexical condition trials were not included in the analyses.

3.4.1.4. Procedure

Each subject participated in an approximately 55-minute session consisting of 24 practice trials and 144 experiment-proper trials. Subjects were run individually in a special room optimized for low noise and dimly-lit conditions, at a viewing distance of about 50cm from the computer screen. Printed instructions were provided on the computer screen and were supported with verbal instructions. Before the main task commenced, a subject underwent the practice trials repeatedly, if necessary, to familiarise themselves with the task. The lag between prime-probe presentations in the practice session varied such that the mean lag interval decreased as the number of presentations progressed. Subjects were required to correctly perform all practice trials before they could start the main trials. Once the main experiment began, the experimenter stayed behind the subject to avoid distractions. The main experiment contained 144 prime-probe trial couplets, divided into 72 word trials and 72 nonword trials. The word trials comprised 24 each of AR, CO, and IR conditions, respectively.

Each trial began with a fixation cross exposed in the centre of the screen for 500ms. The fixation cross was followed immediately by the prime display which was presented for 250ms. After the prime display was extinguished, a blank screen appeared for 1000ms while the subject named the prime target aloud. The probe display then appeared and remained on the screen until the subject made a lexical decision. Subjects were initially informed that both speed and accuracy were important and they were encouraged to respond to trials as fast as they could, while being careful not to commit errors. They were also made aware of the uppercase distractor words and were urged to ignore them, because that would make processing the targets faster and more accurate. Lexical decisions to probe target items were made by pressing the “word” button with the index finger of the right hand, and the “nonword” button with the middle finger of the right hand. Once a response was registered, the next trial sequence began. This sequence recurred throughout the experiment. A sample of a trial couplet sequence is presented in Figure 3.1.

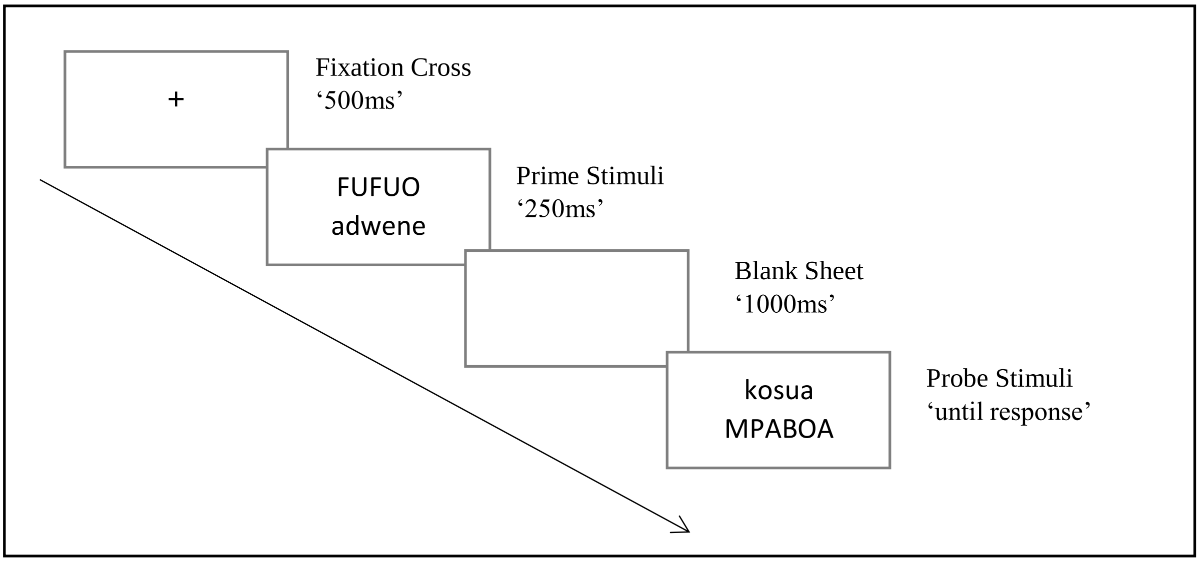

Figure 3.1. Sequence of stimuli presentation. Note that in the Experiments the distance between the closest edges of the top and bottom item in each display was 1 pixel width.

3.4.2. Results and Discussion

We established cut-off scores of 30% and above for naming and response errors, respectively. Based on these cut-offs, one subject was removed and excluded from further analysis. In comparison with the CO condition, the AR condition produced faster response times, while the IR condition produced slower response times. The results are displayed in Figure 3.2. An analysis of variance revealed a significant main effect F (2, 72) = 24.34, MSE = 149478, $p < .001$, $\eta_p^2 = .40$. Due to the specificity of the hypotheses being tested, paired samples t-tests were further conducted to determine whether, compared to the CO condition, AR produced a significant facilitation effect, and IR produced a significant delay. Reinforcing the pattern of RTs depicted in Figure 3.2, the AR condition (M = 2490, SD = 980.91) produced significantly faster RTs than the CO condition (M = 2823, SD = 1070.53), t (36) =

5.12, $p < .001$, $d = .84$, whereas the IR condition ($M = 3116$, $SD = 1238.30$) produced significantly slower RTs, $t\ (36) = 3.24$, $p = .003$, $d = .53$, than the CO condition.

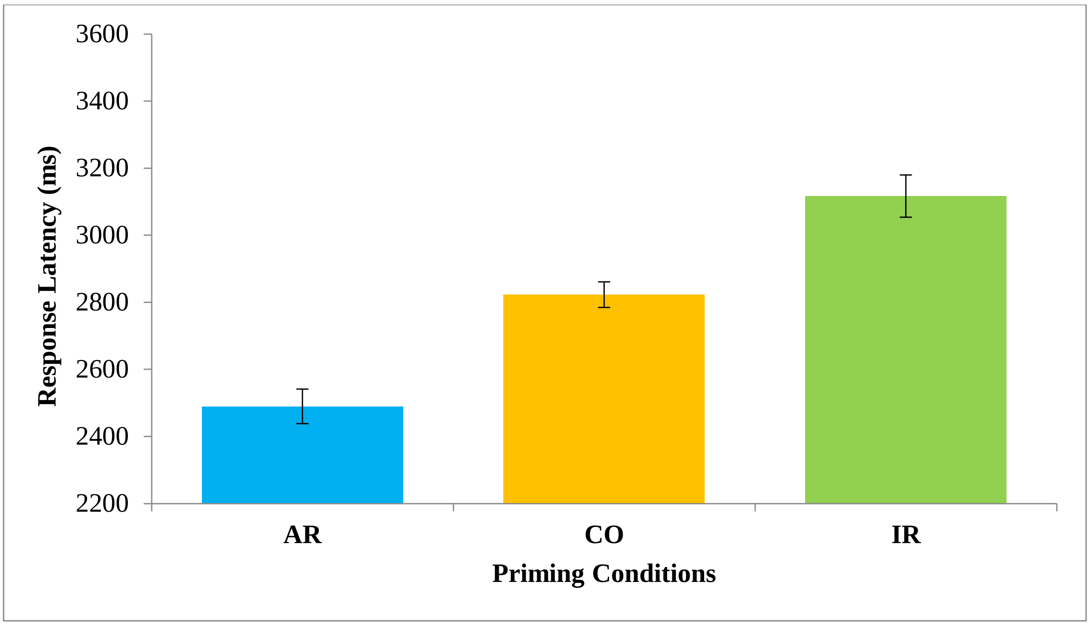

Figure 3.2. Mean response latency (in milliseconds) as a function of attended repetition (AR), control (CO) and ignored repetition (IR) conditions. Error bars indicate standard errors.

Consistent with our predictions, the AR condition produced a speed-up compared to the CO condition, whereas the IR condition produced a delay in comparison with the CO condition, indicative of positive and negative priming effects, respectively. These results show that ignored nontarget prime stimuli that are presented only once prior to becoming a probe target produce significant negative priming. In addition, the present results provide a baseline for comparing both positive and negative priming in Experiments 2 and 3, which involve between language priming effects with different predictions regarding their outcomes, particularly with regard to AR positive priming.

Error rates were analyzed in a similar manner, $F\ (2, 72) = 4.24$, $MSE = 2.884$, $p = .018$, $\eta_p^2 = .11$. The main effect of priming was significant, however, only the contrast between AR (*M* = .37, *SD* = 1.27) and *CO* (*M* = 1.49, *SD* = 2.42) was significant, *t* (36) = 3.07, *p* = .004, *d* = .50, indicating fewer errors in the AR condition. The contrast between IR (*M* = .71, *SD* = 1.93) and CO (*M* = 1.49, *SD* = 2.42), was nonsignificant, *t* (36) = 1.74, *p* = .09, *d* = .29. Together these error rate results indicate that the RT analyses are not compromised by a speed/accuracy trade-off.

The positive and negative priming results obtained for attended repetition and ignored repetition conditions are consistent with other priming studies that included AR, CO, and IR conditions (e.g., Neumann et. al., 1999; Schooler et al., 1997; Tipper, 1985). Uniquely, however, the present results are inconsistent with the findings of Strayer and his colleagues (Grison & Strayer, 2002; Kramer & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999) who have reported results from a number of experiments in which negative priming was contingent upon stimulus repetition, using a small pool of words. In these studies negative priming was only obtained after words were encountered previously as target stimuli prior to becoming a nontarget distractor in an ignored repetition couplet. What might be the source of the discrepancy between their results and ours? The variations between the present findings and those of Strayer and colleagues are likely due to the different selection cues employed. In particular, the use of black uppercase distractors and black lowercase target items in close proximity to one another in the present study increases selection difficulty and is likely to be more demanding than the color selection cue used in their studies. When visual search for target stimuli are distinguished from distractors by a unique feature, such as color, it becomes fast, efficient, and subjectively effortless owing to pop-out effects (Treisman & Gormican, 1988). Numerous studies have shown that NP effects increase when subjects are induced to anticipate selection difficulty between target and distractor stimuli (Fox, 1994; Gamboz, Russo & Fox, 2000; Houghton, Tipper, Weaver, & Shore, 1996; Pritchard & Neumann, 2009, 2011; Richards, 1999). In the studies by Strayer and colleagues, negative priming was only observed when they incorporated frequent duplication of words from a small pool, which likely created heightened baseline activation of the nontarget prime words or lowered the threshold for perceiving the distractor words, consequently augmenting processing difficulties between target and nontarget items enough to elicit inhibitory processing and thus produce NP. One other objective for Experiment 2 is to further test the idea that negative priming effects can emerge even when a large pool of words is used, and only one encounter with a given prime distractor word is necessary to produce a significant negative priming effect.

3.5. Experiment 2

Experiment 2 involved a cross-language modification of Experiment 1 designed to tap into how the modulation of words and languages in the present selective attention task can reveal the characteristics of the mechanisms involved in these processes. Another aim was to provide a potential framework for dissociating the episodic retrieval and inhibition based accounts of negative and positive priming.

The attended prime target and ignored probe distractor words were both presented in Twi (L1 of the bilinguals), whereas the probe target words were in English (L2 of the bilinguals). Single store models of bilingual language representation contend that the effect of a prime target on a probe target occurs in a shared propositional semantic network that should produce AR facilitation priming (e.g., *cup-kuruwa*) across languages. In contrast, separate store models suggest that the associations between separate language-specific memory systems (or modules) are weaker than those within systems. By inference, they assume no or greatly reduced AR facilitation between languages, in comparison with within language positive priming.

To assess the possible contribution of inhibition in resolving competition from irrelevant words, as well as irrelevant languages when they switch from being relevant to irrelevant, Neumann et al. (1999) designed a cross-language task using a positive and negative priming paradigm. They asked English-Spanish bilinguals to name a lowercase prime target word aloud, which was simultaneously presented with an uppercase distractor word. Then in the subsequent probe display, subjects decided whether the lowercase target letter string was a real word in Spanish, while ignoring an uppercase nontarget English distractor word. Their experiment consisted of 144 such prime-probe couplets using 72 target words with which 24 were used to construct each of the three main conditions: AR, CO, & IR. There were also 72 nonword probe targets in order to preserve a 50:50 ratio between “word” and “nonword” responses, which is typical for lexical decision tasks. The authors reported that participants were slower in the IR condition in contrast with the CO condition, thus observing a significant cross-language negative priming effect. However, participants were not faster in the AR condition compared with the CO condition. Their cross-language study thus produced significant negative priming, but no positive priming. These findings were interpreted in terms of two sources of inhibitory control; one directed at the global language of the prime stimuli, and the other directed locally at the prime distractor word. Neumann et al., however, argued that their finding of negative priming in the absence of positive priming provided evidence of a single store model of bilingual language organisation, because separate store models of bilingual language representation would predict that there should be little or no priming effect of *any kind* from one language to another, if languages are encapsulated in different modules.

Neumann et al. (1999) also pointed out that their findings were inconsistent with the episodic retrieval alternative to the inhibition-based account. More specifically, the episodic retrieval model posits that for any prime trial, target and distractor stimuli are stored as an episode that comprises *respond'* and *'do not respond'* tags associated with the target and distractor stimuli, respectively (e.g., Neill, 1997). In this account, AR positive priming is caused by the response compatibility between prime target and probe target ("*respond" "respond"*), whereas IR negative priming results from incompatible response tags elicited by the target probe ("*do not respond" "respond"*). In effect, episodic retrieval theory would predict both positive and negative priming outcomes in cross language-tasks, although the magnitudes may be reduced, compared with those observed in within language conditions, because noncognate translation equivalents, unlike matching words in the same language, would presumably provide less effective retrieval cues.

Extrapolations from the episodic retrieval model in this context are based on Logan's theory of automaticity which rests on the assumptions of obligatory encoding, obligatory retrieval, and instance representation (Logan, 1988, 1990). In Logan's view, performance is automatic when it is based on retrieval of past instances - memories of past solutions to task relevant problems rather than algorithmic computation (i.e., producing a solution by thinking or reasoning) and that automatic performance is more likely the greater the number of task-relevant instances in memory. Logan argues that the benefit in repetition priming is often specific to the physical and conceptual format of the first presentation. Hence there is little transfer from pictures to words and vice versa in Logan's theory of automaticity. In any case, contrary to the local word and global language inhibition-based hypothesis, episodic retrieval would predict both AR facilitatory and IR negative priming effects across languages; and in particular, if one of these effects emerges, the other should as well. Episodic retrieval thus provides no means of dissociating the observance of AR positive priming from IR negative priming across languages in the present task, whereas the inhibition-based hypothesis posits the ability to globally inhibit a language if it is deemed irrelevant to the current task, which would thus eliminate or reduce AR positive priming.

Other researchers have similarly concluded that effective inhibitory control enables bilinguals to overcome cross-language activation during word comprehension (e.g., Misra, Guo, Bobb, & Kroll, 2012; Pivneva, Mercier, & Titone, 2014). Our assumption as to how this control is achieved, based on the work of Neumann et al. (1999), is that language selection involves initial excitation followed by inhibition mechanisms capable of acting locally on individual lexical items as well as globally to activate and inhibit whole languages. Under these parameters we would predict IR negative priming in the current task, but little or no AR positive priming. A further contention is that the finding of excitation and inhibition across languages indicates an integrated single store language system or set of memory representations (see also De Groot & Christoffels, 2006).

3.5.1. Method

3.5.1.1. Subjects

Forty-three students (24 males and 19 females) were recruited from the Colleges of Education in the Central Region of Ghana. Their ages ranged from 19 to 28 years with a mean age of 23.5years, and they all declared having normal color vision. None of the subjects participated in Experiment 1.

3.5.1.2. Stimuli and Apparatus

The 72 probe target words and 452 filler words were the same as those used in Experiment 1, however the Twi probe targets were replaced by their English (noncognate) translation equivalents. Word length for both the English and Twi stimuli ranged from three to thirteen letters. The prime stimuli were presented in Twi and consisted of lowercase target words and uppercase distractor words, one above the other as in Experiment 1. Probe stimuli consisted of either lowercase target words in English or lowercase pronounceable nonwords in English, together with an uppercase Twi distractor word. The experimenter prepared a response sheet to monitor naming of prime targets. All other materials, stimuli presentations and counterbalancing were the same as in Experiment 1. The same HP laptop and response box were used for stimuli presentation and registering lexical decisions as in Experiment 1.

3.5.1.3. Design and Procedure

There were three conditions of interest: AR, CO, and IR. In the AR condition, the probe target word was the noncognate translation equivalent of the prime target word (e.g., *adaka* - *box*), in the IR condition the target probe was the English translation of the nontarget prime Twi word (e.g., SUKUU - school), while in the CO condition none of the stimuli in the prime or probe were related. Subjects were tested individually, seated at about 50cm viewing distance from the computer's screen. Lexical decisions were reported using designated buttons on the response box ("word", "nonword"). In the initial display of prime words, subjects were required to name the lowercase Twi target word aloud. Then the subsequent probe display required a lexical decision response as to whether the lowercase target item was a correct word in English or not. Speed and accuracy were emphasized and subjects were encouraged to ignore the uppercase distractor words as best as they could, because it would make responding to the target faster and more accurate. As in Experiment 1, each subject underwent a series of 24 practice trials to familiarise themselves with the task. The main task consisted of 144 trial couplets; 72 of these were nonword couplets and 72 were word couplets, consisting of 24 AR, 24 CO and 24 IR conditions randomly dispersed. Presentation parameters, randomization, and stimulus counterbalancing were as in Experiment 1. A sample trial couplet is presented in Figure 3.3.

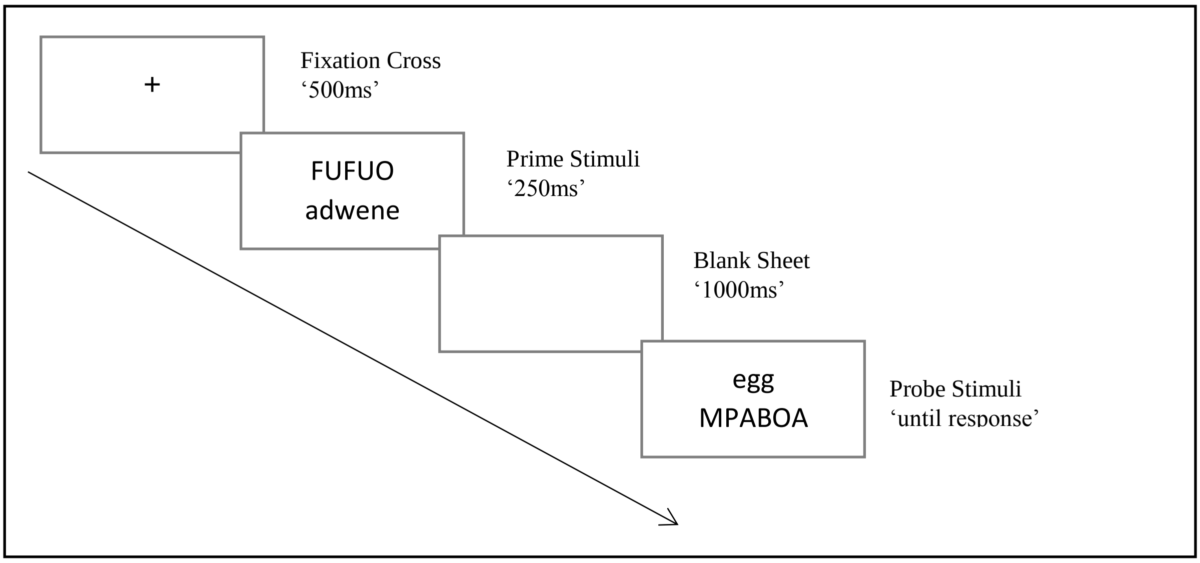

Figure 3.3. Sequence of stimuli presentation. Note that in the Experiments the distance between the closest edges of the top and bottom item in each display was 1 pixel width

3.5.2. Results and Discussion

The cut-off conditions for excluding subjects from further analysis were the same as in Experiment 1. Based on these cut-offs, two subjects were excluded from the analysis. In comparison with the CO condition, the AR condition produced slightly slower response times, whereas the IR condition produced significantly slower response times. The results are displayed in Figure 3.4. An analysis of variance conducted revealed a main effect of *F* (2, 84) = 3.34, *MSE* = 166264, *p* = .040, η_p^2 =.07. Paired sample t-tests were conducted to determine whether compared to the CO condition, AR produced a facilitation effect, and IR produced a significant delay. Reinforcing the pattern of RTs presented in Figure 3.4, the AR (*M* = 3363, *SD* = 1282.72) and CO (*M* = 3350, *SD* = 1230.17) conditions produced a nonsignificant difference, *t* (42) = .15, *p* = .883, *d* = .02, whereas the IR condition (*M* = 3553, *SD* = 1104.65) produced significantly slower RTs than the CO condition (*M* = 3350, *SD* = 1230.17), *t* (42) = 2.21, *p* = .033, *d* =.34. Consistent with our predictions, the AR condition did not produce a faster response time (positive priming), whereas the IR condition produced a significantly slower response times (negative priming).

