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

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ABSTRACT

In the current experiments, within- and between-language primed lexical decision tasks with Twi-English bilinguals were used. The aim was 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 word 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 evidence of positive priming was 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 bilingual language representations in which the words of the two languages are integrated.

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Bilingualism; positive priming; negative priming; selective attention

As the world becomes more interconnected, bilingualism is increasingly prevalent in many countries. In spite of this, the vast majority of psychological research on cognitive processing has focused on monolingual studies. 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 priming experiment, where all stimuli for the task were sourced from a single language (*Twi*, a native language of Ghana, Africa). The within-language experiment then served as a baseline with which to contrast the two subsequent between-language priming experiments. These two versions also used Twi – English bilinguals, but with cross-language (Twi to English) priming manipulations, instead of within-language (Twi to Twi) priming. The three primary objectives of this study were: (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 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). The term bilingual is used here to denote people who "need and use two (or more) languages in their daily lives" (Grosjean, 1992, p. 51).

Overview of major issues

Language selectivity: separate or shared representations?

A number of researchers have shown that there is parallel (non-selective) co-activation of lexical items from both languages when a bilingual identifies a

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word or plans to speak (e.g. Blumenfeld & Marian, 2013; Colomé, 2001). Evidence for language nonselectivity 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 words that are presented in the context of a sentence (Rossmark, van Hell, de 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). What remains unclear, however, is how the different languages of bilinguals are stored and represented in memory, and more specifically what processes underpin the ultimate choice of the momentarily appropriate word within a language, while preventing interference from an activated equivalent word from the nontarget language.

Neumann, McCloskey, and Felio (1999) pursued this debate in the context of a unique within-language and cross-language priming study. Their task involved a prime target naming component followed by a probe target lexical decision (LD). Moreover, a target and a distractor appeared in both the prime display and the probe display. The selection cue designated lower-case letter stings as the targets and upper-case letter strings as nontarget, distractors. By implementing this selective attention facet into the design, they were able to track the consequences of processing the prime target, as well as the conflicting prime distractor. When the prime display was encountered the participant had to name the target word, while ignoring a concurrently presented nontarget word, which entails two prospective priming relationships. On attended repetition (AR) trial couplets the target prime word is the same as the target probe word, whereas on ignored repetition (IR) trial couplets the conflicting prime distractor word is the same as the target probe word. In the all English within-language experiment (Neumann, et al., Experiment 1), response time in the AR condition was faster than on trials where the prime and probe target words were in the unrelated control (CO) condition. In contrast to this positive priming effect, response time in the IR condition was slower than in the CO condition, thereby constituting a negative priming effect. In the bilingual cross-language version of this task, requiring prime target naming in English and probe target LD 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 *chair* in the prime display and making a lexical decision to *silla* (the Spanish translation of "chair") in the AR condition. Crucially, in the between-language task, there was no AR positive priming effect, only IR negative priming was observed. More specifically, if the nontarget distractor word in the prime was *RAIN*, participants were slower to make a lexical decision to *lluvia* (the Spanish translation of the word "rain") in the IR condition, compared to the CO condition.

To account for the absence of positive priming in the cross-language task, Neumann et al. (1999) proposed that keeping L1 (the English language) activated during probe target processing would likely impede making an LD to a Spanish word. Thus, by globally inhibiting English to avoid this potential interference, the typically expected spreading activation between translation equivalents would be attenuated, thereby accounting for the elimination of positive priming. They also asserted that locally inhibiting the conflicting English prime distractor word, coupled with the global inhibition of the English language, accommodated the disappearance of AR positive priming in the context of a task that nevertheless produced IR negative priming. Due to the uniqueness and perhaps surprising nature of their findings, these explanations regarding the modulation of languages and words within them remain ad hoc, but provide working hypotheses for the current study. Corroboration here, using different words and different bilingual language groups, would reinforce the earlier findings and support the explanations they gave rise to. Besides the different bilingual groups, there were a number of other methodological differences between the Neumann et al. study and the present one. For example, a completely different and larger word pool was used in the current study, as well as different computer equipment and experiment generation software (e.g. Macintosh Plus desktop computer vs. Hewlett-Packard laptop, MacLab vs. E-Prime experiment generation software), along with different methods of stimuli randomisation and counterbalancing.