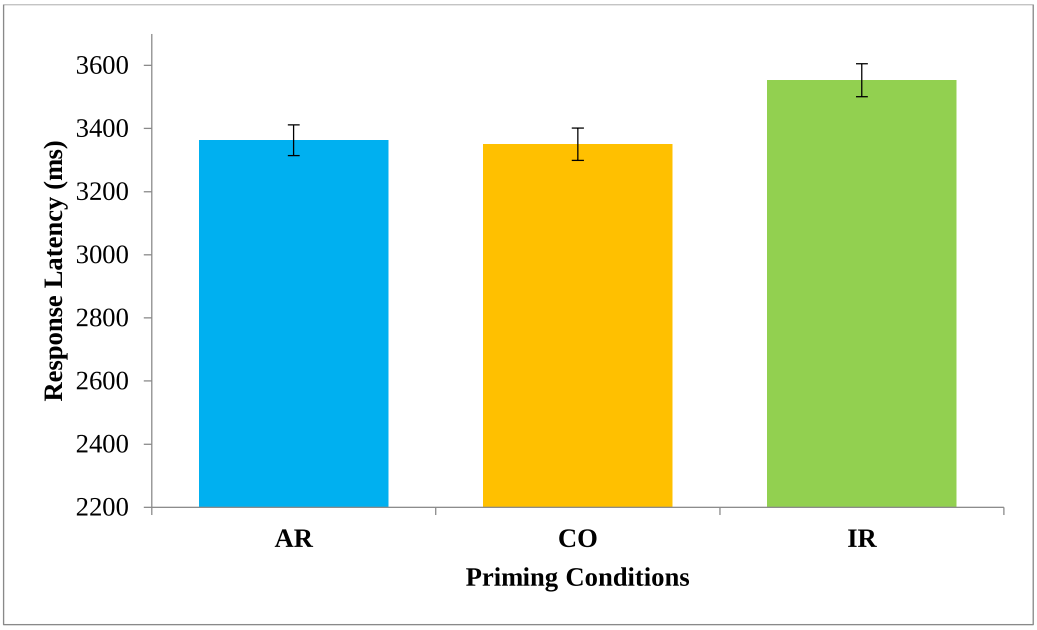

Figure 3.4. Mean response latency (in milliseconds) as a function of attended repetition (AR), control (CO) and ignored repetition (IR) conditions. Error bars indicate standard errors.

The error data were analyzed in a similar manner, F (2, 84) = .972, MSE = 5.248, p = .382, η_p^2 =.023. The main effect of priming was nonsignificant. Specifically, the contrast between AR (M = 1.06, SD =1.96) and CO (M = 1.73, SD = 2.99) conditions was nonsignificant, t (42) = 1.20, p = .237, d = .18. The contrast between IR (M =1.26, SD = 2.65) and CO (M = 1.73, SD = 2.99) conditions, t (42) = .95, p = .347, d =.15 was also nonsignificant. The error data thus do not compromise the interpretation of the RT results, because there was no indication of speed-accuracy trade-offs.

Consistent with the inhibition-based predictions, the AR manipulation did not yield positive priming, despite the fact that the IR manipulation produced significant negative priming. Our explanation for this outcome is that because stimuli were presented in a predictable regularly alternating sequence from one language to the other, subjects were conscious of which language was involved in upcoming targets. Hence, after reacting to the prime target, for instance, they could concentrate their upcoming “word” vs. “nonword” decision in a way that maximizes focus on those lexical representations belonging to the language of the upcoming target. Consequently, the activation of representations in the prime target language are suppressed, reducing potential interference with the upcoming language required for the probe target response. One important consequence of the suppressed state of the global language Twi, in this case, is that it eliminates potential positive priming effects (cross-language facilitation). Subjects appear to inhibit the Twi substratum of their lexicon after naming the prime target to avoid impeding the English substratum needed for making the required probe lexical decision response. This would prevent normal ‘spreading activation’ from the prime target to the probe target when they are conceptually related, and thus would eliminate positive priming in the AR condition. From our perspective, inhibition or suppression of the Twi target word (e.g., ɔkra) is a by-product of the suppression of the Twi language after naming occurs for the target in the prime display. Silencing the L1 in this way helps enable the lexical decision in the L2 English for the upcoming probe display, by avoiding simultaneous activation of both languages. Crucially, if there is global inhibition of the entire Twi (L1) language, then AR facilitation effects should be reduced or eliminated. Our findings showed a complete absence of positive priming in the AR condition, compared to the CO condition. These results parallel those found by Neumann et al. (1999, Experiment 2) with English-Spanish bilinguals and help to establish this pattern as a reliable finding.

Because the ignored (Twi) distractor items were sufficient to produce negative priming in the IR condition, repeating related targets in the AR condition should certainly have been capable of producing a positive priming effect if episodic retrieval had an influence on processing in this instance. Failure to observe positive priming in this situation casts doubts on the explanatory power of the episodic retrieval hypothesis. More specifically, a seemingly plausible explanation for the elimination of AR positive priming across languages, according to the episodic retrieval hypothesis, could be that despite the close conceptual relationship between the target words, they have been altered visually, because they are noncognate translation equivalents. Hence, their physical details do not match, in contrast to the target repetition match in the AR condition of Experiment 1. For this reason, it is possible that the probe target was a less effective retrieval cue for the immediately preceding encounter with the word that is only a translation of that word, rather than identical with it, as might be required by the episodic retrieval account of positive priming. The main problem with such an explanation, however, is that it does not account for the cross-language negative priming produced in the IR condition in the current experiment. Critically, the visual transformation between the prime distractor word and the probe target word is even greater, because, along with translation equivalency, there is also a change due to the form of the word which switches from uppercase to lowercase letters.

By nevertheless observing negative priming in the IR condition, it demonstrates an intimate cross-language connection among the mental representations involved with the prime distractor and probe target. It is our contention that in the process of responding to the prime target, the competing prime distractor is suppressed in order to avoid interfering with it. Moreover, the suppressed state that it is in spreads via spreading inhibition, to the related translation equivalent in the other language. This hinders the response to that translation when it appears as the probe target, ultimately producing the observed cross-language negative priming effect.

In the past the absence of cross-language positive priming would have been interpreted as supporting a separate language store interpretation. The idea was that the absence of positive priming between languages implies an independent and separate memory system for the two languages (DeGroot & Nas, 1991; Keatley, Spinks & de Gelder, 1994). If each of a bilingual’s languages is encapsulated separately, then it would make sense that one would not find facilitatory priming between translation equivalents. Superficially then, the absence of cross-language positive priming seems to go counter to the prediction of a single store model of bilingual language representation. The crux underpinning the single store model in the context of AR facilitatory priming between translation equivalents is that under conditions that require rapid access to meaning to obtain priming, cross-language priming should occur if both languages access a common conceptual store. Because negative priming between the translation equivalents of two languages was clearly obtained in the present paradigm, however, a broader explanation of these results is needed to account for this cross-language priming phenomenon.

Notably, IR negative priming was obtained in the condition in which the probe target was the translation equivalent of the ignored prime word. This is completely consistent with a single-store model. The prime distractor would have thus been initially processed (activated) in parallel with the prime target. However, the mental representation of the distractor would then have undergone inhibition in order to avoid interfering with (and thus facilitating) the naming of the prime target. The inhibition would then have presumably ‘spread’ to its semantic neighbours including its conceptual counterparts in English, and hence impaired further processing of that item if it happened to be the subsequent word requiring a lexical decision.

One open empirical question that remains is whether the IR results observed in this experiment were potentially induced by having the probe distractor in Twi, the language used for the prime stimuli (L1). To render that probe distractor less interfering, it is possible that it encouraged subjects to globally inhibit the language of that distractor (i.e., Twi) to avoid interference with the required probe response using English (L2). Experiment 3 was designed to test this possibility by a slight modification of Experiment 2 whereby the Twi probe distractor word was replaced with an English probe distractor word. This is the first cross-language experiment of this kind using both target and distractor probe items in the L2 of the participants. All other aspects of Experiment 3 were held constant with Experiment 2, with the exception of testing a new group of Twi-English bilinguals.

3.6. Experiment 3

Experiment 3 was intended to pursue the implications of Experiment 2, with a small variation of the design. As indicated above, it is unclear whether the absence of positive priming in the AR condition in Experiment 2 was contingent upon having the probe distractor in Twi, the L1. It is thus an open empirical question whether having the probe distractor as an L1 word is important for inducing the global suppression of the L1 language (Twi, in this case). To clarify, note that the probe target requires a lexical decision response to an L2 (English) word. It may be that the counter-productivity of keeping the Twi language momentarily activated is dependent on having the probe distractor in L1 (Twi). Keeping the Twi language activated, after all, could only make a Twi distractor word more distracting, or more interfering, with the required response involving a decision in English. This issue is pursued by introducing probe distractors that are in the same language as the probe targets (L2).

Our concern regarding the generalizability of the results in Experiment 2 is further motivated by the fact that we are not aware of any cross-language study that has produced a negative priming effect, along with no positive priming, with the exception of Neumann et al. (1999), although studies have produced facilitatory priming for translation equivalents (e.g., Altarriba, 1992; Gollan, Forster, & Frost, 1997; Keatley & de Gelder, 1992; Williams, 1994), in the context of singularly presented prime target stimuli. Quite often the contrast between priming effects for cognates (i.e., translations with similar spellings) and for noncognates (words that are graphemically dissimilar, as in the present study) have shown significant facilitation effects for both types of translation primes, but only when there is a relatively long exposure of the prime and on condition that the prime translation immediately preceded the target word. Even studies that employed very short exposures of the prime stimulus (e.g., de Groot & Nas, 1991; Williams, 1994) have shown facilitatory effects for cognate translation primes. However, results of noncognate translation experiments appear erratic. For example, de Groot and Nas (1991) reported reduced priming effects for noncognate translation equivalents compared to cognate translations in a lexical decision task, and in Sanchez-Casas et al.'s (1992) study cognate translations produced a facilitation effect, but noncognate translations did not. On the other hand, Grainger and Frenck-Mestre (1999) have reported facilitatory priming for noncognate translations in an English-French cross-language study. Such variations among experiments for noncognate items suggest a need for further investigation in this area.

Here we further investigate the modulation of words and languages in a cross-language extension of the selective attention paradigm used in Experiment 2. In particular, we wished to determine if the pattern of results involving positive and negative priming reported in Experiment 2 are strictly dependent on the status of the probe distractor word, as described above.

3.6.1. Method

3.6.1.1. Subjects

Forty-three subjects (17 males and 26 females) participated. Subjects were recruited from the University of Cape Coast, Ghana, and none of the subjects participated in Experiment 2. Their ages ranged from 19 to 29 years with an average age of 22.2 years. All subjects reported normal or corrected to normal vision.

3.6.1.2. Stimuli and Apparatus

The word stimuli were the same as those used in Experiment 2, with the exception that the Twi probe distractor words were replaced by their English noncognate translation equivalents. The experiment was conducted using the same laptop and response box as those used in Experiments 1 and 2.

3.6.1.3. Design and Procedure

The design and procedures were the same as those used in Experiment 2, with the exception that the Twi probe distractor words were replaced by their English noncognate translation equivalents. All presentation parameters, counterbalancing, and randomisation processes were identical to those used in Experiment 2. A sample trial couplet is presented in Figure 3.5.

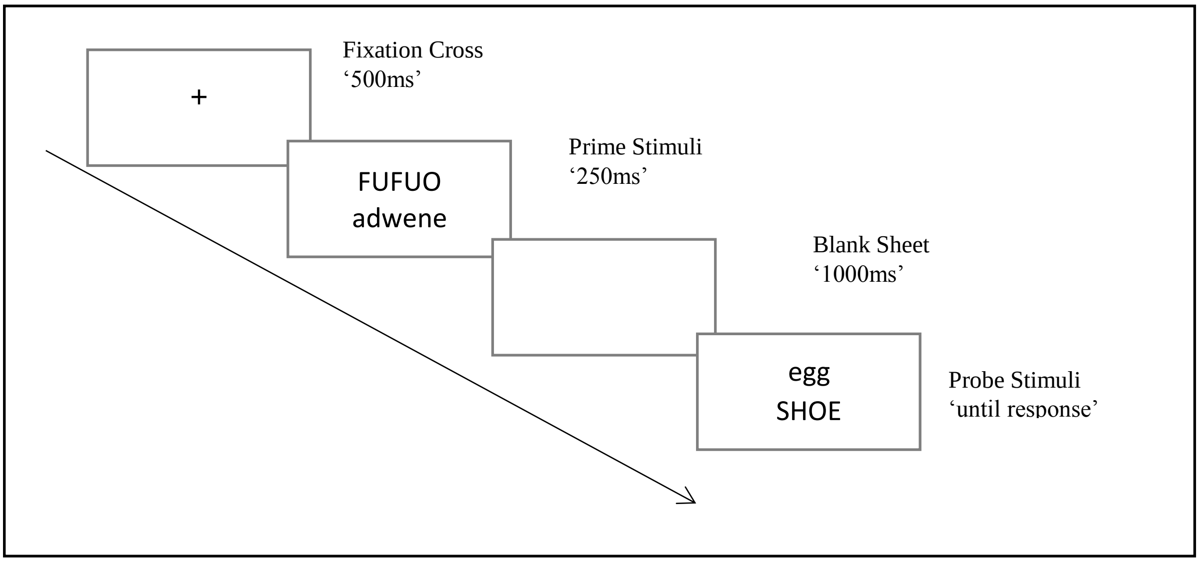

Figure 3.5. Sequence of stimuli presentation. Note that in the Experiments the distance between the closest edges of the top and bottom item in each display was 1 pixel width.

3.6.2. Results and Discussion

Based on the 30% cut-off scores for naming and response errors, one subject was excluded from further analysis. In comparison with the CO condition, the AR condition produced slightly faster response times, whereas the IR condition produced significantly slower response times. The results are displayed in Figure 3.6. An analysis of variance revealed a significant main effect *F* (2, 84) = 6.40, *MSE* = 168896, *p* = .003, η_p^2 =.132. Recognising the specificity of the hypotheses being tested, paired samples t-tests were conducted to determine whether compared to the CO condition, AR produced a facilitation effect and IR produced a delay. Reinforcing the pattern of results presented in Figure 3.6, the difference between AR condition (*M* = 3039, *SD* = 1146.67) and CO condition (*M* = 3048, *SD* = 1216.98) was nonsignificant, *t* (42) =.15, *p* =.884, *d* = .02. A significant difference was, however, obtained between the CO condition (*M* = 3048, *SD* = 1216.98) and IR (*M* = 3318, *SD* = 1271.82) condition, *t* (42) = 2.44, *p* = .019, *d* = .37.

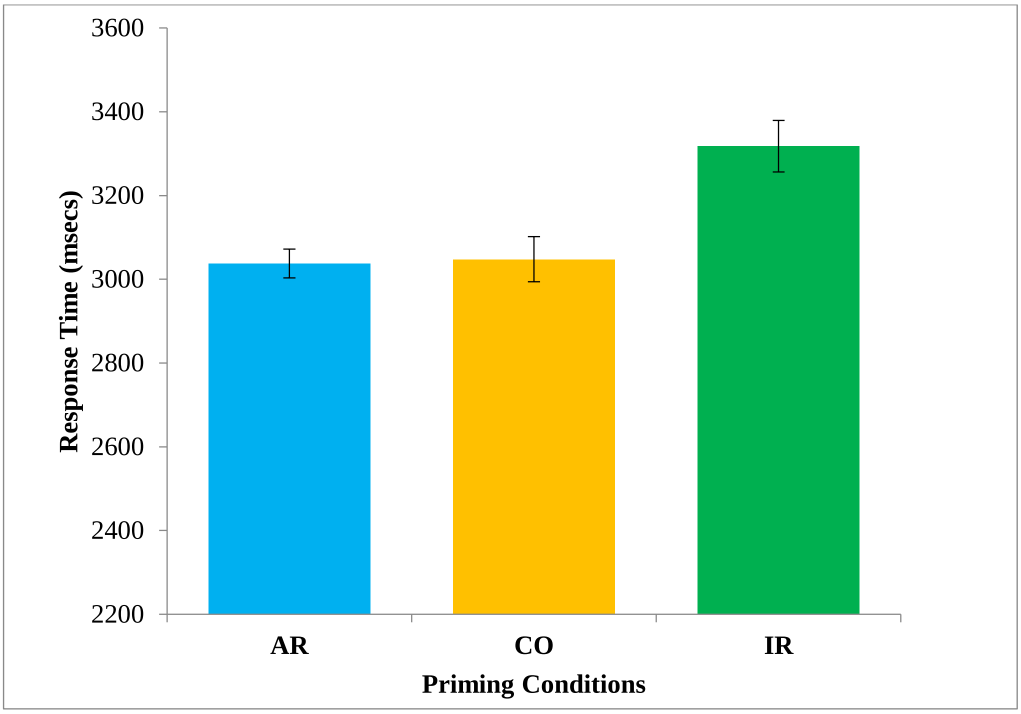

Figure 3.6. Mean response latency (in milliseconds) as a function of attended repetition (AR), control (CO) and ignored repetition (IR) conditions. Error bars indicate standard errors.

Error rates were analysed similarly, *F* (2, 84) = .294, *p* = .746, η_p^2 =.007. The error difference between AR condition (*M* = 4.17, *SD* = 5.69) and CO condition (*M* = 3.76, *SD* =

5.89) was not significant, *t* (42) = .514, *p* = .610, *d* = .08. Similarly, the error difference between IR condition (*M* = 3.56, *SD* = 5.02) and CO condition (*M* = 3.76, *SD* = 5.89), was not significant, *t* (42) = .22, *p* = .826, *d* = .03. The error data thus do not compromise the interpretation of the RT results, because there was no indication of speed-accuracy trade-offs.

The present experiment produced a significant negative priming effect, but no positive priming effect, thus replicating the pattern of findings for Experiment 2. These results show that having the probe distractor in the language of the prime stimuli was not responsible for the observations regarding Experiment 2. The fact that the analysis was again powerful enough to produce a significant negative priming effect in the IR condition suggests that it should also have been sufficiently sensitive to detect an AR positive priming effect, had there been any. Hence, just as in Experiment 2, the results provide no evidence that episodic retrieval processes were employed in these experiments. Although there is a conceptual similarity between prime and probe targets in the AR condition, they were unable to elicit positive priming, yet the conceptual similarity between the nontarget prime distractor and probe target in the IR condition was able to produce negative priming. This pattern of findings is particularly difficult for episodic retrieval theory to handle. More specifically, under the auspices of episodic retrieval, there are always two potential sources for positive priming effects (spreading activation, and compatible response tags), whereas there is only one source for negative priming (incompatible response tags). The present findings are in the opposite direction of what the theory predicts.

On the other hand, the results are consistent with an inhibition-based approach. According to this view, inhibition can also be locally applied to a nontarget distractor in one language, and the suppressed state of such a word hampers the ability to subsequently respond to its translation equivalent in another language, as evidenced by the significant negative priming. Inhibition can also be globally applied to a language, which can account for the absence of positive priming between languages, as described earlier. Although we have concentrated on the global inhibition of a native language as an explanation for the absence of positive priming here, and for Experiment 2, another inhibition-based alternative explanation must also be considered.

Rather than global suppression of the unwanted prime language, Twi, it could be argued that the absence of positive priming was the product of item-specific inhibition. For example, while the bilinguals are naming the target Twi word, there could be simultaneous competition from the English noncognate translation equivalent of that Twi target word, especially if conceptual representations are integrated across languages in bilinguals. To avoid mistakenly naming this internally generated English competitor on the naming trial, it may undergo some degree of item-specific suppression. Proficient bilinguals could well be at risk from this source of competition during the naming part of the trial so may need to impose inhibition on potentially conflicting stimuli, whatever their source (von Studnitz & Green, 2002). However, if inhibition was indeed applied item-specifically, instead of at the global language level, it should have led to a negative priming effect in the AR condition, rather than a null effect. With global inhibition of the prime language, however, the inhibition would be more diffuse among the lexical items of that language. Negative priming would therefore not be expected, whereas the elimination of positive priming would be expected, which is what was observed. Inhibition applied globally to a language thus appears to provide a better explanation for the absence of positive priming, compared to inhibition applied item-specifically to an individuated word. Despite this finding having greater consistency with the global inhibition idea, it is notable that both of the explanations for why positive priming disappears in our bilingual experiments require a suppressive mechanism to modulate momentarily irrelevant, potentially conflicting, information.

Collectively, the present cross-language experiment constitutes the third verification showing a significant negative priming effect in the complete absence of a positive priming effect within the same experiment (Neumann et al., 1999, Experiment 2; current Experiments 2 and 3). This is an important pattern of findings, because it is only rarely the case that the inhibition-based account makes distinctly different predictions about the outcome of an experiment than the episodic retrieval account. To further elucidate the suppressive mechanism involved, future research should directly address the circumstances under which different loci and/or degrees of inhibitory control are elicited in bilingual priming tasks.

3.7. General Discussion

Understanding the nature of mental representations and control processes within and between languages is fundamental for constructing adequate models of bilingual language representation and processing. Investigating both positive and negative priming effects within and across languages provides unique opportunities to examine the intricacies of bilingual language representation and processing in an empirical way. The present experiments also enabled us to test predictions from two main rival theories regarding the underpinnings of such priming effects in the context of a selective attention task involving concurrent target and distractor stimuli in each attentional display. In contrast to the within-language (Experiment 1), the between-language experiments (Experiment 2 and 3) were specifically designed to expose conspicuous differences regarding the outcomes that the inhibition and episodic retrieval theories would predict. The findings that emerged enhance our understanding of the scope of inhibitory processes for modulating words and languages in bilinguals. Collectively, the findings from this series of experiments also contribute unique insight regarding debates about single versus separate-store natural language structures.

3.7.1. Implications for Memory (Episodic) Retrieval Theories of Priming

Experiment 1 was a within-language, Twi-Twi, experiment. Target and distractor stimuli in both prime and probe displays consisted of Twi items. This experiment produced significant positive and negative priming effects. These effects were consistent with predictions from both episodic retrieval theory, and the rival inhibition-based theory.

Experiments 2 and 3 were cross-language, Twi-English, experiments. These experiments produced significant negative priming effects, but neither of them produced positive priming. In light of the fact that negative priming was capable of being produced, the absence of positive priming in these experiments is inconsistent with predictions from the episodic retrieval theory put forward by Neill and colleagues (Neill & Valdes, 1992; Neill, Valdes, Terry & Gorfein, 1992; Neill, 1997). According to episodic retrieval, it is the similarity relationship between prime and probe stimuli that dictates whether the probe stimulus is similar enough to the prime to elicit the response attached to that prime. In the attended repetition condition, if the attended prime and probe targets are similar enough, a compatible response ("*respond*" "*respond*") is elicited, which should speed-up processing, relative to prime and probe stimuli that are not similar. This is why attended repetition conditions usually produce facilitatory priming. One could argue that perhaps noncognate translation equivalents are not similar enough to elicit the compatible response tags in the cross-language experiments, and that is why no positive priming was observed. This argument does not work, however, because negative priming was observed. In the ignored repetition condition, if anything, the similarity gradient is even more different between the prime distractor and probe target, and yet negative priming was fully intact. More specifically, in the ignored repetition condition, not only is the relationship between the prime distractor and probe target based on noncognate translation equivalence, but the structure of the words also changes from upper to lowercase letters. Yet here the probe translation equivalent can be interpreted as being capable of eliciting the “do not respond” tag, and thus producing a negative priming effect from the incompatibility of the tags (“do not respond” “respond”). Because the prime and probe targets were more similar in the attended repetition condition, there should have been a greater likelihood of finding positive priming than negative priming in the bilingual experiments, but the opposite was the case.

The findings described above also question the classic separate-store hypothesis of bilingual memory organisation (Neumann et al., 1999; Durlik, Szewczyk , Muszynski & Wodniecka, 2016). That research (e.g., Kirsner, Brown, Abrol, Chadha & Sharma, 1980; Kirsner, Smith, Lochart, King, & Jain, 1984; Scarborough, Gerard & Cortese, 1984) claimed that repetition priming tasks rarely produce positive priming across languages, and such findings were taken as evidence for separately stored lexical representations for the bilingual’s two languages, because activation of a lexical entry in one language did not facilitate translation matches. The negative priming effects recorded in the present between-language experiments caution against using positive priming indices alone when trying to tap into the nature of bilingual language organization. If languages were separated or encapsulated from one another, it should make it difficult to observe any kind of priming across languages, much less negative priming. While the mechanisms underpinning the episodic retrieval theory may have a role in priming and selective attention studies, it seems clear that in the present bilingual experiments they are being overridden by more potent inhibition-based mechanisms (see Frings et al., 2015).

3.7.2. Implications for Inhibition-Based Accounts of Negative and Positive Priming

The current cross-language experiments, especially Experiment 2, were modelled closely after Neumann et al. (1999). In their study, English-Spanish bilinguals alternated between two languages in a trial: naming a word in English and making a lexical decision in

Spanish. Individuals were required to name an English target word aloud, and ignore an accompanying English distractor word. When making subsequent Spanish lexical decisions, they were presented with a target letter string, and ignored an accompanying English distractor word. On attended repetition trials, subjects made a lexical decision about a Spanish word that was a noncognate translation equivalent of the English word named immediately beforehand. On ignored repetition trials, the Spanish word was a noncognate translation of the previously ignored English distractor word. On the neutral control trials, subjects made a lexical decision to a Spanish word that was not present in the previous display. They observed a significant negative priming effect, but not positive priming. Despite using a vastly different bilingual language group (Twi-English), precisely the same pattern of results were observed in the present cross-language experiments. Because these experiments produced the same results, the same explanations and implications hold for both of them.

Our favoured explanation is that two sources of inhibition can account for the absence of positive priming, coupled with the observance of negative priming, in the cross-language tasks. While positive priming occurred in the within-language experiment (Experiment 1), it failed to emerge in the cross-language experiments. Why might that be? It is possible that, since our participants were generally quite proficient in both Twi (L1) and English (L2), once prime display processing was finished, it would have been counter-productive to keep the Twi language active. Instead, inhibition was applied globally to the Twi language, so that it became less, or non-interfering with the upcoming requirement to make a lexical decision in English. This would curtail any potential spreading activation effect from the Twi named target to its English translation. Hence, there would be no cross-language positive priming effect.

In addition to this global language-wide inhibition, there is also local inhibition that is selectively applied to the prime distractor word. In order to resolve the conflict between the target and distractor in the prime display, the irrelevant distractor becomes inhibited. The inhibition spreads automatically to its translation equivalent, such that if that translation becomes the subsequent English probe target, as in the ignored repetition condition, a significant impairment ensues. These explanations taken together, point to a striking flexibility of inhibitory influences, which seem capable of being directed to different properties of stimuli, as warranted by task demands (Tipper & Weaver, 1994). We are not suggesting, however, that conscious strategies are involved. From our perspective, individuals do not know that they are using inhibitory processes to supress irrelevant distracting information. Instead, the suppression that the conflicting, irrelevant information undergoes is an automatic by-product of attending to what is momentarily relevant (Neumann & DeSchepper, 1991, 1992). Such suppression is induced by task demands when highly conflicting targeted and distracting information compete for priority. Other bilingual researchers seem to agree that selective inhibitory control can be applied to individuated words, as well as more globally to a language (e.g., Green, 1998; Kroll, Bobb, Misra, & Guo, 2008; Misra, Guo, Bobb, & Kroll, 2012). To our knowledge, however, the present cross-language paradigm is the only one that provides evidence for both of these mechanisms in a single task.

Another critical observation was that all three of the present experiments produced negative priming. This was despite using a large pool of words, and having words only encountered once as a prior distractor in the ignored repetition condition. This goes against numerous studies that appear to show that in order to obtain negative priming with words in an experiment, it is necessary to encounter such words multiple times as previous targets before they become a prime distractor in an ignored repetition trial (Grison & Strayer, 2002;

Kramer & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999). In these studies, color was used as the selection cue, and because a single feature distinguished the target from the distractor in such cases, selection was quite easy due to pop-out effects. When words are encountered as earlier targets, however, perceptual fluency (e.g., Jacoby & Dallas, 1982) toward those words develops, making them somewhat more competitive if they become a subsequent prime distractor on an ignored repetition trial. The consequence is that they now conflict enough (and thus induce a greater degree of inhibition) to produce negative priming. It is worth reiterating that it is not that conscious strategies are involved, but rather automatic adjustments reactively induced by the selective attentional conflict between the target and distractor in the prime display (Wyatt & Machado, 2013). By using the same color for both target and distractor words and uppercase versus lowercase as the selection cue in our experiments, ease of selection is avoided, because conflict between target and distractor words is ever-present throughout the task (see also Pritchard & Neumann, 2011). When this is the case, negative priming emerges, even when the probe target word is a translation equivalent in a different language of the previous distractor word, encountered and ignored only once during the entire experiment.

3.7.3. Implications for Bilingual Language Representation and Processing

As far as we know, the present experiments are the first priming experiments to have been conducted with bilinguals in Africa. By investigating potential positive and negative priming effects within one of a Twi-English bilinguals' languages (Twi-Twi), and between languages in cross-language experiments (Twi-English), a number of implications arose regarding how words and native languages are capable of being modulated. The findings, in turn, have broader implications for how languages are represented and processed in the minds of bilinguals. The generalizability of the conjectures forwarded in this paper is bolstered, by the fact that the pattern of performance across the present tasks replicated and substantially extended an earlier within (English-English) and between languages (English-Spanish) priming study conducted in America (Neumann et al., 1999). An interesting feature of the findings was that although the Twi-English response times were much slower overall than the response times in Neumann et al's English-Spanish study, the pattern of the data was the same. The slower Twi-English responses could be attributed to unfamiliarity with computerized tasks and the unique, highly syllabic nature of the Twi language.

Perhaps the most provocative findings from these experiments is the uniquely original way in which they support single-store models, wherein conceptual representations are deemed to be integrated across languages in bilinguals. All previous priming studies claiming to support single-store models have used the existence of cross-language positive priming among translation equivalents as the key indicator of support for their claim (e.g., Altarriba, 1992; Sanchez-Casas, Davis, & Garcia-Albea, 1992; see for review, Altarriba, & Basnight-Brown, 2007). Despite finding no hint of positive priming across languages in our bilingual experiments, our support for an integrated languages model comes from the even more compelling result of negative priming between languages. Collectively, these patterns of findings led to proposals for how words and languages appear to be capable of being regulated in the context of selective attention circumstances. Moreover, unpublished work in our lab involving synonyms in a within-language task (instead of translation equivalents in a cross-language task), produced *no* negative priming. Hence, it should not be surprising if it turns out that noncognate translation equivalents actually have an even closer cognitive intimacy than within-language synonyms (see also Francis, 2005). A recent neuroscientific approach has been developed that shows promise for substantiating these behavioural findings (Huth, de Heer, Griffiths, Theunissen, & Gallant, 2016).

There are a number of intriguing possibilities for further exploring the nature of bilingual processing and storage stemming from our study. For instance, the current cross-language experiments used L1 as the language required for processing the prime display and L2 for processing the probe display. This leaves open the issue of whether the results would differ if this was reversed and the weaker language was the one that required suppressing. Such experiments might shed additional light on the nature of global language modulation when a less dominant prime language is involved. We are also currently investigating the role an individual's proficiency level in both languages plays in shaping the results, in an effort to develop more fine-grained analyses about the mechanisms involved in the orchestration of two languages. In summary, our findings make the case that incorporating bilingual selective attention versions of positive and negative priming tasks provides an illuminating perspective from which to further pursue issues of bilingual language representation and processing.

Chapter 4

Bilingual Cross-Language Positive and Negative Priming Effects as a Function of L2 Proficiency

4.1. Abstract

The ability to use multiple languages selectively is an impressive feat of the human information processing system. Although bilinguals scarcely commit random cross-language errors when they speak, there is evidence that both languages are active when one is in use (e.g., Colomé, & Miozzo, 2010). This paper builds on previous work using cross-language priming techniques to examine the system that regulates the activation and suspension of target and nontarget languages during bilingual language processing. Twi (a native language of Ghana, Africa)-English bilinguals named a target prime word in Twi that was flanked by a Twi distractor word and then made a lexical decision to an English target probe item in order to investigate potential positive and negative priming effects. Participants were classified according to their second language (L2) proficiency. Greater L2 proficiency was associated with the absence of attended repetition positive priming, coupled with greater ignored repetition negative priming, compared to those with less L2 proficiency. These outcomes are discussed in terms of differences in the way less and more proficient bilinguals juggle their languages. The implications from these findings are also discussed with regard to conflicting predictions stemming from episodic retrieval and inhibition-based accounts of positive and negative priming phenomena in cross-language selective attention tasks.

4.2. Introduction

Bilingual speakers exhibit remarkable plasticity in language processing. They can confine their speech to one language, and can painlessly switch between languages in appropriate situations. However, there is evidence that the intention to speak one of the bilingual's languages does not necessarily restrict activation of items in the other language (e.g., Colomé & Miozzo, 2010; Dijkstra, 2005; Kroll, Bobb, & Wodniecka, 2006; Lagrou, Hartsuiker & Duyck, 2013; Marian & Spivey, 2003; Misra & Singh, 2016), thus endorsing the hypothesis that bilingual language production is initially nonselective. This observation is particularly striking for language production where intuitively it is assumed that the intention to speak in one language should curb activation of items in the unintended language (Bobb & Wodniecka, 2013). The enduring question is how bilinguals manage to select the target language for use and avoid interference from the nontarget language and, more specifically, what mechanisms underlie the ultimate selection of the response language?

There is considerable debate about the degree to which past findings distinctively demonstrate the presence and locus of cross-language activation in the planning of words in either of the bilingual's two languages (see Costa, La Heij & Navarrete, 2006). Earlier studies suggested that in order to speak one language rather than the other, the bilingual must throw the equivalent of a mental switch (Penfield & Roberts, 1959). McNamara and Kushnir (1971) proposed a two-switch model with input and output switches that were thrown to allow comprehension of one language and production in the other language during translation tasks (for reviews see Bobb & Wodniecka, 2013; Heredia & Altarriba, 2001). The underlying assumption in both cases was that a language system (or subsystem) is either on or off. The "mental switch" account provided a parsimonious interpretation of how bilinguals map an input of one language onto the suitable mental lexicon, as well as conferring the ability to ignore the occasional spurious mappings of that input onto the unintended mental lexicon of the other language (Spivey & Marian, 1999).

Other researchers surmise that language systems can be at different points of activation and in order to speak one language rather than the other, the activation levels of the target language must exceed those of the nontarget language (e.g., Grosjean, 1997, 1998, 2001). The alternative account is that the unintended language is actively inhibited while the target language is actively in use (e.g., Abutalebi & Green, 2008; Green, 1998). One of the most contentious debates in cognitive psychology is the extent to which cognition depends on the activation of abstract representations (e.g., Houghton & Tipper, 1994; Monsell, 1985; Morton, 1969, 1979) versus the retrieval of specific episodes or instances in memory (e.g., Hintzman, 1986; Jacoby & Brooks, 1984; Logan, 1988; Neill & Valdes, 1992). This debate is particularly germane to priming research, which explores the effect a previously encountered stimulus (e.g., word, letter, or picture) has on the response to a subsequent related stimulus.

Neumann, McCloskey, and Felio (1999) pursued this debate in the context of a within-language and cross-language priming study using a task in which a prime naming component is followed by a probe lexical decision. In contrast to previous priming studies, which typically involve singularly presented prime and probe stimuli (e.g., Altariba & Basnight-Brown, 2007), their task involved a target and a distractor in both the prime display and the probe display. By doing so, they were able to track the consequences of processing the prime target, as well as the conflicting prime distractor. This experimental procedure inherently entails a selective attention component. Upon encountering the prime display the participant was required to name the target word, while ignoring a concurrently presented nontarget word. This procedure entails two potential priming relationships. On attended repetition (AR) trials the target prime word is the same as the target probe word, whereas on ignored repetition (IR) trials the conflicting distractor prime word is the same as the target probe word. When the experiment was conducted within the same language, all English in this case (Neumann et al., Experiment 1), response time in the AR condition was faster than on trials where the prime and probe target words were unrelated control trials (CO). In contrast to this *positive priming effect,* response time in the IR condition was slower than on CO trials, thus constituting a *negative priming effect*. In the cross-language version of this task, requiring target naming in English and probe lexical decisions in Spanish (Neumann et al., Experiment 2), however, participants were presented with a prime target in one language and a probe target in another language. For example, overtly naming *apple* in the prime display and making a lexical decision to *manzana* (the Spanish translation of the word apple) in the AR condition. Interestingly, in the between-language task, there was no positive priming effect in the AR condition, only negative priming was observed. As such, if the nontarget distractor word in the prime was *DOG*, participants were slower to make a lexical decision to *perro* (the Spanish translation of the word DOG), compared to the unrelated CO condition. Moreover, when these bilinguals were categorized into more and less proficient, on the basis of their proficiency in Spanish (L2), the more proficient showed no hint of positive priming, coupled with amplified negative priming, relative to the less proficient in L2.

To account for the absence of positive priming in the more proficient bilinguals, Neumann et al. (1999) suggested that since they were proficient in their L2, keeping L1 (English language) activated during probe target processing could only hamper making a lexical decision to a Spanish word. By globally inhibiting English to avoid this potential conflict, the normal spreading activation between translation equivalents would be attenuated, thereby accounting for the elimination of positive priming. On the other hand, locally inhibiting the conflicting English prime distractor word, coupled with the global inhibition of English, could account for the exacerbation of the negative priming effect evidenced by the more proficient L2 bilinguals. Due to the unprecedented between-language selective attention task they used and the uniqueness of their findings, these explanations were necessarily ad hoc. A corroboration here using different words and different bilingual language groups would reinforce the earlier findings and place the explanation for them on much firmer grounds. The initial aim of the current experiments was thus to determine if the same pattern of findings would be obtained in a vastly different bilingual language group.

It is important to note that in Neumann et al.'s (1999) study, participants were required to name a prime target English word while ignoring a simultaneously presented English distractor word, and in the probe display make a lexical decision to a Spanish target word while again ignoring a concurrently presented English distractor word. Perhaps, having the probe distractor in the same language as the prime stimuli (English) was an incentive to globally inhibiting the English language after reacting to the prime target (English). To test whether the reported findings of Neumann et al. (1999) were conditional on having the probe distractor in the same language as the prime stimuli, the present study extended their procedure by incorporating two versions of the task. In one version the probe target and distractor were in different languages [(Twi and English), similar to Neumann et al.'s study]. In the other version, the probe target and distractor were in the same language (English). This enabled us to determine if having the probe distractor in L1 (the same language as that used for response to the prime) was a necessary condition for inducing the global inhibition of L1 by the more proficient bilinguals.