An important aim of the current experiments was thus to test whether the same pattern of findings would nonetheless be obtained in within- and between-language experiments, compared with those of Neumann et al. (1999), and to further determine if the same explanations hold up. In the case of the within-language (Experiment 1) and cross-language experiments (Experiments 2 and 3) a vastly different bilingual language group is tested, with Experiment 3 also implementing a uniquely novel priming manipulation involving the status of the probe distractor word. As will be seen, our population of bilinguals is composed of non-WEIRD participants (i.e. participants who are not from Western, Educated, Industrialised, Rich, and Democratic societies), hence constituting a commendable new addition to the bilingual literature. To our knowledge, this is also the first priming study conducted in Africa, using an indigenous language.

The aforementioned issues are investigated in the present study with a prime target naming followed by a probe target LD task. In the cross-language experiments 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 et al., 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 momentarily 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 colour 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 upcoming 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.

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 has been proposed in the Inhibitory Control Model (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).

Positive priming and lexical decisions within and across languages

One technique for studying bilingual memory is an examination of cross-language priming using a naming task followed by an LD task with singularly presented prime and probe stimuli (e.g. Altarriba & Basnight-Brown, 2007). In a lexical decision task 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. ikby). Subjects are typically faster and more accurate processing 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 LD task, subjects perform the task in one language, whereas in a cross-language LD task, bilingual subjects perform the task in two different languages, such as naming a prime target word in Twi and then deciding whether the letter string that follows is a correct word in English or not. Researchers have generally shown that within-language priming yields more of the facilitation effect than cross-language priming (e.g. Travis, Torres Cacoullos, & Kidd, 2016).

Cross-language positive priming appears to be the product of the activation of a word in one language "spreading" to semantically related nodes in the other language. 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 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 has been interpreted as being indicative of independent and separate memory systems for the two languages (De Groot & Nas, 1991; Keatley & de Gelder, 1992; Keatley, Spinks, & de Gelder, 1994; but see Neumann et al., 1999, for an alternative explanation).

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 actively *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 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 the consequence of a conflicting "response tag" generated when an item that was ignored in a prior episode becomes relevant in a subsequent encounter. In this account, it is the extra time required to resolve the conflict between the "do not respond" tag and the subsequent "respond" tag that causes the response time impairment. The logic 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. Fox (1996) concluded that her finding of negative priming in a bilingual selective attention task could be explained by "spreading inhibition" between languages (e.g. Neumann & DeSchepper, 1992) or episodic retrieval elicited by the probe stimulus (e.g. Neill & Valdes, 1992), while 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 positive and negative priming within and across languages provides a unique avenue for dissociating these two theories, because the bilingual version of the LD task elicits different predictions than the within-language version (see Neumann et al., 1999).

Inhibition-Based account of positive and negative priming

In distractor inhibition accounts, selection is simultaneous and twofold: initial excitatory processing of both the target and distractor information, coupled with subsequent inhibitory processing of the distractor information. In tasks involving attentional selectivity, inhibitory control can also act on previously attended information that is no longer required but has the potential of being disruptive (Li, Neumann, & Chen, 2017; Neumann & DeSchepper, 1992; Neumann, Cherau, Hood, & Steinnagel, 1993). 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). They found that subjects deciding whether pairs of English words were related 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; Neumann et al., 1993) surmised that, in situations that provoke attentional selectivity, an inhibitory mechanism can operate on previously attended relevant information that is no longer needed and has the potential to become disruptive. They contended that such an inhibitory mechanism was 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 et al., 1993). 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. According to Neumann et al. (1999), the suppression of the nontarget prime *word* should nonetheless produce negative priming if its translation equivalent becomes the next probe target. 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, but not positive priming.