The present study involved a native language of Ghana, Africa (Twi) with Twi-English bilinguals. Participants overtly named the prime target Twi word [e.g., *anwea* (Twi word for *sand*)] while ignoring a simultaneously presented Twi distractor word and then had to decide whether a letter string that followed was a correct English word or not (e.g., *spyder*), while ignoring a simultaneously presented Twi or English distractor word. The aim was to examine potential positive and negative priming effects across languages in order to test predictions about the mechanisms underlying bilingual language selection and processing and further track them as a consequence of language proficiency. In the next section, we briefly discuss predictions from the two major rival theories (inhibition-based and episodic retrieval) on positive and negative priming in a cross-language priming task involving selective attention components.

4.2.1. Inhibition based and Episodic Retrieval models of negative (and positive) priming

Early cognitive theories assume that cognition is largely driven by the activation of *abstract* mental representations such as described in Morton's (1969, 1979) logogen theory. Within the abstractionist hypothesis, an encounter with a stimulus or an object leads to activation of abstract mental representations of that object, so that the object's representation becomes more highly accessible (e.g., Morton, 1969). This heightened accessibility produces faster and more accurate recognition of a repeated object relative to a novel object. More recently, an extension of this view suggests that successful object identification and selection is accomplished by an excitatory mechanism that acts to enhance target information, coupled with an inhibitory mechanism that suppresses distractor information. By this account, the presentation of distracting stimuli results in the activation of an abstract internal representation of the distracting stimulus which an inhibitory mechanism then suppresses and disengages from the response output. Thus, whereas the attended stimuli remain momentarily activated, the abstract mental representations of ignored stimuli are rendered provisionally inaccessible (e.g., Frings, Wentura & Wuhr, 2012; Neill, 1977; Neumann & DeSchepper, 1991; Paradis, 2004; Tipper, 1985). Put another way, when people have to selectively attend to a stimulus, their attention mechanisms concurrently enhance the target (including its semantic neighbors), but actively suppress the representation of the nontarget stimulus (and its semantic neighbors). This dual process has the merit of highlighting the target on the prime trial, but with the cost of making it more difficult to retrieve the inhibited or suppressed representation of the conflicting nontarget subsequently on the probe trial. As such, positive priming is due to the activation from a recent experience with a stimulus increasing its accessibility, as well as that of its semantic neighbours owing to preactivation, whereas negative priming is due to active inhibition of ignored information during target selection on the prime trial. This inhibition persists over time and the subsequent processing of the nontarget prime item (or its semantic relation) that has recently been ignored would be delayed due to this suppression (e.g., Tipper & Driver, 1988).

To emphasise the distinctiveness of binary-processing in inhibitory terms, Neumann and DeSchepper (1992) conjectured that whenever selective attention is warranted, an inhibitory mechanism also operates on encountered relevant information that is no longer needed and likely to become disruptive. Such inhibitory inducements parallel the distractor inhibition that apparently causes negative priming effects, except that it is an endogenous form of such inhibition. Endogenous inhibition acts on internally represented information that is apt to interfere with responses to targeted information, whereas exogenous inhibition refers to the suppression of distractors that are visible in the environment. Experimental indices of endogenous and exogenous inhibition are gauged by evidence of the suppression of internal and external distracting nontarget information (Neumann, Cherau, Hood & Steinnagel, 1993; Neumann & DeSchepper, 1992; see also Anderson & Spellman, 1995).

In the present cross-language experiment, it is surmised that endogenous inhibition is applied to the Twi *language* after the processing of the prime display is finished, because keeping Twi activated would only interfere with the probe lexical decision required in English. Inhibition of Twi should curtail any potential spreading activation from the prime target (in Twi) to its translation equivalent (in English) if it becomes the probe target in the AR condition. Conversely, suppression of the Twi prime distractor word, while naming the target, should spread to the distractor's semantic relations in the other language (English), such that if that English translation equivalent then becomes the probe target requiring a lexical decision, as in IR trials, a significant cost in reaction time should occur. Collectively, the local inhibition of the prime distractor word together with global inhibition of the entire prime language should thus produce negative priming in the IR condition, but no positive priming in the AR condition. If the proficiency effects predicted by Neumann et al.'s (1999) cross-language experiment were also to be confirmed, this outcome should be especially prominent for the more proficient bilinguals.

An alternative to inhibition-based models of priming has been proposed by Neill and his colleagues (Neill & Valdes, 1992; Neill, Valdes, Terry & Gorfein, 1992). In the episodic retrieval model performance in selective attention priming tasks is mediated by the retrieval of specific "episodes" or "instances" in memory (Logan, 1988). Episodic representations may contain information about the identity or location of objects and their status as target ("respond") or distractor ("do not respond"). A participant may therefore recognise a current probe target object as similar to one recently experienced, which would in turn elicit either a compatible or incompatible response tag (e.g., Jacoby, 1983; Logan, 1990). By this account, positive priming is caused by the retrieval of an episode that is automatically triggered by the onset of the same stimulus (or a conceptually related stimulus) that was attended to and responded to in the prime display. As such, AR positive priming occurs as a result of access to an episodic representation that contains response information that matches, and hence facilitates, the required response. Negative priming on the other hand is provoked by the automatic retrieval of information from the prime display which conflicts with the current correct response (Neill & Valdes, 1992; Neill et al., 1992). Thus when the target encountered was a previous distractor, retrieval of recent related information occurs, but the item most likely to be retrieved – the distractor prime stimulus – conveys with it a tag that disrupts the response to that same item, now that it is the probe target. This creates a response conflict between the “do not respond” tag associated with the prime distractor item and the “respond” tag attached to the probe target item, when it is an identical or closely related item.

The episodic retrieval model is an extension of Logan’s theory of automaticity involving obligatory encoding, obligatory retrieval, and instance representation (Logan, 1988, 1990). In Logan’s (1990) terms, the conditions for the automatic retrieval of episodes of the type that can produce positive priming effects are quite restricted. For instance, the benefit in repetition priming is often particular to the physical and conceptual format of the initial presentation. Therefore there is little transfer from words to pictures and from pictures to words. Hence in order for the episodic model to account for data showing abstract conceptual transfers from pictures to words (e.g., Tipper & Driver, 1988), a fairly broad similarity gradient is essential, possibly incorporating semantic, lexical, phonological and or perceptual information in magnitudes that correspond to the demands of the task. In episodic retrieval postulations, it is the similarity relationship between prime and probe stimuli that determines whether the prime stimulus is sufficient to elicit the response attached to the probe target, and create facilitation or delay. Extrapolating from the foregoing, the episodic retrieval model predicts both AR positive priming and IR negative priming in the present cross-language experiment, if it is the case that a conceptually equivalent probe target word is sufficiently similar to a prime distractor to elicit their accompanying response tag. Hence, the clearest predictions from the episodic retrieval theory are that if positive priming is observed in the AR condition, so should negative priming be observed in the IR condition, and vice versa. Notably, in addition to translation equivalence, there is also an additional physical change from upper-to lower-case letters in the IR condition, which if anything should reduce the likelihood of obtaining negative priming, compared to positive priming in the AR condition.

4.2.2. The puzzle of inhibitory control and L2 Proficiency

Language proficiency is considered to be the main factor influencing bilingual processing and is defined as the degree of *control* that an individual has over a language (Hernandez, & Li, 2007). Costa and colleagues (Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006) have shown that the control strategies employed by less proficient bilinguals are different from those employed by highly proficient bilinguals. According to Kroll et al. (2006) cross-language alternatives may be active at any level, and the degree to which there is sustained activity of the nontarget language depends on a variety of factors including the language of production, proficiency in the L2, the task that initiates speech planning, and the degree to which specific lexical alternatives are primed. Language proficiency is one of the major factors that control the activity of the nontarget language and of the network responsible for language control (e.g., Kroll et al., 2006, Green, 2011).

It is assumed that as learners become more proficient in their L2, the level of activation associated with each of their two languages becomes relatively equivalent, and thus they may suffer from an increasing amount of competition between their two languages (Kroll et al., 2008). Extrapolating from this assumption, Linck, Hoshino, and Kroll (2008) required participants to perform a battery of language tasks (Simon task, reading span, and a rapid serial visual representation technique) designed to examine various aspects of lexical processing to test whether more proficient bilinguals exhibit greater inhibitory control. Contrary to their predictions, more proficient learners showed reduced inhibitory control relative to their less proficient counterparts. The researchers conjectured that the enhancement of inhibitory control in bilinguals is not just a matter of acquiring greater L2 proficiency but other experiential factors such as the frequency of L1 use in the L2 environment and the frequency of code-switching.

On the other hand, Neumann et al. (1999) in a study with English-Spanish bilinguals recorded a positive relationship between L2 proficiency and inhibitory control in a priming experiment. They contrived a naming and lexical decision task that required participants to identify a target Spanish word while ignoring a concurrently presented distractor Spanish word in the prime display. In the probe presentation, participants decided whether a string of letters was a correct word in English or not. These researchers found that more proficient Spanish-English bilinguals produced greater negative priming (inhibition), than the less proficient who, indeed, did not produce significant negative priming. The present study attempted to track the link between language proficiency and inhibitory control, using cross-language prime target naming, followed by probe target lexical decision tasks.

4.2.3. Twi-English bilinguals

During linguistic colonisation, European English spread vertically from the upper-classes to the lower-classes; then horizontally from the capital to small cities and then to villages (Calvet, as cited in Seawright, 2014). Currently, most urban dwellers show competence in spoken English, whereas villagers tend to use Twi. Written English, however, is used at all levels of the Ghanaian educational system. L2 proficiency status for a population like Ghana becomes incomprehensive if proficiency judgements are based on speaking or writing alone, so the proficiency questionnaire employed in this study tested four core areas of L2: reading, writing, comprehension, and speaking.

4.3. Method

4.3.1. Participants

Eighty-two Twi-English bilinguals from Ghana volunteered to take part in the experiment. Thirty-nine (22 men, 17 women) were sampled from the Colleges of Education and 43 (16 men, 27 women) from the University of Cape Coast. Their ages ranged from 19 to

29 years. Self-reports showed that all the participants spoke Twi as a first language (L1) and English as a second language (L2), and they all judged themselves to be reasonably proficient in the English language. They also reported frequent, deliberate switches of spoken language in Twi and English on a daily basis.

4.3.2. Proficiency Dichotomization

A 25 item Language Proficiency Questionnaire was prepared to group participants into more and less proficient categories (see Appendix C for the questionnaire). Lecturers/instructors in both schools were asked to provide information about the students' English language proficiency levels by rating them on the questionnaire. The questionnaire had five sections and each section measured one core area relating to speaking, reading, comprehension, writing and a general language instructor's knowledge of the ratee's English language competence. Questions on the questionnaire were rated on a 4 point Likert scale ranging from never (1), sometimes (2), often (3), and very often (4). We aggregated scores on each participant's questionnaire and developed a median split for each group.

The Raters employed were lecturers/tutors from both institutions who have been teaching for over ten years and have had a minimum of one year experience with the students under study. It is important to note that since the raters were different and belonged to different institutions, we did not combine scores from both schools, because judgements by Rater 'A' may be more lenient or harsh compared to Rater "B" or vice versa. The median score for participants from the College of Education (COE) was 75 and a median split based on this score categorized 19 participants as more proficient and 17 as less proficient. The three participants ranking in the midrange of proficiency were the most difficult to classify and so were excluded from further analysis. Similarly, a median score for participants from the University of Cape Coast was 75 and a median split based on this score categorized 16 participants above the median as more proficient, and 21 participants below the median as less proficient. The six participants ranking in the midrange of proficiency were excluded from further analysis, because they would be the most difficult to classify.

4.3.3. Stimuli and Apparatus

The stimuli were 620 English words randomly selected from Francis and Kucera (1982). Word frequencies varied from 32 to 50 uses per million. The Twi noncognate equivalents of the English words were taken from the Twi-English, English-Twi *Hippocrene Concise Dictionary* (Kotey, 2007). The Twi words used in the experiment, together with their English translations, are shown in Appendix B. One-hundred and sixty-eight items from the word pool were used as targets, and the remainder were retained as filler words. Ninety-six pronounceable English nonwords were created to fulfill nonword conditions (e.g., *agple* - instead of *apple*). The number of letters in letter strings was similar for word and nonword targets to prevent ease of discriminability between probe targets and distractors. The three priming conditions were: attended repetition (AR – wherein the probe English target was the Twi translation of the prime target word - (e.g., *safoa (Twi word for key)* - *key*); control (CO – wherein prime and probe stimuli had no relationship); and ignored repetition (IR - wherein the target probe English word was the translation of the ignored prime Twi word (e.g., MFONINI (*Twi word for photo*) - photo).

In the experiment, there was a slight difference between the task responded to by participants from the College of Education (COE) and those from the University of Cape Coast (UCC). In the COE group, the probe distractor was a Twi word (See Table 1). In the UCC group, the probe distractor was an English word (See Table 2). Thus in the COE group, participants named a Twi prime target word while ignoring an uppercase Twi distractor word, and then made a lexical decision to an English probe item while ignoring an uppercase *Twi* *probe* distractor word. The UCC students named a Twi prime target word while ignoring an uppercase Twi distractor word, and then made a lexical decision to an English probe item while ignoring an uppercase *English probe* distractor word. The logic was to examine if the language of the probe distractor has any influence on whether the hypothesized elimination of the cross-language facilitation is dependent on having the probe distractor word in L1 (the language required for response to the prime target word), as specified earlier. Sample trial couplet sequences for each group are presented in Figures 4.1 and 4.2. All other stimuli, presentation parameters, and conditions of the experiment were the same for both groups.

Table 1

Sample of Conditions for Word/Nonword Trials in COE Experimental Group

Condition	Prime Display	Probe Display
Attended Repetition	ABAKƆN	star
	nsoroma	GYIDIE
Control Condition	asɛm	promise
	BƆSUO	NTAKRA
Ignored Repetition	KURUWA	cup
	adwuma	SAFOA
Nonword Condition	toa	schudent
	AFUNUMU	ADWENE

Note: Lowercase letters in each case were the targets and the uppercase letters were the distractors. Lowercase words in the prime display required naming, lowercase words in the probe display required a lexical decision. Only word trials were analysed.

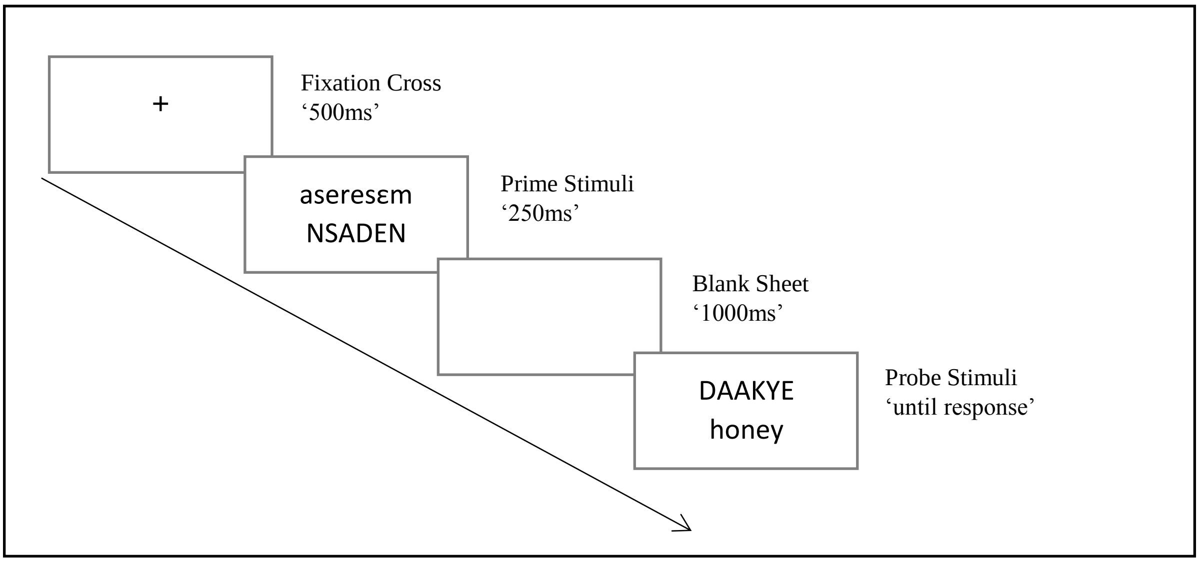

Figure 4.1. Sequence of stimulus presentation in a trial couplet for the COE group. The probe distractor was a Twi word. Note that in the experiments the distance between the closest edges of the top and bottom item in each display was 1 pixel width.

Table 2

Sample of Conditions for Word/Nonword Trials in the UCC Experimental Group

Condition	Prime Display	Probe Display
Attended Repetition	AKWADAA	linguist
	ɔkyeame	BUTTER
Control Condition	asɛm	LEMON
	BƆSUO	kitchen
Ignored Repetition	OBUBUANI	lame
	adwuma	KEY
Nonword Condition	toa	pawdar
	AFUNUMU	BRAIN

Note. Lowercase letters in each case were the targets and the uppercase letters were the distractors. Lowercase words in the prime display required naming, lowercase words in the probe display required a lexical decision. Only word trials were analysed.

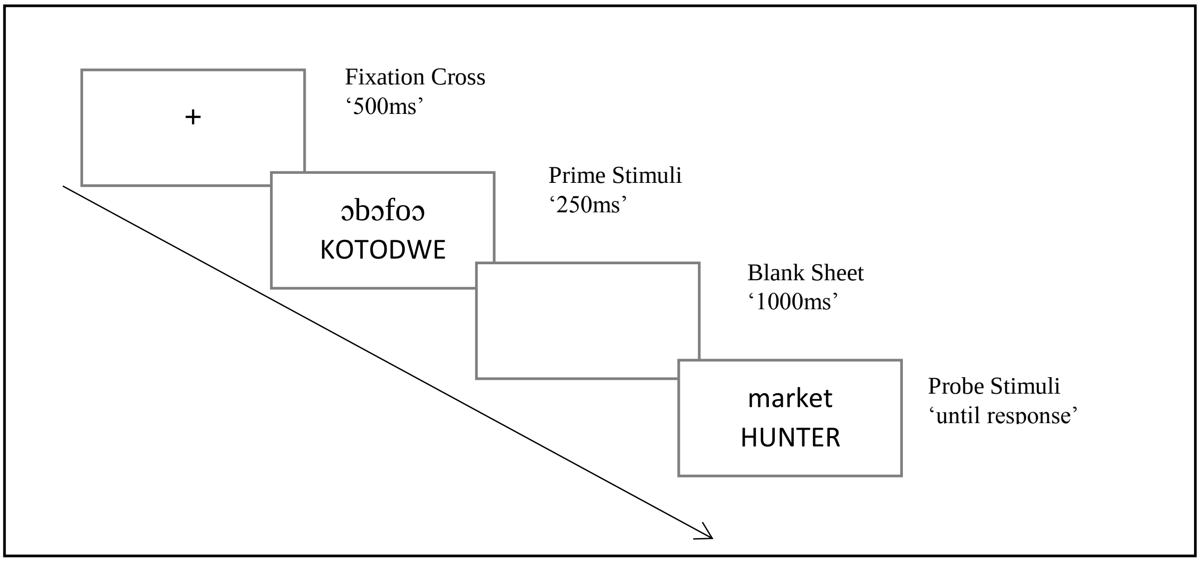

Figure 4.2. Sequence of stimulus presentation in a trial couplet for the UCC group. The probe distractor was an English word. Note that in the experiments the distance between the closest edges of the top and bottom item in each display was 1 pixel width.

Each condition (AR, CO, and IR) of the experiment consisted of 24 trials, plus 72 nonword trials. Two hundred and sixteen Twi words from the stimulus pool were divided into 72 each of prime distractors, probe distractors (for the COE group) and probe targets. Another 72 Twi words (matched translations of the English probe distractors for the COE group) were selected from the Twi stimuli pool to serve as probe distractors for the UCC group. The 72 probe target words were randomly assigned into sets A, B, and C of 24 words in each of the three conditions (AR, CO and IR) and participants were randomly assigned to these groups for the purpose of counterbalancing. The entire sets of 72 word and 72 nonword trials were arranged in random order and the same order appeared for all participants irrespective of the counterbalancing group. Each target or distractor word was presented only once in a prime-probe couplet except to satisfy the AR or IR condition. The aim was to curtail any possible carry-over effects from the repetition of words, thus helping to elicit pure priming effects. The experiment was deliberately set up with a low ratio of AR trials (1/6th of the total trial couplets), because as relatedness proportion increases, respondents are apt to formulate expectancies and benefit by speeded performance when repetition is predicted (e.g., Neely, 1991). Similarly, the logic underlying the 72 nonword trials (equalling the number of word trials) was to eliminate any bias toward responding "word" or "nonword" (Altarriba & Basnight-Brown, 2007). The experiment was preceded by 24 practice trial couplets (12 word and 12 nonword trials) that were not repeated in the main experiment.

Word length for both Twi and English stimuli ranged between three to fourteen letters. All word stimuli were printed in lowercase (target) and uppercase (distractor) black letters (Calibri, font size 11) on a white background. Nonword letter strings served only as probe targets and were always in lowercase black letters. The distance between the closest edges of the top and bottom letter string was 1 pixel width. The width of the words covered approximately 1.4cm (1.6 degrees of visual angle) for the shortest to 5cm (5.7 degrees of visual angle) for the longest. Prime displays were presented either centred, or slightly to the left or right of centre, in equal proportions on the computer screen, because research shows that varying stimulus position helps to increase the magnitude of negative priming by taxing attentional selectivity more than when static stimulus positions are held (Langley, Overmier, Knopman, & Prod'Homme, 1998). The distance between the left and right words from the centre was about 1.5cm (1.7 degrees of visual angle). Probe stimuli were displayed at the centre of the screen at all times.

Testing was carried out on a 15.6 inch Hewlett-Packard (HP) laptop computer. All programming was done with E-Prime 2.0 software (Psychology Software Tool, Inc.). A 5-button PST Chronos response box, which features milliseconds accuracy across machines was used for recording lexical decision reaction times (Psychology Software Tools, Inc., 2012). The two leftmost buttons were activated and designated "word" and "nonword". A response sheet that contained the prime target words was used to monitor the naming of primes.

4.3.4. Design and Procedure

A mixed design was employed. The between-subjects' variables were probe distractor (Twi vs. English) and proficiency (More vs. Less). The within-subjects variable was priming condition (AR vs. CO vs. IR). Each participant was tested individually in a session lasting about 55minutes in a dimly-lit room optimised for low noise. They sat at approximately 50cm from the computer screen. Instructions emphasised strict accuracy as well as quick reaction time. Participants underwent the practice trials repeatedly if necessary, to become familiar with the task before starting the main trials. They were instructed to overtly name the prime target word (lowercase letters) and subsequently decide whether the probe target (lowercase letters) was a correct English word or not. Lexical decisions to probe target items were made by pressing the "word" button with the index finger of the right hand, and the "nonword" button with the middle finger of the right hand. The lag between prime-probe presentations in the practice session varied such that the mean lag interval decreased as the number of presentations progressed. Once the main experiment began, the experimenter stayed behind the participant to avoid distractions.

The following sequence of events occurred in the experiment: (1) a message was presented stating "Press the Spacebar to begin the next trial" (2) a fixation cross emerged at the centre of the screen for 500msec (3) the prime display appeared for 250msec (4) a blank screen was presented for 1000msec while the participant named the prime target aloud and (5) the probe stimuli were displayed until the participant made a lexical decision. This sequence was repeated throughout the experiment.

4.4. Results

Cut-off scores of 30% naming errors or lexical decision errors were pre-set in order to exclude participants with large numbers of errors. However, no one exceeded these error rates so the analysis was carried out on the 73 participants (35 belonging to COE and 38 to UCC). Nonword trials were not included in the analysis. Only those probe trials in which *both* the prime and probe targets were correctly identified were included in the calculation of the mean RT. The mean RT for each participant was then converted into the adjusted RT, or AdjRT [AdjRT = RT/(1-% error)]. The AdjRT technique controls for speed-accuracy trade-offs (e.g., Chambers, Stokes, & Mattingley, 2004; Pavani, Làdavas, & Driver, 2002; Townsend & Ashby, 1983) and it is considered a more sensitive measure for processing efficiency than just RTs alone. See Figure 4.3 for the AdjRT results as a function of priming condition and L2 proficiency. The error bars show the within-subjects standard error of the means (Cousineau, 2005). The mean RTs and error rates are shown in Table 3.

A 2 x 2 x 3 mixed analysis of variance (ANOVA) was conducted on the AdjRT data, with probe distractor and proficiency as between-subjects factors and priming condition as a within-subjects factor. A significant main effect of priming was found [F (2, 138) = 10.68, MSE = 1852872, p =.001, η_p^2 = .13], indicating significant differences among the three priming conditions. In addition, there was a marginally significant interaction between language proficiency and priming [F (2, 138) = 2.68, MSE = 465595, p =.07, η_p^2 = .04], suggesting that the pattern of data differed between the bilinguals of different language proficiency. No other effects reached significance. To test our specific hypothesis, i.e., relative to the less proficient bilinguals, the more proficient ones would show amplified negative priming but no positive priming, we next conducted two separate ANOVAs, one comparing the results from the AR and CO conditions, and the other from the CO and IR conditions.

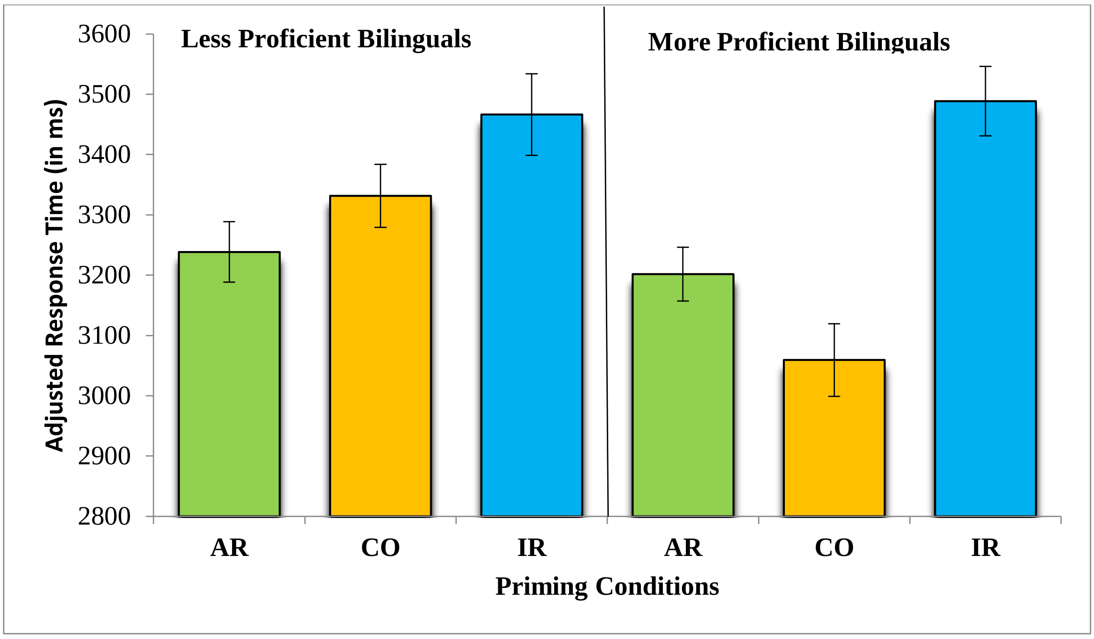

Figure 4.3. Adjusted mean response latency (in milliseconds) as a function of Attended Repetition (AR), Control (CO), and Ignored Repetition (IR) conditions in Experiment 1. Error bars indicate standard errors.

Table 3

Mean reaction times (in milliseconds) and error rates (percentage incorrect) as a function of L2 proficiency and priming condition. Within-subjects standard errors are in parentheses.

Language Proficiency Group	Priming Condition AR	CO	IR
		Reaction Times	
More Proficient	3111 (41.69)	3006 (56.36)	3418 (57.29)
Less Proficient	3130 (43.90)	3180 (43.29)	3352 (60.80)
		Error Rates	
More Proficient	2.55 (.36)	1.40 (.42)	1.82 (.24)
Less Proficient	2. 45 (.39)	3.54 (.45)	2.41 (.43)

4.4.1. Attended Repetition vs. Control Condition

Mean AdjRTs were entered into a 2 x 2 x 2 three-way mixed ANOVA. The only statistically significant effect was the interaction between priming and proficiency [*F* (1, 69) = 4.13, *MSE* = 519006, *p* =.05, η_p^2 = .06]. The source of this interaction stems from the more proficient in L2 producing somewhat slower responses in the AR condition (3202 msec) relative to the CO condition (3059 msec), whereas the less proficient in L2 produced somewhat faster responses in the AR condition (3239 msec) relative to the CO condition (3332 msec). The main effect of priming was not significant [*F* (1, 69) = .27, *MSE* = 34177, *p =.60*, η_p^2 = .00]. Similarly, no significant effects were found for the main effect of probe distractor or any interaction involving it (with *p* ranged from .26 to .73), suggesting that the language of the probe distractor had a negligible effect on the processing of the probe target. No other effects reached significance, either.

To clarify the priming by proficiency interaction, we conducted t-tests for correlated means for the more and less proficient groups separately. Although the less proficient participants produced a tendency towards positive priming (93ms), the effect was not significant [*t* (37) = 1.21, *p* =.12, *d* = .20]. The more proficient in L2, on the other hand, produced slower responses (i.e., a negative priming effect of 142ms) in the AR condition relative to the control condition. The effect was marginally significant [*t* (34) = 1.60, *p* =.06, *d* = .27]. This pattern of data indicates that different processes differentiate the more and less proficient bilinguals. For the more proficient in L2 it is as if inhibition is applied more broadly, or globally, to a language as a whole when they are finished responding in the language required for the prime response. The implications of this interaction are explored further in the general discussion.

4.4.2. Ignored Repetition vs. Control Condition

A 2 x 2 x 2 three-way mixed ANOVA was also conducted on the mean AdjRT's data. The main effect of priming was significant [F (1, 69) = 14.03, MSE = 3068999, p < .001, η_p^2 = .17], with longer RT in the IR condition (3477 msec) than in the CO condition (3201 msec). The interaction between priming and proficiency was marginally significant [F (1, 69) = 3.84, MSE = 839445, p = .05. η_p^2 = .05]. There was no main effect of probe distractor or any interaction involving it (with p ranged from .18 to .82), suggesting that the language of the probe distractor did not influence the processing of the probe target. No other effects were significant. To clarify the priming by proficiency interaction, we again conducted two paired t-tests, one for the more proficient and the other for the less proficient bilinguals. The less proficient participants produced a tendency towards negative priming (135msec), however, this was not statistically significant [t (37) = 1.23, p = .11, d = .20]. The more proficient participants on the other hand, produced a statistically significant impairment (429msec) in the IR compared with the CO condition [t (34) = 3.93, p < .001, d = .66].

4.5. Discussion

4.5.1. Implications for the Inhibition-Based Theory

In the current cross-language selective attention context, the results provide strong support for the inhibition-based account of negative and positive priming. Overall, the study did not produce any significant positive priming effects in the AR condition wherein the prime and probe targets were translation equivalents, irrespective of whether the probe distractor shared the same language as the prime or was presented in the same language as the target probe. However, negative priming effects were produced in the IR condition (in the more proficient subgroup only) where the probe distractor was the translation equivalent of the ignored prime. Here too, the language of the probe distractor had no bearing on the results.

The robust negative priming effects observed in the IR vs. CO (in the more proficient subgroup) trials coupled with no positive effect in the AR vs. CO trials are consistent with the inhibition hypothesis. What accounts for this? According to Tzelgov, Henik and Leiser (1990), the mental representations of lexical items relating to a *momentarily irrelevant language* (or some salient component(s) thereof) undergo inhibition. The nature of the present tasks required a purposeful alternation of inhibition and activation of languages because the applicability of each language changed systematically and foreseeably between primes and probes. Hence, after naming the prime target in Twi in the present paradigm, the Twi language system becomes irrelevant and potentially disruptive. Because participants know that the ensuing probe task is in English, keeping the Twi language system activated could impair the subsequent task of making a lexical decision to the English probe target. Consequently, global inhibition of the Twi language system aborts any potential spread of activation from one language to the other, and thus obliterates the prospective benefit from a pre-activated related probe word in the other language. In addition, a local form of inhibition is applied selectively to the Twi prime distractor word, during naming of the prime target. In this case, it seems clear that the inhibition spreads to its translation equivalent in English and consequently delays processing of that word if it becomes a probe target. The cumulative effect of global inhibition of the irrelevant language and selective inhibition of the prime distractor word is manifested in the large negative priming effect, coupled with a complete absence of positive priming recorded in the present paradigm.

The parallel activation of the prime stimuli (target and distractor words) and subsequent inhibition of the prime distractor word during naming of the target, accentuates a crucial assumption of the inhibitory account in that inhibition applied to the mental representation of the prime distractor (Twi) word during selection of the target spreads to its semantic neighbours, including its conceptual English counterpart, and impairs the further processing of that concept, if it becomes the next word that requires a lexical decision. This observation strongly suggests that the conceptual representations of individual words that are highly related (such as translation equivalents) have rather direct links, regardless of language, particularly for the bilinguals who are more proficient in their L2.

4.5.2. The Role of L2 Proficiency in Inhibitory Control

The overarching aim of the current study was to explore the role of L2 proficiency in shaping the mechanism underlying bilingual lexical selection and processing. We hypothesised that if the proficiency effects predicted by Neumann et al.'s (1999) cross-language experiment are substantiated, then the IR negative priming effect should be especially strong for the more proficient bilinguals, and that AR positive priming was more likely to be eliminated in the more proficient than the less proficient participants. In Neumann et al.'s study with English-Spanish bilinguals, the more proficient participants produced a nonsignificant positive priming effect in the AR condition, coupled with this enhanced negative priming in the IR condition, whereas their less proficient participants showed a trend towards positive priming in the AR condition, coupled with a reduced negative priming effect in the IR condition. In the present experiment, besides not showing positive priming in the AR vs. CO conditions, the more proficient actually tended toward negative priming in the AR condition. The less proficient participants, on the other hand, demonstrated an inclination towards positive priming, a trend consistent with the less proficient bilingual in the Neumann, et al. study. In the present IR vs. CO conditions, significant IR negative priming was observed in the more proficient group, but the less proficient participants did not produce significant negative priming effects, findings also consistent with the English-Spanish bilingual study.

To explain this intriguing pattern of results we first assume that more proficient participants are induced to inhibit one language (Twi) when the upcoming lexical decision response required a different language (English). According to the Revised Hierarchical

Model (Kroll & Stewart, 1994), bilinguals with less L2 proficiency tend to exploit existing word-to-concept connections in L1 to access meaning for words in L2. As learners become more proficient in the L2, however, they are able to initiate direct conceptual processing of L2. More proficient bilinguals are thus less likely to need to rely on the L1 (Twi language) to perform an L2 (English) task. Hence, after requiring Twi to name the prime target, a global inhibition of the now irrelevant Twi language ensues, rendering priority to the forthcoming relevant language (English). In our view, this accounts for the elimination of positive priming, as well as the magnified negative priming recorded in the more proficient, compared to the less proficient group.

The less proficient participants appear to be more dependent on their Twi (L1) language to respond to the probe task in the English (L2) language. They might access the meaning of L2 (English words) via the L1 (Twi words) such that completely inhibiting one language is less likely to occur. After naming the prime target (Twi), a less proficient participant may be unable to entirely suppress the Twi language system, because it may be necessary for processing the upcoming English task. For less proficient participants successful L2 processing might be contingent on keeping the L1 and L2 languages active (see Kroll & Tokowicz, 2005), and this may help account for their trend toward positive priming in the AR condition, coupled with the nonsignificant negative priming effect in the IR condition. Less proficient bilinguals may be more inclined to rely on their native language as a type of crutch when accessing their second language (Chen & Ng, 1989; Frenck-Mestre & Prince, 1997), whereas more proficient bilinguals may employ a global form of inhibition to suppress the potential interference from L1 when it becomes irrelevant for a response requiring L2 (Neumann et al., 1999). These observations seem compatible with monolingual studies by Gernsbacher and Faust (1995), who showed that higher level skill in reading was associated with superior ability to suppress inappropriate information. Similarly, Kharkhurin's (2011) study with bilinguals showed that more proficient bilinguals demonstrated a weaker Stroop effect, indicating stronger inhibition (interference suppression) of the conflicting distractor word than their less proficient counterparts.

More proficient bilinguals appear to be able to isolate their languages more efficiently than their less proficient counterparts, such that once the response to a prime L1 (Twi) is accomplished, L2 (English) activation is prioritised. For the more proficient, this prioritisation of English appears to involve the inhibition of Twi, which becomes irrelevant and potentially interfering when the prime Twi response is over and done with. Not only do the more proficient show an elimination of AR positive priming, they actually show the opposite trend in the AR condition. It is plausible that the inhibition of the Twi language, as well as the attended Twi target prime are inhibited strongly enough to produce this negative priming trend in the AR condition. Whereas the less proficient indicated a trend toward positive priming, the more proficient showed a trend toward negative priming and this observation was substantiated by the significant interaction effect between priming and proficiency for both the AdjRT and error rate measures (see Table 3). In addition, there is a simultaneous automatic spread of inhibition from the selectively inhibited prime distractor (Twi word) to its English translation equivalent.

From our perspective, the above descriptions help to explain the significant interaction effect between priming and L2 proficiency in the AR vs CO condition. They were also exemplified in the IR vs CO analysis by the interaction between priming and L2 proficiency. The combination of the proposed inhibitory processes not only attenuates positive priming between the prime and probe target words in the AR condition, but also augments the negative priming in the IR condition. Global inhibition of Twi eliminates the spread of activation to the translation equivalent in English, thus preventing AR positive priming, especially for the more proficient. Additionally, this global inhibition, coupled with local inhibition of the Twi prime distractor strengthened the degree of inhibition attached to that concept. The amalgamation of these factors accounts for the large amount of negative priming in the IR condition for the more proficient bilinguals.

4.5.3. Problems for the Episodic Retrieval Model

The present manipulations and subsequent outcomes are hard to explain within episodic retrieval suppositions. How can the episodic retrieval model account for a dissociation between negative and positive priming effects within the same experiment? Why do the results from more and less proficient participants trend towards different patterns when both groups responded to the same task? These two questions are particularly difficult to accommodate within the purview of the episodic retrieval account.

As a result of its backward acting nature, positive and negative priming effects produced by the episodic retrieval model depend largely on the extent to which the probe display target serves as a retrieval cue for the target or distractor word in the previous prime display. Thus one mechanism to examine the episodic retrieval model is to manipulate prime-probe similarity because episodic retrieval is determined by the similarity of context between encoding and retrieval episodes (e.g., Fox & De Fockert, 1998; Tulving, 1983). The important point in this framework is that negative and positive priming should be maximized to the extent that probe targets share similarity with either the prime target or prime distractor. The greater the similarity, in both cases, the more likely the attached tag would be elicited.

In effect, episodic retrieval theory would predict both positive and negative priming outcomes in cross language-tasks, although, if anything, there should be a greater likelihood of obtaining an AR positive priming effect than an IR negative priming effect. It is important to note that the presence of either of these effects would necessitate an intimate conceptual connection between a word from one of the languages to the translation equivalent of that word in the other language. More crucially, however, in a test of the predictions from episodic retrieval, there should be a reduced likelihood of demonstrating IR negative priming than AR positive priming. Because the uppercase nontarget in the prime becomes the lowercase target in the probe in the IR condition, there is an additional contextual change between prime and probe words compared to the AR manipulation in which both prime and probe targets are in lowercase letters. Hence the IR condition should provide a less effective retrieval cue, according to the dictates of the episodic retrieval account. It is thus problematic for the episodic retrieval account that a nontarget prime distractor had enough influence on the probe target to induce negative priming, but the attended prime target was not sufficiently similar to the probe target to produce positive priming. Episodic retrieval is therefore incompatible with the finding of robust negative priming in the IR versus CO condition, but no positive priming in the AR versus CO condition. There is nothing inherent about episodic retrieval that would predict such a dissociation between AR positive priming and IR negative priming effects (Neumann et al., 1999).