Episodic retrieval approaches 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, 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 the same or similar stimulus in a subsequent task is achieved by either analytically computing a response or by retrieving the response from the previous encounter with the same stimulus from memory.

Expanding on Logan's work, Neill and colleagues (Neill, 1997; Neill et al., 1992; Neill & Valdes, 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, which 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.

Potential positive and negative priming phenomena 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.

The Twi language: overview of major differences with the English language

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 mainly in religious publications, 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:

(1) 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, a 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).

(2) 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). 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.

(3) 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. For example, *daabi* (meaning *no* in English) is pronounced as da/a/bi and constitutes three syllables.

(4) In English, vowels preceding nasal consonants are nasalised, but there is no phonemic distinction between nasal and oral vowels (and all vowels are considered phonemically oral). In Twi, however, all vowels are nasalised. They are not nasalised because they follow nasal letters (m, n), rather, speakers of the language spontaneously nasalise 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).

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. The selective inhibition and episodic retrieval theories both make the same predictions regarding the outcome of this within language experiment as follows.

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 rival inhibition-based theory (e.g. Neumann & DeSchepper, 1991; 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, an active suppression mechanism applied to 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 distinctly different predictions based on the two theories.

Method

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. In each experiment of the current study, the participants were native speakers of the Twi language. They were also generally proficient in the English language. For example, they all began to acquire English around age 6, which is the official school entry age in Ghana. The English language is introduced and used along with Twi in the classroom until students graduate from high school. After high school, Twi is taught as a subject in tertiary institutions. At university, all of the participants reported regular and deliberate use of English and Twi languages on a daily basis, generally using English in the classroom, and Twi outside of the classroom. 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.

Stimuli and apparatus

Six hundred and twenty words were chosen from the word norms of Francis and Kucera (1982) for stimuli construction. One hundred and sixty-eight words were randomly selected to act as targets (see appendix A) and the remaining 452 served as filler words (see Appendix B). 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 [1996]). 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 having been exposed to the word lists. 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 lists from a two week test-retest interval were $\alpha = .89$ and $\alpha = .86$ for the Twi and English sets respectively. 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. 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, respectively.

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 minimise 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 (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 (Table 1).

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 centrally on the screen at all times. Word length for the Twi stimuli ranged from three to thirteen letters. The shortest words were 1.4 cm wide, whereas the longest words were 5 cm wide. On average, the distance between the closest edges of items appearing in the centre and those appearing to the right was about 1.5 cm. Similarly, the distance between the closest edges of items appearing in the centre and to the left was also about 1.5 cm. 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 for the "word" and "nonword" responses, respectively. Reaction times were automatically recorded from the onset of the probe display until a lexical decision judgement was made via button-press. A response sheet with prime target words was also used to enable the experimenter to monitor the naming of primes for omission and commission errors for each subject. Trials on which such errors were made were later removed from analyses, because they could indicate a failure to attend to the prime target word.

Table 1. Sample of conditions for word/nonword trials in Experiment 1.

Condition	Prime display	Probe display
Attended Repetition	ABAKƆN	Nokware
	nokware	GYIDIE
Control Condition	asɛm	ɔkyeame
	BƆSUO	NTAKRA
Ignored Repetition	KURUWA	kuruwa
	adwuma	SAFOA
Nonword Condition	toa	abofrɔ
	AFUNUMU	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.

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.

Procedure

Each subject participated in an approximately 45-minute session consisting of 24 practice trials and 144 experiment-proper trials. Subjects were run individually in a room optimised for low noise and dimly-lit conditions, at a viewing distance of about 50 cm from the computer screen. Printed instructions were provided on the computer screen and were supported with verbal instructions. Due to relative unfamiliarity with technical equipment, it was particularly important to explain the task thoroughly to the participants in Twi, the local language. 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 in the centre of the screen for 500 ms. The fixation cross was followed immediately by the prime display which was presented for 250 ms. After the prime display was extinguished, a blank screen appeared for 1000 ms 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 1.