It would also be difficult for an episodic retrieval theory to explain why the more proficient bilinguals produced vastly different results from the less proficient participants. Because the stimuli and conditions of the experiment were the same for more proficient and less proficient L2 participants, any tags that are automatically elicited by a current target should be identical for both groups and should produce similar outcomes. As such, the episodic retrieval theory would have difficulty accounting for the observed results involving interaction effects between proficiency and priming.

Although it is beyond the scope of the present article to discuss in detail, it should be pointed out that the dissociation we observed between AR positive and IR negative priming effects is contradictory to a major pre-theoretical assumption in the selective attention literature more generally. As articulated by Christie & Klein (2008), attended information should always produce stronger priming effects than ignored information in selective attention tasks, such as a negative priming paradigm, that includes a positive priming manipulation. This pre-theoretical assumption, held by most selective attention researchers, should be re-evaluated in light of the present findings. It seems intuitively obvious that attending to something should be more likely to have a subsequent impact on priming, compared to something that has been ignored, but this intuition should henceforth be questioned. Taken collectively, it is clearly the case that in the present cross-language context it is the nontarget, ignored information that is having the greater impact on modulating the priming effects. These results provide a step toward understanding how proficient bilinguals are able to vacillate between their languages with such virtuosity. It will be important for future researchers to get a fuller understanding of how this language control transpires and what exactly differentiates less and more proficient bilinguals.

4.6. Conclusion

The results reported here corroborate and extend the study by Neumann et al. (1999). Each of these studies directly tested differentiable predictions from an active inhibition perspective in contrast to the episodic retrieval account via cross-language priming tasks with bilinguals. The inhibition-based account more successfully accommodated the collective findings. What is fundamentally amiss in the episodic retrieval theory is the prediction that the likelihood that the AR condition should produce positive priming is greater than the likelihood that the IR condition should produce negative priming. Instead, our findings suggest that local and global forms of inhibition have critical roles in bilingual lexical selection and processing and can operate simultaneously within the same task. The overall outcomes, and in particular the demonstrated effect of language proficiency indicate that bilingual language processing can be regulated by two sources of active inhibition: one stemming from the global suppression of a language that becomes irrelevant and potentially distracting, and another that acts on a local word level that suppresses a competing word.

These findings extend our understanding of inhibition phenomena and how they might be used to track the crucial roles of L2 proficiency in modulating bilingual language representation and memory processes.

Chapter 5

Cross-language positive and negative priming effects reverse when priming manipulations proceed from L2-L1, compared to L1-L2.

5.1. Abstract

A bilingual primed lexical decision task was used to investigate priming effects produced by attended and ignored words. Subjects were required to name prime target words in their weaker language (L2) and then make lexical decisions to probe target items in their dominant language (L1). Accelerated lexical decisions to probe target words resulted when the word was a translation equivalent of the preceding prime target word, but subjects were not slowed in making lexical decisions to probe target words when the word was a translation equivalent of the preceding ignored nontarget word. This "paradoxical" finding of a positive priming effect, coupled with the absence of negative priming, is tentatively explained as a reflection of how degrees of inhibitory modulation can vary based on first versus second language dominance.

5.2. Introduction

Parallel activation is a consequence of knowing more than one language, regardless of what those languages are, or whether they share similar or distinct scripts. Numerous studies have shown that both languages of a bilingual are active when bilinguals perform a given task (e.g., Freeman, Blumenfeld & Marian, 2016; Mishra & Singh, 2016). Much less is known, however, about how languages (or the words within them) are independently up-and-down-regulated after such a parallel activation. What is clear is that the bilingual has to choose a specific representation between competing alternatives involving the two languages; what Finkbeiner, Gollan & Caramazza (2006) describe as the "hard problem". Selecting one language for response is associated with the question of how the nontarget language is controlled to prevent it from being interruptive.

There is evidence that bilinguals acquire a sophisticated mechanism of control that inhibits influences from the unintended language during task performance (Green, 1998). Support for the inhibitory mechanism has been reported in a range of behavioural and neuroimaging studies (for a review, see Kroll, Bobb, Misra & Guo, 2008). In the Inhibitory Control (IC) model, competing potential outputs of the lexico-semantic system are inhibited according to the purpose of the interlocutor (Green, 1998). Put another way, selection in the IC model is attained by the inhibitory mechanism that suppresses lexical nodes of the unintended language. The IC model has three significant features: first, the inhibition applied to the lexical nodes of the unintended language is 'reactive', that is, more active lexical nodes are more strongly inhibited. Next, the conceptual system activates the lexical nodes of the two languages, but candidates of the unintended language are suppressed later, and finally, there is discrete processing between lexical and sublexical levels, and thus, phonological activation is limited to the targeted lexical node (see Costa, 2005).

Evidence for the inhibitory control account has been widely reported in language switching experiments (e.g., Linck, Schweiter & Sunderman, 2012; Macizo, Bajo & Paoleiri, 2012; Wang, 2015). The switching technique is a mechanism for investigating language selection in bilingual speakers that implicates language network prioritisation as a function of task requirements and the currently active schema. Such research examines language control and selection processes as well as nontarget language interference avoidance processes that are presumably invoked during cross-language tasks. The experimental protocol involves the random presentation of stimuli (e.g., pictures or numbers) and the response language of naming is cued by a feature such as background colour. Participants are required to name the stimuli in either their L1 or L2 language and the difference in naming latencies between switch and nonswitch trials is expressed as the *language switching cost*.

Most language switching research has reported asymmetrical switch costs, largely driven by language dominance. In such studies, switches into a more dominant (L1) language produces considerably greater reaction time (RT) delays than the reverse (e.g., Filippi, Karaminis, & Thomas, 2014; Kletcha, 2013; Meuter & Allport, 1999; Wang, 2015). Such research supports the conjecture that naming in L2 entails inhibition of the L1, and naming in L1 following L2 requires overcoming that inhibition to a greater degree than naming in L2 following L1. Thus, when naming in L1, the inhibition of the weaker L2 is assumed to involve a reduced magnitude of inhibition. In the seminal study of Meuter and Allport (1999) bilinguals named numerals in either their first (L1) or second language (L2) unpredictably, based on a concurrent background colour cue. Response latencies on switch trials (where the response language changed from the previous trial) were slower than on nonswitch trials. Moreover, language-switching costs were larger when switching to the dominant L1 from the weaker L2, than vice versa. The researchers surmised that naming in the weaker language (L2) necessitated a greater degree of active inhibition or suppression of the stronger competitor language L1 (the L1 lexicon as a whole), and this was why there was a greater switch cost from L2 to L1, than from L1 to L2.

So far, all the cross-language experiments reported in this dissertation required subjects to name prime target words in their dominant L1 (Twi) followed by making lexical decisions to probe target items in their weaker L2 (English). In contrast with a control condition (CO), the experiments produced significant negative priming (NP) effects in the ignored repetition (IR) condition, where the prime distractor word was a translation equivalent of the probe target word. However no positive priming effects emerged in the attended repetition (AR) condition where the prime target word was a translation equivalent of the probe target word. It was conjectured that because stimuli were presented in a predictable regularly alternating sequence from one language to the other, participants could concentrate their upcoming “word” vs. “nonword” decision on those lexical representations belonging to the language of the upcoming target after reacting to the prime target. This entailed global inhibition of the prime target language (Twi) to prevent it from interfering with the impending task in the other language (English), which consequently eliminated cross-language facilitation (positive priming). The NP effects in the IR condition were interpreted as the consequence of inhibition applied to the local competing prime distractor (Twi) word during naming of the target, which spread to its translation equivalent in the other language (English) and impaired response to the English word when it became the probe target.

Extrapolating from the language switching asymmetries stated earlier, it appears that the order of language presentation determines switch cost because there is more cost incurred when L2 precedes L1 than vice versa. Hence, it is hypothesised that in cross-language experiments, of the sort used here, the order of prime-probe language presentation might likewise have an impact on the priming effects that are produced, such that, priming effects produced when the prime task is in L1 and the probe is in L2 should be different from the reverse (from L2 to L1). In the cross-language experiments in chapter 3, prime words were in L1 (Twi) and probe target words were in L2 (English). The present experiment follows the same protocol, but reverses the order of prime-probe languages. Here prime words are in L2 (English) and probe target items are in L1 (Twi). The overarching goal is to examine whether the pattern of priming effects observed in the current experiment will differ from the previous cross-language findings here, and in Neumann et al. (1999, Experiment 2), based on the reversal of language dominance in prime and probe displays.

5.2.1. Method

5.2.1.1. Participants

Thirty-three Twi-English bilinguals (23 men and 10 women) from the Foso College of Education in Ghana voluntarily participated. All the participants had normal or corrected to normal color vision. They ranged in age from 19 to 30 with an average age of 22 years. The participants were all native speakers of the Twi language and they were all generally proficient in the second (English) language. They all began to acquire the L2 around age 6, where English is introduced and used along with Twi in the classroom. At university, all of the participants reported regular and deliberate switches of English and Twi languages on a daily basis, because they generally use English in the classroom, and Twi outside of the classroom.

5.2.1.2. Stimuli and apparatus

The stimuli were 620 three to thirteen letter words from Frances and Kucera (1982). Word frequency varied from 32 to 50 uses per million. Their corresponding Twi noncognate equivalents were chosen from the Twi-English, English-Twi *Hippocrene Concise Dictionary* (Kotey, 2007). Ninety-six pronounceable Twi nonwords were also generated to cater for the nonword condition [e.g., *mpɛtɛɛ* - instead of *mpataa* (meaning fish in English)]. There were approximate equal numbers of letters in letter strings for the word and nonword targets, in order to curtail ease of discriminability between targets and distractors. One-hundred and sixty-eight items from the word pool were used as targets, and the rest as filler words. Three priming conditions were created: (AR) – in which the probe target (Twi word) was the English translation equivalent of the prime target word [e.g., pen (meaning twer*ɛdua in Twi)* ~ twer*ɛdua*]; (CO) – in which prime and probe stimuli had no relationships [e.g., stick (meaning *dua* in Twi) ~ ɔbɔfoɔ (meaning *hunter* in English)] and (IR) - in which the probe target Twi word was the translation equivalent of the ignored prime English word [e.g., NEEDLE (meaning pane*ɛ in Twi)* ~ pane*ɛ*).

The experiment contained 72 word (24 in each of AR, IR, and CO trials) and 72 nonword trial couplets. There was a low ratio of AR trials (24 total trial couplets) because evidence shows that as the relatedness proportion increases, participants are apt to create expectancy biases which can artefactually boost performance (Neely, 1991). Two hundred and sixteen Twi words from the stimulus pool were divided into 72 each of prime distractors, probe distractors, and probe targets. The 72 probe target words were randomly distributed into sets A, B and C of 24 words in each of the three conditions (AR, CO, and IR). Participants were randomly assigned to these groups for the purpose of counterbalancing. The word and nonword trial couplets were randomised and the same order appeared for all participants irrespective of the counterbalancing group. Each target or distractor word appeared once in a prime-probe display except to satisfy AR or IR conditions. Similarly there were equal numbers of word and nonword trials, and this was done to eliminate bias toward responding “word” or “nonword”. Twenty-four practice trial couplets preceded the main experiment. No practice word was repeated in the main experiment.

Stimuli were presented on a 15.6 inch Hewlett-Packard (HP) laptop computer using E-Prime 2.0 software programme (Psychology Software Tools, Inc.). A 5-button PST Chronos response box (Psychology Software Tools, Inc., 2012) was used for recording lexical decision reaction times (RTs). The two leftmost buttons were activated and labelled “word” and “nonword”. A response sheet was created with prime target words to enable the experimenter to observe the naming of primes. All word stimuli were printed in lowercase (target) and uppercase (distractor) black letters (Calibri, font size 11) on a white background. Target and distractor items were displayed one above the other pseudorandomly such that they each appeared at the top 50% of the time and at the bottom 50% of the time across all conditions. Nonword letter strings served only as probe targets. The width of the words covered approximately 1.4cm (1.6 degrees of visual angle) for the shortest to 5cm (5.7 degrees of visual angle) for the longest. The distance between the closest edges of the top and bottom letter string was 1 pixel width. Prime displays were presented either centred, or slightly to the left or right of centre, in equal proportions on the computer screen. By taxing attentional selectivity (Langley, Overmier, Knopman, & Prod’Homme, 1998; Neumann & DeSchepper, 1991) in exactly the same way as in the previous experiments, this presentation style is designed to augment the probability of obtaining NP. Probe stimuli were displayed at the centre of the screen at all times.

5.2.1.3. Design and Procedure

A within-subject design was adopted. Priming condition (AR vs. CO vs. IR) was manipulated in order to track participants’ RT and accuracy rates on responding to the probe target stimulus. The nonword lexical condition trials were not included in the analyses. The experiment was carried out in an isolated, dimly-lit room optimised for low noise. Participants were tested individually in a session lasting about 55 minutes. They sat at an approximate viewing distance of 50cm from the computer screen. The task started with 24 practice trial couplets including all four possible experimental conditions (AR, CO, IR, and nonword trials). They were instructed to say aloud, as quickly and accurately as possible the prime target word (lowercase letters) while ignoring the uppercase distractor word. Then in the probe display, decide whether the probe target (lowercase letters) was a correct Twi word or not. Participants were guided through the practice trial and feedback on accuracy appeared after each practice trial. The experimenter stayed behind the participant once the main experiment started, to avoid distractions.

Each trial began with a black fixation cross displayed for 500ms, followed by the prime stimuli that stayed on the screen for 250ms while the participant named the prime target word. A blank sheet was presented for 1000ms, and the probe stimuli were displayed on the screen until the participant made a lexical decision to the probe target item. Lexical decisions to probe targets were made by pressing the “word” button with the index finger of the right hand, and the “nonword” button with the middle finger of the right hand. Once a response was registered, the next trial began. A sample of trials for all conditions in the experiments is shown in Table 5.1. Figure 5.1 shows a sequence of stimuli presentation in the experiment.

Table 5.1

Sample of Conditions for Word/Nonword Trials in the Experiment

Condition	Prime Display	Probe Display
Attended Repetition	truth	nokware
	TELEPHONE	GYIDIE
Control Condition	book	ƆKYEAME
	BOTTLE	asɛm
Ignored Repetition	CUP	kuruwa
	profession	SAFOA
Nonword Condition	table	abofrɔ
	WISDOM	ADWENE

Note: Lowercase letters in each case were the targets and the uppercase letters were distractors. Lowercase words in the prime display required naming, lowercase words in the probe display required a lexical decision. Only word trials were analysed.

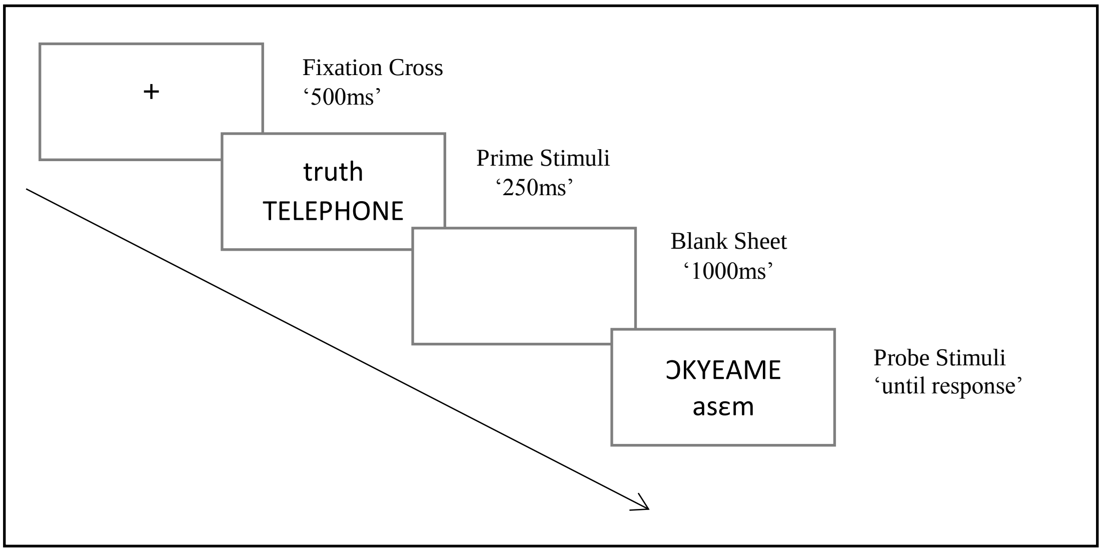

Figure 5.1. Sequence of stimuli presentation. Note that the distance between the closest edges of the top and bottom item in each display was 1 pixel width.

5.4. Results

Individual data sets that contained 30% or above naming or response errors were excluded from analysis. One subject was removed from further analysis based on this criterion. Nonword data were not analysed. A one-way within-subjects analysis of variance (ANOVA) was conducted on the mean RT data contrasting the priming conditions (AR, CO, and IR). A significant effect was observed [F (2, 62) = 3.89, MSE = 163414.695, p = .03, n^2_p = .11]. To ascertain whether AR vs. CO trials produced facilitation and IR vs CO produced a delay, planned t-tests were conducted. The AR condition (M = 3413, SD = 929.54) produced significantly faster RTs than the CO condition (M = 3645, SD = 1146.01), t (31) =2.35, p =.01, d =.42. There was a nonsignificant difference between the IR condition (M = 3667, SD = 1057.06) and the CO condition (M = 3645, SD = 1146.01), t (31) = .21, p =.42, d = .04. The mean RT data are shown in Figure 5.2.

Error rates were analyzed in a similar manner. The main effect of priming was significant [F (2, 62) = 4.36, MSE = 16.95, p = .02, n^2_p = .12]. Planned t-tests showed significant facilitation in the AR condition (M = 2.89, SD = 3.63) compared with the CO condition (M = 5.64, SD = 4.53), t (31) = 2.61, p = .01, d = .46, indicating fewer errors in the AR condition. There was no difference between IR condition (M = 5.39, SD = 5.97) and the CO condition (M = 5.64, SD = 4.53), t (31) = .31, p =.38, d = .05. Hence, the error data closely emulated the RT data, and there was no evidence of speed-accuracy trade-offs.

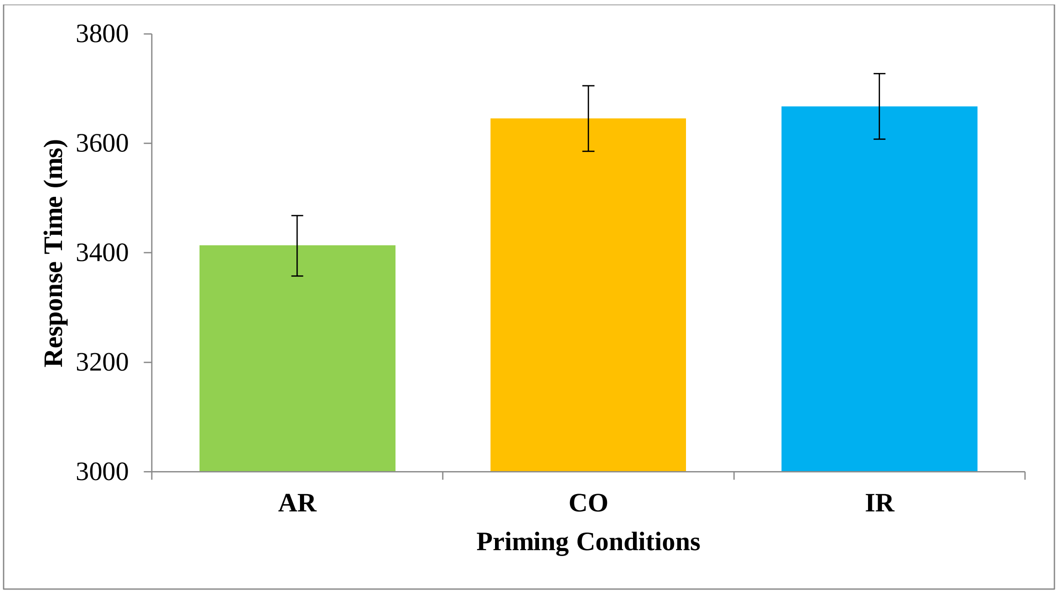

Figure 5.2. Mean response latency (in milliseconds) as a function of attended repetition (AR), control condition (CO) and ignored repetition (IR) condition. Error bars indicate standard errors.