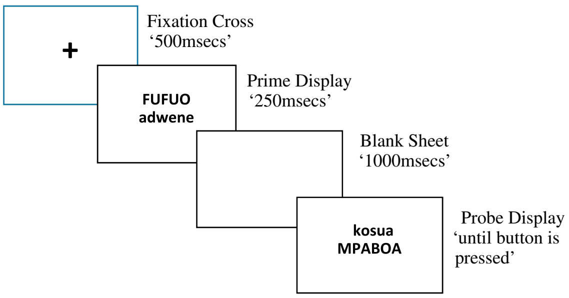

Figure 1. Sample sequence of stimulus presentation in Experiment 1. Note that in the experiments the distance between the closest edges of the top and bottom item in each display was 1 pixel width.

To summarise, 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. Participants first named the prime target word and then made word/nonword decisions to the probe target item.

Results and discussion

Analysis

We established cut-off scores of 30% or 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 2. An analysis of variance revealed a significant main effect of priming, F (2, 72) = 24.34, $MSE = 149{,}478$, $p < .001$, $\eta_p^2 = .40$. 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 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

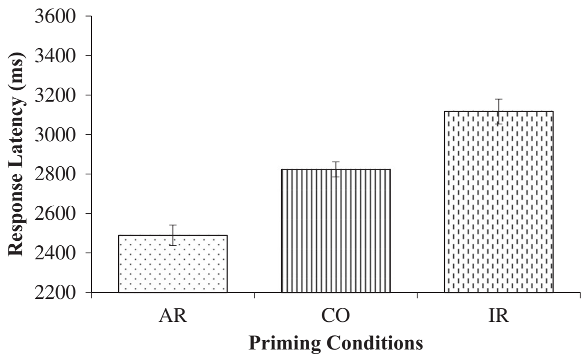

Figure 2. Results from Experiment 1. Mean response latency (in milliseconds) as a function of attended repetition (AR), control (CO) and ignored repetition (IR) conditions. Error bars indicate within-subject standard errors.

= 3116, *SD* = 1238.30) produced significantly slower RTs, *t* (36) = 3.24, *p* = .003, *d* = .53, than the CO condition.

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 words that are presented only once prior to becoming a probe target can 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. Cock, Berry, & Buchner, 2002; Neumann et al., 1999; Schooler et al., 1997; Schrobsdorff, Ihrke, Behrendt, Herrmann, & Hasselhorn, 2012). Uniquely, however, the present results are inconsistent with the findings of Strayer and colleagues (Grison & Strayer, 2001; Kramer & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999) who have reported results from a number of experiments in which identity 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. The discrepancy 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 colour selection cue used in their studies. When visual search for target stimuli are distinguished from distractors by a unique feature, such as colour, it becomes fast, efficient, and subjectively effortless owing to pop-out effects (Treisman & Gormican, 1988). Numerous studies have shown that negative priming 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).

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 words enough to elicit inhibitory processing and thus produce identity negative priming (e.g. Grison & Strayer, 2001). By using noncognate translation equivalents across languages, Experiment 2 also tests a more extreme version of 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.

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 bilingual language processing and storage. 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 (L1of 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. *kuruwa* - *cup*) 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 (e.g. Dong, Gui, & MacWhinney, 2005; Heredia & Brown, 2012).

Neumann et al. (1999) argued that their cross-language 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 (e.g. Durlik, Szewczyk, Muszynski, & Wodniecka, 2016; Kirsner, Brown, Abrol, Chadha, & Sharma, 1980; Kirsner, Smith, Lockhart, King, & Jain, 1984; Scarborough, Gerard, & Cortese, 1984). Neumann et al. also pointed out that their findings were inconsistent with the episodic retrieval alternative to the inhibition-based account, because the 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). 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 and potentially interfering with the current probe target 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. Mercier, Pivneva, & Titone, 2014; Misra, Guo, Bobb, & Kroll, 2012). Our assumption as to how this control is achieved is that language selection involves initial excitation followed by inhibition mechanisms capable of acting locally on individual nontarget lexical items as well as globally to activate and subsequently inhibit whole languages (Neumann et al., 1999). 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 IR negative priming, in spite of the absence of AR positive priming, clearly indicates an integrated single store language system shared in common by the two languages (see also De Groot & Christoffels, 2006).

Method

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 colour vision. None of the subjects participated in Experiment 1.

Stimuli and apparatus

The 72 probe target words and 452 filler words were the same as those used in Experiment 1, except that the Twi probe targets were replaced by their English (noncognate) translation equivalents (see Appendix

A). 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. 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.

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 50 cm 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 (see Figure 3). Speed and accuracy were stressed 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

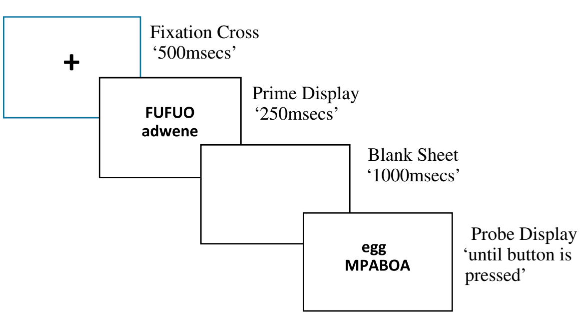

Figure 3. Sample sequence of stimulus presentation in Experiments 2 and 3. Note that in Experiment 2 the probe target word was in English and the distractor word was in Twi, whereas in Experiment 3 both the probe target and distractor were English words.

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 Control and 24 IR conditions. Presentation parameters, randomisation, and stimulus counterbalancing were as in Experiment 1.

Results and discussion

Analysis

The cut-off conditions for excluding subjects from further analysis were the same as in Experiment 1. Fairly lenient 30% cut-off percentages for naming or LD errors were used because it was deemed important to keep as many participants in the data sets as possible. This was especially important because we were anticipating statistically significant ignored repetition negative priming, but null attended repetition positive priming across languages. It was therefore crucial to have as much statistical power/sensitivity as possible, so that we would be able in particular to detect attended repetition facilitatory priming, if there was such an effect to be found. 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. An analysis of variance revealed a main effect of priming, F (2, 84) = 3.34, MSE = 166,264, p = .040, $\eta_p^2 = .07$. 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, 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 time (negative priming).

The error data were analyzed in a similar manner. The main effect of priming, F (2, 84) = .972, MSE = 5.248, p = .382, $\eta_p^2 = .023$ was nonsignificant. Moreover, neither the contrast between the AR (M =

1.06, $SD = 1.96$) and CO ($M = 1.73$, $SD = 2.99$) condition was significant, t (42) = 1.20, $p = .237$, $d = .18$, nor the contrast between the IR ($M = 1.26$, $SD = 2.65$) and CO ($M = 1.73$, $SD = 2.99$) condition, t (42) = .95, $p = .347$, $d = .15$. 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 maximises 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. 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 (for examples, see Appendix A) and thus less effective retrieval cues. 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 noncognate translation equivalency, there is also a change due to the form of the word which switches from uppercase to lowercase letters.

The observation of negative priming in the IR condition clearly 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 finding of positive cross-language priming would be deemed consistent with a single store model of language storage, whereas its absence would seem to support a separate store model (De Groot & Nas, 1991; Keatley et al., 1994). The mixed finding of intact IR negative priming along with the absence of AR positive priming is problematic for both storage models, and a broader explanation of these results is needed to account for these cross-language priming phenomena.