5.5. Discussion

This study reports a cross-language naming and lexical decision task that examined the priming effects of attended and ignored stimuli, when participants execute prime naming in their L2 followed by making a lexical decision to probe target items in their L1. The experiment was a slight modification of the previous cross-language experiments that required participants to name prime words in their dominant L1 and subsequently make lexical decisions to probe target items in their weaker L2. The aim was to ascertain whether the priming effects in cross-language experiments are modulated by the order of prime-probe language manipulations.

Similar to the preceding cross-language experiments, prime and probe displays in the present study followed a formulaic constant alternating pattern from one language to the other. Hence it was assumed that after participants had reacted to the prime target (English) word, the English language system would become irrelevant and be suppressed, so that participants could focus their impending "word" vs. "nonword" judgement on those lexical candidates belonging to the forthcoming target language (Twi). Globally suppressing the English language system should reduce or prevent the potential spread of activation from the prime (English) target to its translation equivalent the probe (Twi) target, and thereby possibly eliminate positive priming. It was further assumed that, the prime distractor English word would be locally inhibited during naming of the target and this inhibition would spread via spreading inhibition to its translation equivalent in the other language (Twi), and impair response to that word if it appeared as the probe target. These predictions in anticipation of a significant NP effect coupled with the absence of positive priming were incompatible with what was obtained. Instead, the AR condition showed substantial positive priming, but no NP emerged in the IR condition. What could account for these results?

Most switching experiments (e.g. Meuter & Allport, 1999; Costa & Santesteban, 2004) that report asymmetric switch-cost especially in unbalanced bilinguals argue that when naming in the dominant (L1) language, lexical entries corresponding to the weaker L2 are not inhibited very much (or at all). Thus, when production occurs in L1, there may be little indication of L2 influence because L1 is relatively more skilled than L2 and the rapid time course of speech planning in L1 may not provide much opportunity for L2 to come into play (see Kroll et al., 2008). By definition L1 is acquired first and generally receives the greater amount of practice throughout life. According to Meuter and Allport (1999), the weaker L2 can only win the competition with L1 for the control of spoken production, when L1 is suppressed. Moreover, L1 is globally suppressed more strongly whenever it is in competition with L2, and L2 is more weakly suppressed whenever it is in competition with L1. If this is an accurate portrayal, it would seem to suggest that AR positive priming should be less likely to occur when the prime requires overt L2 processing. If the prime target concept in L2 is automatically activating its L1 counterpart, but L1 is globally strongly inhibited, it seems that there should be a lessened chance to obtain an AR positive priming effect, than in the reverse scenario. Specifically, if the prime target concept in L1 is automatically activating its L2 counterpart, but L2 is not so globally strongly inhibited, it seems that there should be a greater chance to obtain AR positive priming effect. In contrast to these predictions derived from Meuter and Allport, however, it is only when the prime words are in L2, that AR positive priming was observed. Furthermore, it is only when the prime words were in L1 that AR positive priming disappeared, as shown in the cross-language experiments of chapter 3.

The present results seem more consistent with the idea that the weaker L2 does not have to be inhibited strongly (or at all) in order to perform the probe task in the dominant L1. From the results, it was as if the prime (L2) language system which became transitorily irrelevant after the prime task had been accomplished, did not have to be inhibited strongly (or at least not inhibited enough to eliminate positive priming) in order to perform lexical decision in the probe (Twi) language and hence there was facilitation in AR condition. Thus, counter to what might be expected based on Meuter and Allport's (1999) position on language switch costs, perhaps there was little (or no) global inhibition of the English language system after the prime task because it is relatively weaker and so did not require much inhibition due to its weak competition with making a lexical decision to the probe target in Twi. In retrospect, however, it may be that the assertion that switching from L2 to L1 generally induces greater cost due to the greater inhibition of L1 during L2 processing, does not apply to the current paradigm. Several reasons for this are given below.

There are a number of important differences in methodology between the present study and those of language switching experiments that potentially account for why the switching assumptions failed to predict the present findings. Probably most importantly, in switching experiments response language is at random (i.e., not known before each stimulus is displayed), whereas in the present study prime-probe language presentations followed a predictable, regularly alternating sequence in which participants were always aware of the language of the upcoming target. Other differences were that the current participants performed two tasks, a naming followed by lexical decision task, while in switching experiments participants perform only naming. Switching experiments also involve presentations of single items, whereas in the present paradigm, every prime-probe couplet had two items (a target and a distractor). The aggregate of these differences may account for why the claim that L2 to L1 manipulations should generally produce larger cost, due to greater suppression of L1, do not accommodate the observation of AR positive priming reported here.

Furthermore, in cross-language experiments where prime-probe manipulations followed a dominant L1 to a weaker L2 order, the substantial IR NP effect obtained was attributed to spreading inhibition from the prime distractor (L1 word) to its translation equivalent, the probe target (L2 word). Subsequent response to the target on IR trials required a time consuming reactivation of the inhibited word. Thus performance delay emerged from the reactivation of the translation equivalent of an inhibited distractor word. Similarly, naming the prime (L2) target word in the present experiment required inhibition of the concurrently presented (L2) prime distractor word. However, because English (L2) was a weaker language in this context, the activation level of an English distractor word was presumably also relatively weak. It is plausible that a relatively weak distractor requires little inhibition (Green, 1998; Houghton & Tipper, 1996). Therefore, it is possible that the amount of inhibition applied to the prime distractor (L2 word) was not strong enough to be able to persist and impede its Twi (L1) translation equivalent in the probe target. In other words, the probe (Twi) target in IR trials might not have experienced initial inhibition (during prime task performance) to the degree necessary to produce a significant NP effect.

It appears that varying language strengths have a significant influence on inhibitory control and in eliciting both positive and NP effects in cross-language experiments. Distractor words from a dominant L1 language are potentially more interfering, and receive stronger inhibition. As shown in chapter 3, the strong inhibition is able to spread to its translation equivalent in the L2 language and elicit NP on IR trials. However, prime distractor representations of a weaker L2 language may receive less inhibition. The weak inhibition appears to be unable to spread and suppress its translation equivalent in the dominant L1 language, thus accounting for the absence of NP in the current experiment. From the present perspective, the stronger a distractor is activated, the more interfering it is and the greater the amount of inhibition it receives, hence producing the NP effects reported in the previous L1 to L2 cross-language experiments.

Although the results in the current experiment were inconsistent with the predictions, they can still be explained within an inhibition-based framework, as discussed above. In contrast, the results pose a challenge to the episodic retrieval account. The episodic retrieval model would explain the positive priming effect in the present paradigm as a consequence of the compatible ‘response tags’ that were created between the prime target and its translation equivalent, the probe target. However, this explanation cannot account for why the ‘incompatible response tags’ between the prime distractor and its translation equivalent in the probe target did not induce NP. As stated earlier, the episodic retrieval theory provides little room for dissociation between positive and negative priming effects in the same paradigm when the similarity gradient among the eliciting stimuli is comparable. In principle, the compatibility and non-compatibility between response tags that underlie positive and NP effects, respectively, should be equally likely to be elicited. Hence, the episodic retrieval account predicts that when one of these effects is produced, the other should be as well.

The AR positive priming effect that emerged across languages in the present experiment also augments the hypothesis that languages are encapsulated in one memory system. This is consistent with other studies that claim that the existence of cross-language positive priming among translation equivalents support the single store hypothesis (e.g., Altarriba, 1992; Sanchez-Casas, Davis, & Garcia-Albea, 1992; see also Altarriba & Basnight-Brown, 2007). Because of mixed findings in that literature, one should be cautious about using positive priming indices alone to tap into the nature of bilingual language representations, because support for the single store hypothesis was shown most clearly in Chapter 3 via IR NP effects in the absence of AR positive priming, and only in the current experiment by the presence of AR positive priming. If languages are stored independently from each other, there should be little likelihood to produce positive priming or NP across languages. From the present perspective, obtaining NP across languages is especially good evidence that the languages of a bilingual are intimately interconnected in a single storage system. The inhibitory mechanism(s) unveiled in the present work, however, provide evidence for an important means by which they can operate as if they are functionally separated in such a single store (see also Neumann et al. 1999).

5.6. Conclusion

The present experiment suggests that the order of prime-probe language manipulations influence negative and positive priming effects elicited in cross-language studies. When the results are contrasted with those of the cross-language experiments in Chapter 3, it is clear that these language dominance issues are a factor in modulating the mechanism underscoring bilingual lexical selection and processing (see also Costa & Santesteban, 2004; Kroll et al., 2008). Replicating and extending the present experiment while the language proficiency of participants is systematically categorized and analysed, will be a project for future research.

CHAPTER 6

6.1. Review

The overarching aim of this dissertation was to examine lexical representation and selection in bilingual memory using negative and positive priming effects. To summarize, Chapter 2 investigated negative and positive priming effects using large pools of nonrecycled words and further assessed whether these are expressed differently in bilinguals from monolinguals. The aim of Chapter 3 was to draw theoretical and empirical parallels and differences between the mechanisms of excitation and inhibition and to identify the different circumstances in which these mechanisms operate in bilingual language processing. Chapter 3 further tested predictions stemming from the episodic retrieval and inhibition based theories of negative and positive priming and examined whether one of these theories provide a better account of cross-language findings than the other. Chapter 4 explored the system that regulates the activation and suspension of target and nontarget languages (as well as the words within them) during bilingual language processing and also determined how this system is influenced by different levels of L2 proficiency. The aim of Chapter 5 was to examine whether priming effects obtained in cross-language experiments are influenced by the order of prime-probe language manipulations. Together, all the cross-language experiments reported in the dissertation had a secondary purpose of contributing to the debate of whether the languages of bilinguals are stored and accessed together or separately in memory.

6.2. Summary of Findings

This dissertation makes relevant contributions to the selective attention literature in general, and to the burgeoning of research on bilingual language processes in particular. Foremost, this is one of the first attempts to test and flesh out an account for the disparate reports of negative priming (NP) with large pools of nonrecycled words. It was found that a word encountered only once as a distractor, but never as a target, can nonetheless be significantly impeded if it appears as a subsequent probe target, as evidenced by NP effects. Hence, NP with words is not conditional on stimulus repetition. Second, by way of a systematic investigation of priming across languages this dissertation found evidence for a dissociation between the inhibition based and episodic retrieval theories of negative and positive priming. The inhibition based theory provided a parsimonious account of the cross-language negative and positive priming effects, while the results raised challenges to the episodic retrieval model's suppositions. There was also favourable evidence for the hypothesis that inhibition is a flexible mechanism that operates at both the local and global levels of abstraction. Findings from the cross-language studies further provided support for the assumption that the two languages of the bilingual are encapsulated in one memory system. Another interesting discovery was the varied processing engaged by less and more proficient bilinguals in negotiating cross-language competition. More proficient bilinguals appeared to inhibit the dominant (L1) language when performing the probe task in the weaker (L2) language, whereas less proficient bilinguals were more inclined to rely on their dominant (L1) language as a form of crutch to perform task in the weaker (L2) language. Finally, evidence suggested that inhibition applied to a distractor item during task performance, is proportionate to the activation levels of the distractor. Specifically, it was found that the weaker L2 does not have to be globally suppressed strongly (or at all) when performing the probe task in the dominant L1, and representations of a weaker L2 prime distractor word receives little inhibition (when it is in competition with an L2 target) which is unable to spread and inhibit its translation equivalent in another language. The implications of these findings are discussed further in the following sections.

6.3. Evidence for negative priming with large pools of nonrecycled words

The question of whether NP can be obtained with large pools of nonrecycled words was pursued due to the prevailing counterevidence concerning it, and more importantly, because of its implications for the use of stimuli with the wide ranging flexibility of words in NP tasks, if such effects were actually to be observed. All of the within-language experiments (Chapters 2 and 3, Experiment 1) did find negative and positive priming effects with large pools of nonrecyled words, that appeared maximally twice in the experiments. The NP findings in particular showed that a word encountered only once as a distractor, but never as a target, can nonetheless be significantly impeded if it appears as a subsequent probe target. This was shown to be the case even when bilinguals performed the task in their non-dominant language. Moreover, the negative and positive priming effects occurred with bilingual and monolingual groups of participants, suggesting that the results were independent of the language characteristics of the respondents.

The assumption that NP is contingent on stimulus repetition when *words* are used as stimuli was formed on the basis of an account that claimed that word activation levels increases with repetition, and NP then occurs because selection difficulty in the prime display is high. That is, when the distractor is highly activated, it is more likely to compete with responding to the target, and it is in such situations that the conditions for producing NP are met. However, the activation levels of experimentally novel (nonrecycled) words in some paradigms are relatively low and thus NP does not occur. An experimentally novel distractor in the prime display that is less likely to compete strongly with response to the target does not satisfy the conditions necessary for NP to emerge. Although the experimental manipulations employed in the present experiments differed from those that involved repeated word presentations, the results were still consistent with the assumption that, a high degree of competition between target and distractor words is required to produce NP effects. The specific methodological features employed in the present experiments helped to create a heightened selective state in an experiment-wide manner. These features included the elimination of using colour as the selection cue, by instead, using lettercase as a target selection cue with uniformly black stimuli, spatial uncertainty of the words in the prime display, and the close spatial proximity of the target and distractor in each encountered display. In addition, there was a change in response requirement from naming in the prime display to lexical decision to the probe target item. Collectively, this created a high degree of competition between target and distractor words that was sufficient to produce NP effects, in the absence of stimulus repetition, across most of the present experiments.

6.4. Cross-language negative and positive priming effects: A dissociation between inhibition based and episodic retrieval theories

The inhibition based and episodic retrieval theories made similar predictions in the within-language experiments. Their differences became apparent in the cross-language studies. The episodic retrieval theory predicted both negative and positive priming effects across languages, albeit reduced, whereas the inhibition based account predicted a dissociation between negative and positive priming effects across-languages. The cross-language experiments reported in Chapters 3 and 4 presented prime stimuli in the subjects' L1 and the probe target items in the L2. These experiments produced robust IR NP, but no AR positive priming. The collective findings were more successfully accommodated by the inhibition based assumptions, but raised challenges for the episodic retrieval model. To account for the NP effects, it was conjectured that the prime distractor (Twi) word was inhibited during naming of the target, and this inhibition spread to supress its English translation equivalent. Hence response latency to the English equivalent word was impaired when it appeared as the probe target (on IR trials) requiring lexical decision. Regarding the absence of positive priming, it was assumed that the prime (Twi) language system became irrelevant after the prime naming task was done with, and was therefore inhibited in order to help avoid interfering with the lexical decision requirement in the other language. This inhibition, in turn, prevented any potential spread of activation from the prime target word to its translation equivalent, the probe target (on AR trials) and thus positive (facilitation) priming was eliminated. This pattern of findings is particularly difficult for episodic retrieval theory to handle.

The most significant factor in the episodic retrieval framework is that negative and positive priming should be maximized to the extent that a probe target share similarity with either the ignored prime target or the attended prime target. Therefore, as already elaborated, proponents of the episodic retrieval model may argue that the absence of positive priming was due to the differences in visual forms between the prime and probe targets, because the words that were used were noncognate translation equivalents. Thus despite the close conceptual relation between the prime and probe target words, their physical features did not match and therefore did not meet the conditions necessary for producing positive priming in episodic retrieval terms. For instance, a prime target word *abaa* (meaning *cane* in English) does not provide an effective retrieval cue for its translation equivalent *cane* (on AR trials), because the physical similarity between the words have been altered. While such an explanation can account for the absence of positive priming, it cannot explain why NP emerged.

According to Schooler et. al., (1997), it is as if the similarity gradient that underlies episodic retrieval is broader than the one originally proposed by Logan. Perhaps, a processing episode encodes semantic, perceptual, associative, lexical, and phonological information in proportions, that are commensurate with the requirements of the task. The failed prediction stemming from episodic retrieval theory in the present context consists of the fact that, although the supposedly 'incongruous response tags' between the ignored prime and the target probe could have caused the observed NP in the IR condition, there should have also been a facilitation effect in the AR condition, since the similarity gradient in the IR condition was even more different. Specifically, in the IR condition, not only was the relationship between the prime distractor and probe target based on noncognate translation equivalence, but the structure of the words changed from uppercase to lowercase letters. Yet the probe translation equivalent can be interpreted as being capable of eliciting the "do-not-respond" and hence producing NP. Because the prime and probe targets were relatively similar in the AR condition, there was a greater possibility of producing positive priming than NP, but the reverse was observed. In addition, Neill (1997) has emphasised that the processes that underlie negative and positive priming are the same and there should not be dissociation between the two within the same experiment. The present data speak directly to this proposal, because if episodic retrieval processes were elicited in the experiments, one would have expected an AR positive priming benefit to be at least as likely to emerge as the IR NP that was observed, and to be of comparable magnitude.

While the mechanisms underpinning the episodic retrieval theory may have a role in other priming and selective attention tasks, it seems clear that in the present experiments they are being superseded by more potent inhibition-based mechanisms. From the present perspective, the episodic retrieval theory is not detailed in its predictions as to be able to handle the present results. Such concerns have been shared by other researchers (e.g., Tipper, 2001; Tipper & Milliken, 1996). As articulated by Tipper and Milliken (1996), the lack of specification in the episodic retrieval model is such that it does not detail on how the 'do-not-respond' tag becomes associated with the internal representations of the distractor object. In their view, some processes acting on the internal representations of the distractor during selection of the target causes the 'do-not-respond' tag to be assigned and perhaps that process is inhibition associated with the internal representations of distracting stimuli during selection of the target. Future research could replicate and perhaps extend the present studies with different populations of bilinguals. This could help to specify how and when inhibition or episodic retrieval, or both theories play their respective roles.

6.5. Language selection and processing in the bilingual lexicon

The extent to which the linguistic systems of bilinguals interact is an enduring issue in cognitive psychology and psycholinguistics. There is evidence that the two languages of the bilingual are activated when one language is required to perform a given task (e.g., Colomé, 2001), and it is hypothesised that lexical selection is achieved by inhibiting the mental representations of the unintended language (e.g., Green, 1998). The cross-language priming effects observed in Chapter 3 were consistent with the hypothesis that bilingual language processes are regulated by a system of active inhibition. It was conjectured that inhibition applied to the prime distractor (Twi) word during naming of the target (Twi) word spread to suppress influences of its translation equivalent in the English language. Hence response latency to the English translation equivalent was impaired when it appeared as the probe target requiring lexical decision. Similarly, the prime language (Twi) system was assumed to have been *globally* inhibited after the prime naming task was accomplished, and this inhibition prevented any potential spread of activation from the prime target word to its translation equivalent, the probe target (on AR trials), hence positive priming was eliminated. These cross-language observations supported the argument that inhibition is a flexible mechanism that operates at both the local (inhibiting specific language representations) and at a global (inhibiting an entire language system) levels of abstraction. In addition, the local and global forms of inhibition have critical roles in bilingual lexical selection and processing and can operate simultaneously within the same task.