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. The absence of positive priming in turn can be accommodated by the involvement of two sources of inhibition, as posited by Neumann et al. (1999). Inhibition at the local distractor word level can accounts for the IR negative priming effect discussed above, whereas inhibition at the global language level of the prime language can account for the elimination of spreading activation between the prime target and probe target, and thus the elimination of cross-language positive priming.

One open empirical question that remains is whether the priming results, and in particular the null AR priming, 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 encourages subjects to globally inhibit the language of that distractor (i.e. Twi) to avoid interference with the required probe target 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.

Experiment 3

Experiment 3 was intended to pursue the implications of Experiment 2, with a unique 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, an L1 word. 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). It is worth noting 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 L2 probe targets.

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, Experiment 2), 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 and 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 are inconsistent. 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. By contrast, Grainger (1998) 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. This issue has not previously been investigated, despite the potential implications the outcome may have for understanding why AR positive priming effects may vanish across translation equivalents, while IR negative priming effects remain fully intact.

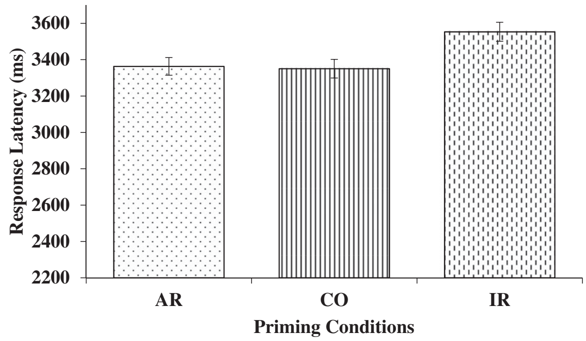

Figure 4. Results from Experiment 2. Mean response latency (in milliseconds) as a function of attended repetition (AR), control (CO) and ignored repetition (IR) conditions in Experiment 2. Error bars indicate within-subject standard errors.

Method

Subjects

Forty-three subjects (17 males and 26 females) participated. They were recruited from the University of Cape Coast, Ghana, and none of them 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.

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.

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. As such, this is the first time, using the current paradigm, where both prime words were in L1, whereas both probe items were in L2. Otherwise, all presentation parameters, counterbalancing, and randomisation processes were identical to those used in Experiment 2.

Results and discussion

Analysis

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 4. An analysis of variance revealed a significant main effect F (2, 84) = 6.40, MSE = 168,896, p = .003, η_p^2 = .132. Due to 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 4, 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 5).

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

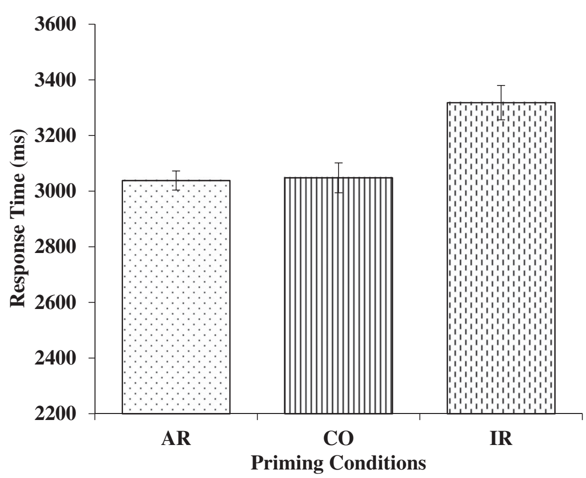

Figure 5. Results from Experiment 3. Mean response latency (in milliseconds) as a function of attended repetition (AR), control (CO) and ignored repetition (IR) conditions. Error bars indicate within-subject standard errors.