Although not part of the initial goals of this dissertation, it seems reasonable that the mechanisms of excitation and inhibition may characterize bilinguals' ability to restrict communication to one language, but in other instances, also borrow words from the other language when communication is planned in a particular language. For this capacity, the mechanisms of excitation and inhibition would need to be finely tuned, rendering accessibility to lexical items from each language on a moment to moment basis. For example, a Twi-English bilingual can communicate in the Twi language without any trace of an English word which may imply that the English language system is globally inhibited in that context. However, in most cases, a Twi-English bilingual can also insert some Twi words in a situation where production is planned in English, which also seem to be a manifestation of excitation and inhibition of the languages in turn depending on the goals of the interlocutor. The explanations in Chapter 3 highlight the interconnected, mutually informative priming technique and research on bilingual memory processes. By examining negative and positive priming across languages, and their relationship with bilingual language selection, the present findings have added to the literature on the cognitive mechanism that regulates cross-language interference.

6.6. Language organisation and representation in the bilingual memory

One of the major outstanding questions in bilingual memory research is whether bilingual speakers have two distinct lexicons, for each language or one big lexicon for both languages. This issue was raised by the early years of bilingual memory research but continues to be a matter of debate because it has generated inconclusive answers (French & Jacquet, 2004). The observation of priming effects across languages in Chapters 3 and 5 provided evidence to the single-store models of bilingual language representation, wherein conceptual representations are deemed to be integrated across languages in bilinguals. All previous priming studies supporting single-store models have used the existence of cross-language positive priming among translation equivalents as the key indicator of support for their claim (e.g., Altarriba, 1992; Sanchez-Casas, Davis, & Garcia-Albea, 1992; see also, Altarriba, & Basnight-Brown, 2007). The observations in Chapter 5 are consistent with the assumption that positive priming across languages supports the single-store hypothesis. On the other hand, Chapter 3 also found evidence for the single store hypothesis, via NP across languages. The cross-language NP that emerged in Chapter 3 seem to suggest that it is insufficient to use positive priming indices alone when trying to tap into the nature of bilingual language representation and processing. In summary, if languages are encapsulated from one another, it should make it difficult to observe any kind of priming across languages. The contrast between AR positive priming (in Chapter 5), and IR NP (in Chapter 3) across languages also contradict a widely held assumption that attended information should always elicit stronger priming effects than ignored information in selective attention tasks, such as a NP experiment that includes positive priming manipulation (Christie & Klein, 2008). Because in the cross-language priming effects reported in Chapter 3, it is the ignored information that had a greater impact on modulating the priming effects.

6.7. Effect of L2 proficiency on inhibitory control

Bilingual language selection and processing entails inhibitory control to maximally balance the competition between the two languages in the linguistic system when one language is needed to perform a given task. The degree of inhibition required to prevent interferences from the nontarget language differs across speakers as a function of L2 proficiency and perhaps the requirements of the task. The differential patterns of results produced by the less and more proficient bilinguals in Chapter 4 suggested that the two groups engaged different processing strategies in negotiating cross-language competition. More proficient subjects depended on inhibition of the L1 in order to perform task in the L2. However, the less proficient subjects appeared to rely on the L1 to perform a task in the L2 such that completely inhibiting the L1 was less likely to occur. Thus for less proficient subjects, successful completion of an L2 task was somewhat contingent on keeping the L1 active. These diverse processing strategies employed by the less and the more proficient bilinguals indicate that the 'hard problem' of lexical competition in bilingual lexical processes, does not dissipate with increased L2 proficiency. Rather, bilinguals of different proficiency levels adopt different strategies in resolving the 'hard problem'. This elucidation is congruent with the hypothesis that bilingualism overall leads to enhanced cognitive control (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004).

The findings in Chapter 4 have contributed to the literature on the diverse attentional mechanisms employed by less and more proficient bilinguals in their lexicalization processes. These observations confer with the assertion that the effects of bilingualism are not confined to language, but seem to result in a reorganisation of brain networks that have implications for the ways in which bilinguals negotiate cognitive competition in general (Kroll, Bobb & Hoshino, 2014). A study on the relationships among linguistic control, L2 proficiency and cognitive skill will be a rich area for further research to explore.

6.8. Inhibition is 'reactive' to the strength of the distractor stimulus

Within the purview of the present selective attention task, the contrast between negative and positive priming was largely driven by what was inhibited. Findings from Chapter 5 in contrast with those obtained in Chapter 3 suggest that the strength of the distractor language is a significant determinant of negative and positive priming effects in cross-language studies. In Chapter 3, where the prime stimuli were presented in the subjects' dominant (L1) language, inhibition applied to the competing prime distractor (Twi) word during naming of the target, could persist and suppress its translation equivalent in the weaker (L2) language, and impair response to that word when it appeared as the probe target, hence NP occurred. Thus, inhibition of a Twi distractor word for example *kanea, meaning lamp in English,* could persist and attenuate influences of its translation equivalent *lamp.* Hence if *lamp* became the probe target word (on IR trials) requiring lexical decision, response latency was impaired. However, in Chapter 5 the inhibition applied to the competing prime distractor (English) word, during naming of the target, could not persist and inhibit its translation equivalent in the dominant L1, and thus, NP disappeared.

Again, in Chapter 3, the prime (Twi) language system that became transitorily irrelevant after the prime naming task had been accomplished, appeared to have been *globally* suppressed in order to perform lexical decision in the probe (English) language. This prevented any potential spread of activation from the prime target word to its translation equivalent, the probe target (on AR trials) and thus positive priming was eliminated. However, in Chapter 5 it was as if the prime (English) language system that became irrelevant after the prime naming task had been completed, was not inhibited much (or at all) as to be able to perform lexical decision in the probe (Twi) language. Hence, positive priming occurred. Thus the English language system was not suppressed so strongly as to be able to eliminate positive priming. The cross-language findings in Chapter 3, relative to those in Chapter 5 illuminated on an essential characteristic of the inhibitory model: that inhibition adapts to the strength of the to-be-ignored input (e.g., Houghton & Tipper, 1996; Green, 1998). Hence, the stronger a distractor the more highly it is activated and the greater the amount of inhibition needed to suppress its activation levels. The reverse applies to weak distractors.

6.9. Final Thoughts and Future directions

As far as I know, no previous selective attention research involving priming manipulations has ever been published using an African language. This served as one of the motivations for the present research. There are some characteristics of this bilingual population that may be worth pointing out. For example, the participants in the current experiments were predominantly from a low level technological background. About 85% of these participants indicated that their first encounter with computers were in high school while, only 5% reported having a personal computer. Most of the participants also experienced initial trepidation at the beginning of the experiment, because they assumed the response box was subject to delivering an electric shock. People from this particular bilingual culture also tend to be socialised in a way that makes them overly meticulous and circumspect at risk-taking. In contrast to the New Zealand respondents, for example, the bilinguals were often found to ponder over options before registering their lexical decision responses, which may have led to the overall lengthier reaction times. Nonetheless, by employing a population that is not from a Western, educated, industrialised, rich democratic society, this dissertation expands our understanding about priming effects to an African language, and thus brings the study of bilingualism to a new destination. Our future research will continue to explore this area with other African populations and languages, which would otherwise be obscured if research is confined to Western populations.

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Appendix A. Stimuli used in Chapter 2.

knee	orange	snake	tower
tongue	pain	snow	towel
beads	palace	soft	trousers
ghost	soul	stain	toilet
crown	parents	stool	personality
goat	passage	stove	character
plague	shoe	stream	scholar
money	pawpaw	struggle	confidence
welcome	peace	subtraction	parliament
parrot	pencil	suggestion	cock
purity	people	supporter	legend
egg	photo	sweat	religion
bone	pigeon	sword	priest
night	pilot	symbol	pestle
map	pineapple	syringe	mortar
perfume	fingers	competition	fox
law	guineaworm	conscience	wealth
disgrace	nuisance	cottage	voice
death	treason	cotton	january
gun	heart	country	loan
frog	resurrection	crab	school
rabbit	calabash	crops	stick
alcohol	maize	cross	wheat
beach	cockroach	cutlass	poverty

saviour	insanity	dance	birth
blood	stew	demonstration	bow
university	toe	desire	charm
food	spectacle	destiny	coward
bucket	sorry	dirt	disease
wish	humbleness	disaster	dream
twins	absurd	divorce	confession
pledge	teacher	quarry	sponge
polio	teeth	cataract	trap
potato	throne	academy	month
president	name	palanquin	axe
professor	train	debtor	greedy
pulpit	trial	hero	guardian
purpose	tribe	why	guide
rank	unique	bamboo	sore
rape	urine	turkey	hand
rash	vagabond	fellowship	harvest
rebel	valley	ruler	callous
response	vein	earring	history
responsibility	veranda	cassava	accident
retaliation	victory	challenger	ache
donkey	eagle	hope	advice
driver	earth	hypocrite	aeroplane
elbow	deer	injury	sun
elder	feast	june	alliance

electricity	freedom	knife	appetite
envy	boil	white	apprentice
evening	hour	lament	argument
fisherman	kingdom	magician	arithmetic
flesh	letter	mushroom	arrangement
tobacco	pig	smooth	beans
flute	sermon	malaria	basket
footstep	prophet	mango	bed
music	sand	mask	retreat
fortress	security	accurate	reward
visit	status	mirror	rogue
warning	suffering	multitude	royal
water	swamp	murderer	sack
web	umbrella	nurse	sacrifice
border	hunter	obedience	saint
whale	bridegroom	bedroom	scissors
wisdom	pant	billion	education
womb	niece	bladder	scripture
wood	okay	bounty	secret
word	okro	boy	shadow
zone	labour	brethren	ginger
forehead	miracle	bush	shepherd
neck	steam	butterfly	shoulders
door	beetle	canoe	sieve
snail	shark	covenant	silence

mouse	correction	captain	silver
creation	cataract	carpenter	slow
beef	academy	castle	fraud
herring	palanquin	chair	gallon
floor	debtor	chairman	game
greetings	okay	chapel	garden
dove	okro	chief	glory
weaver	labour	cistern	gossip
ambush	miracle	clan	governor
allegory	growth	comedian	fear
wrist	deaf	sky	bachelor
worker	bravery	village	prayer
trader	market	foam	merciful
vacation	citizen	brisk	thirst
research	second	audience	stomach
river	hospital	judge	happy
obstacle	marriage	affluence	finance
blind	pot	judgement	proverb
baptism	queen	faith	sabbath
thumb	promise	abroad	politics
care	navel	ancestors	taboo
dress	garment	banana	holy
court	landlord	cold	fire
lake	cow	destitute	rivalry
sports	blessing	donation	uncle

tetanus	tuberculosis	farmer	messenger
zebra	bee	feather	charcoal
deception	tears	jealousy	papers
bottle	blow	grave	myth
leprosy	breast	wall	knowledge
needle	antelope	heat	funeral
prisoner	bird	manner	thunder
praise	laughter	moon	nose
gloom	salt	mountain	rock
gentile	half	musician	dear
slave	soldier	north	clock
cup	writer	plenty	locust
powder	book	poison	bruise
forest	morning	problem	net
lame	princess	sugar	yellow
widow	traveller	profit	saliva
kitchen	meat	flag	piles
ladder	request	week	box
butter	bank	prophecy	fugitive
bribe	apology	weapon	pity
lamp	short	street	big
love	season	new	cloud
debt	porridge	future	rumour
fluency	ugly	truth	contempt
pair	assistance	sheep	tomb

meeting	witnesses	spoon	female
bridge	length	example	lamb
camel	barrel	compulsory	corpse
inheritance	threat	waves	triplet
manifest	guitar	fish	leaf
shovel	trifle	punishment	comedy
blacksmith	youth	piety	dew
dough	pride	gravel	honey
tour	mosquito	lagoon	error
dawn	mother	comb	lemon
bitter	heaven	servant	asylum
star	dog	horse	pumpkin
immigrant	necklace	baby	monday
deliverance	ocean	smoke	question
spring			

Appendix B. Stimuli used in Chapters 3, 4 and 5

Twi (English) Prime Target/Distractor Words

asobrakyeɛ (deaf)	ɛwoɔ (honey)	toa (bottle)	kanea (lamp)
aseresɛm (comedy)	ɔbaa (female)	mukaase (kitchen)	amanaman (gentile)
awareɛ (marriage)	bɔsuo (dew)	nokware (truth)	nnaadaa (deception)
odwan (sheep)	mfomsoɔ (error)	akoa (slave)	obubuani (lame)
efunu (corpse)	mpataa (fish)	hyire (powder)	atwedeɛ (ladder)
abɔfra (baby)	ɔmanba (citizen)	ɔdɔ (love)	esum (gloom)
nhwɛsoɔ (example)	asotwe (punishment)	afiase (prison)	kɛtɛasehyɛ (bribe)
atere (spoon)	ahenasa (triplet)	kuruwa (cup)	kwata (leprosy)
asoɔkye (waves)	ayaresabea (hospital)	daakye (future)	ayɛyie (praise)
edwam (market)	ɔhyɛ (compulsory)	sradeɛ (butter)	aberebeɛ (zebra)
ahaban (leaf)	oguamma (lamb)	paneɛ (needle)	okunafoɔ (widow)
simma (second)	akokoduru (bravery)	kwaeɛ (forest)	ɛka (debt)

Note. These words appeared twice in the experiments either as prime and probe target in the AR conditions or prime distractor and probe target in the IR conditions.

Filler Words

aponkyerɛni (frog)	ɔbɔfoɔ (hunter)	nisuo (tears)	ahemakye (dawn)
agyapade (inheritance)	ɛtwene (bridge)	ɛfa (half)	ɔkraman (dog)
aduhwam (perfume)	akwatia (short)	bɔhyɛ (promise)	abɔnten (street)
samanwa (tuberculosis)	aduane (food)	ɔtwerɛfoɔ (writer)	asubɔ (baptism)
agyenkwa (saviour)	anoteɛ (fluency)	anomaa (bird)	ntomtom (mosquito)
adaeso (dream)	sofi (shovel)	anɔpa (morning)	ɔhwɛ (care)
animguaseɛ (disgrace)	adanko (rabbit)	nhyira (blessing)	ankaadwea (lemon)

nsaden (alcohol)	ankora (barrel)	nufoɔ (breast)	nsoroma (star)
aprapransa (porridge)	tenten (length)	twɛdeɛ (blow)	nwononwono (bitter)
mpoano (beach)	ɔgyeɛ (deliverance)	ɔwansene (antelope)	ahomasoɔ (pride)
afidie (trap)	gyitae (guitar)	ɛnam (meat)	ɔtadeɛ (lake)
ɔtomfoɔ (blacksmith)	mmabunu (youth)	sikakorabea (bank)	asensene (tetanus)
mogya (blood)	baanu (pair)	sereɛ (laughter)	maame (mother)
bosome (month)	biribiwa (trifle)	abisadeɛ (request)	agokansie (sports)
ntaafoɔ (twins)	adiyi (manifest)	nwoma (book)	mmara (law)
etuo (gun)	mmoa (assistance)	wowa (bee)	nsrahwɛ (tour)
funuma (navel)	kyɛwpa (apology)	ɔhemmaa (queen)	akodeɛ (weapon)
sapɔ (sponge)	ahunahuna (threat)	ɔkwantuni (traveller)	asɛnnibea (court)
sukuupɔn (university)	nhyiamu (meeting)	nkyene (salt)	ɔsoro (heaven)
adansefoɔ (witnesses)	kooko (piles)	ahina (pot)	nkɔmhyɛ (prophecy)
owuo (death)	ahoɔtan (ugly)	apɛde (wish)	mmɔre (dough)
kokurobetie (thumb)	ɛbere (season)	nantwie (cow)	adefoforo (new)
bɔneka (confession)	akuma (axe)	ɔheneba (princess)	ataadeɛ (dress)
bokiti (bucket)	yoma (camel)	ɔsraani (soldier)	anifura (blind)
asuten (river)	ɔberɛfo (destitute)	ɛnne (voice)	ahoɔhare (brisk)
aboɔden (dear)	pii (plenty)	nkasɛɛ (bone)	ntoma (garment)
adwumayɛni (worker)	amannɔne (abroad)	ahenkyɛw (crown)	afuro (stomach)
nimdeɛ (knowledge)	nneyɛe (manner)	yaredɔm (plague)	sikasɛm (finance)
ntwitwieɛ (bruise)	asikyire (sugar)	akwaaba (welcome)	homeda (sabbath)
egya (fire)	akyɛdeɛ (donation)	asubura (spring)	ehu (fear)
akwamma (vacation)	kwadu (banana)	ɔsaman (ghost)	sukɔm (thirst)
ntasuo (saliva)	nnawɔtwe (week)	kosua (egg)	kronkron (holy)

akorasɛm (rivalry)	okuani (farmer)	sakraman (fox)	akurase (village)
wɔfa (uncle)	takra (feather)	bosea (loan)	ɔtɛmmuafoɔ (judge)
agradaa (thunder)	bepɔ (mountain)	ɔpɛpɔn (january)	abadwafoɔ (audience)
ɔdwontofoɔ (musician)	ɛhwene (nose)	ahweneɛ (beads)	ako (parrot)
abɔsrɛmka (myth)	ɔhyew (heat)	kotodwe (knee)	osugyani (bachelor)
ɔsomafo (messenger)	ninkunu (jealousy)	apɔnkye (goat)	anigyeɛ (happy)
abotan (rock)	etifi (north)	sika (money)	mmebusɛm (proverb)
ayie (funeral)	ɔsram (moon)	ahotew (purity)	akyiwadeɛ (taboo)
nkrataa (papers)	ɛban (wall)	abaa (stick)	atemu (judgement)
gyabidie (charcoal)	adakamoa (grave)	sukuu (school)	ahonya (affluence)
nananom (ancestors)	mfasoɔ (profit)	atokoɔ (wheat)	gyidie (faith)
ntutummɛ (locust)	dadwene (problem)	ahonyade (wealth)	ahuro (foam)
nhwehwɛmu (research)	awɔ (cold)	tɛkrɛma (tongue)	mpaebɔ (prayer)
adetɔnni (trader)	asau (net)	anadwo (night)	efiewura (landlord)
akokɔsradeɛ (yellow)	frankaa (flag)	asasemfoni (map)	wiem (sky)
ɛdɔn (clock)	ɛborɔ (poison)	mmɔborohunu (merciful)	amanyɔsɛm (politics)

Appendix C. Questionnaire used in Chapter 4.

ENGLISH LANGUAGE PROFICIENCY QUESTIONNAIRE- TEACHER RATING

Student ID: ………………………………….

Directions: Please, consider each rating within the context of what is appropriate for the academic status of each student. When completing this form, please think about the student's performance in the past six months.

	Speaking	**Never**	**Occasionally**	**Often**	**Very Often**
1.	Initiates communication in English				
2.	Observes grammatical rules when speaking				
3.	Does not seem to make great pauses and gaps in speaking				
4.	Articulate words clearly				
5.	Speaks with ease				
6.	Gives appropriate responses in a conversation				
	Comprehension	**Very well**	**Good**	**Somewhat of a problem**	**Problematic**
7.	Can analyze and draw inferences from events narrated in English				
8.	Can answer questions relating to a passage.				
9.	Can summarise a passage meaningfully				
10.	Can use the English language to ask relevant questions in the course of a lecture.				
11.	Can follow directions communicated in English language.				
	Reading	**Never**	**Occasionally**	**Often**	**Very Often**
12.	Pronounces words correctly				
13.	Places vocal emphasis on appropriate words				
14.	Can pronounce unusual spellings, e.g., knew				
15.	Observes punctuations and suitable pauses				
16.	Reads primarily in larger, meaningful phrase groups				
	Writing	**Never**	**Occasionally**	**Often**	**Very Often**
17.	Organizes ideas meaningfully				
18.	Pays attention to correct spellings				
19.	Uses punctuations marks suitably				
20.	Appropriate use of verbs, pronouns				
21.	Writes complete sentences				
	In comparison to other student's how will you rate the students overall performance in:	**Very Good**	**Good**	**Average**	**Below Average**
22.	Reading				
23.	Writing				
24.	Speaking				
25.	Comprehension				