($M = 3.76$, $SD = 5.89$) was nonsignificant, 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 nonsignificant, 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 and the earlier English-Spanish findings (Neumann et al., 1999). The current novel result shows, for the first time, that having the probe distractor in the language of the prime stimuli was not responsible for the results in Experiment 2 or, by implication, the prior English-Spanish study results. The fact that it does not matter whether the probe distractor is a word in L1 or L2 suggests that prospectively knowing that the language requirements switch systematically between prime and probe is sufficient to induce the global suppression of the language used for responding to the prime. Proactive inhibitory control, based on this prospective knowledge, helps to reduce or eliminate intrusion from the wrong language when responding to the probe. Global suppression of the irrelevant, potentially distracting, language apparently overrides any consequences of the particular language status of the probe distractor word. Twi – English, just like English – Spanish, bilinguals actively inhibit the language not-to-be-used before the onset of the probe stimuli to avoid interference (see also Wu & Thierry, 2017).

Moreover, the fact that both Experiment 2 and 3 of the present study had sufficient power to produce a significant negative priming effect in the IR condition suggests that they should each also have been sufficiently sensitive to detect an AR positive priming effect, had there been any. Hence, just as in Experiment 2, the present 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, it was 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.

In contrast, the results are consistent with an inhibition-based approach. According to this view, inhibition can be locally applied to a nontarget distractor in one language, and the suppressed state of such a word impairs 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 during prime target naming, it may undergo some degree of item-specific suppression. 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 in the AR condition, 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 and 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. In spite of the challenges imposed by such experiments, their potential importance is exemplified by findings that are not only informative about bilingual language representation, but also in their ability to resolve theoretical disputes in the domain of selective attention. 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.

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 bilingualism. The present study 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 (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. For example, an important implication from these findings is that there seems to be a universality of mechanisms involved in the modulation of languages and the words within them for bilinguals, even if they are from very different language groups. The mechanisms involved also appear to be general cognitive mechanisms that are shared in common with findings in selective attention studies, and particularly in the negative priming literature. Collectively, the findings from this series of experiments also contribute unique insight regarding debates about single versus separate-store language structures.

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, 1997; Neill et al., 1992; Neill & Valdes, 1992). 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 non-cognate 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 (Durlik et al., 2016; Neumann et al., 1999). That research (e.g. Kirsner et al., 1980; Kirsner et al., 1984; Scarborough et al., 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 organisation. 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).

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 unrelated to either English word 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 et al., 2012). To our knowledge, however, the present cross-language paradigm is the only one that provides evidence for both of these suppressive mechanisms emanating within the same task. Inhibition may thus be a more ubiquitous form of cognitive control than previously realised (see also, Li et al., 2017).

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, 2001; Kramer & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999). In these studies, colour 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, 1981) 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 more with the prime target word and are thereby more likely to induce the degree of inhibition required 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 (Neumann & Levin, in press; Wyatt & Machado, 2013). By using the same colour 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.

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 language (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 results for each condition was the same, thus attesting to their robustness. The slower responses from the Twi-English bilinguals could be attributed to unfamiliarity with computerised tasks or the unique, highly syllabic nature of the Twi language, or a combination of these factors.

Perhaps the most provocative findings from these experiments is the uniquely original way in which they support single-store models of bilingual language representation, 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; Altarriba & Basnight-Brown, 2007; De Groot & Christoffels, 2006; Sanchezcasas, Davis, & Garciaalbea, 1992). Despite finding no hint of positive priming across languages in our bilingual experiments, our support for an integrated languages model comes from negative priming between languages. Crucially, the cross-language negative priming findings may be seen as even more compelling in that conscious strategies can be effectively ruled out when ignored stimuli are the source of the priming.

Collectively, the present patterns of findings lead to proposals for how words and languages appear to be capable of being regulated in the context of selective attention circumstances. This is particularly the case in light of unpublished work in our lab involving synonyms in a within-language task (instead of cross-language translation equivalents), producing *no* negative priming. It should, therefore, not be surprising if it turns out that noncognate translation equivalents across languages 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 further 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 within the same task provides an illuminating perspective from which to further pursue issues of bilingual language representation and processing.

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No potential conflict of interest was reported by the authors.

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Appendices

Appendix A. 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.

Appendix B. 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)