ORIGINAL ARTICLE

Second language proficiency effects on cross-language positive and negative priming in Twi-English bilinguals

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AIM OF THE STUDY: The ability to use multiple languages selectively is an impressive feat of the human information processing system. Although bilinguals scarcely commit random cross-language errors when they speak, there is evidence that both languages are active when one is in use.

BACKGROUND: This article builds on previous work using a selective attention variant of cross-language priming techniques to examine the mechanisms that regulate the activation and suppression of target and nontarget languages and the words within them. Twi (a native language of Ghana, Africa)-English bilinguals named a target prime word in Twi that was presented with a Twi distractor word and then made a lexical decision to an English target probe item in order to investigate potential cross-language positive and negative priming effects.

METHODS: Participants were classified according to their second language (L2) proficiency. Greater L2 proficiency was associated with the absence of attended repetition positive priming, coupled with greater ignored repetition negative priming, compared to those with less L2 proficiency.

RESULTS: These outcomes are discussed in terms of differences in the way less and more proficient bilinguals modulate their languages and the words within them.

CONCLUSION: The implications from these findings are also discussed with regard to conflicting predictions stemming from episodic retrieval and inhibition-based accounts of positive and negative priming and the potential of uniting language processing, memory, and attention under a common processing mechanism.

Key Words: *Bilingualism; L2 proficiency; Positive priming; Negative priming; Selective attention*

Bilingual speakers exhibit remarkable plasticity in language processing. They can confine their speech to one language, and can switch between languages in appropriate situations. However, there is evidence that the intention to speak one of the bilingual's languages does not necessarily restrict activation of items in the other language (1-6), thus endorsing the hypothesis that bilingual language processing is initially nonselective. This observation is particularly striking for language production where intuitively it is assumed that the intention to speak in one language should curb activation of items in the unintended language. The enduring question is how bilinguals manage to select the target language for use and avoid interference from the non-target language and, more specifically, what mechanisms underlie the selection of the response language?

There is considerable debate about the degree to which past findings distinctively demonstrate the presence and locus of cross-language activation in the production of words in either of the bilingual's two languages (7). Earlier studies suggested that in order to speak one language rather than the other, the bilingual must throw the equivalent of a mental switch (8). Macnamara and Kushnir proposed a two-switch model with input and output switches that were shown to allow comprehension of one language and production in the other language during translation tasks (9-11). The underlying assumption in both cases was that a language system (or subsystem) is either on or off. The "mental switch" account provided a parsimonious interpretation of how bilinguals map an input of one language onto the suitable mental lexicon, as well as conferring the ability to ignore the occasional spurious mappings of that input onto the unintended mental lexicon of the other language (12).

More contemporary proposals surmise that language systems can be at different points of activation and in order to speak one language rather than the other, the activation levels of the target language must exceed those of the non-target language (13-15). The alternative account is that the unintended language is actively inhibited while the target language is actively in use (16,17). One of the most contentious debates in cognitive psychology is the extent to which cognition depends on the activation of abstract representations and their subsequent active inhibition if they become irrelevant or conflicting (18-21) versus the retrieval of specific episodes or instances in memory (22-26). This debate is particularly germane to priming research, involving positive and negative priming effects that explore the effect a previously encountered stimulus (e.g., word, letter, or picture) has on the response to a subsequent related stimulus.

Neumann, McCloskey, and Felio (27) pursued this debate in the context of a within-language and cross-language priming study using a task in which a prime naming component is followed by a probe lexical decision. In contrast to previous priming studies, which typically involve singularly presented prime and probe words (28), their task involved a target and a distractor in both the prime display and the probe display. By doing so, they were able to track the consequences of processing the prime target, as well as the conflicting prime distractor in English, the dominant (L1) of the participants. This experimental procedure inherently entails a selective attention component, which is absent in all other cross-language priming studies that we know of (29). In this unique paradigm, upon encountering the prime display, the participant was required to name the target word, while ignoring a concurrently presented non-target word. This procedure entails two potential priming relationships. On attended repetition (AR) trials the target prime word is the same as the target probes word, whereas on ignored repetition (IR) trials the conflicting distractor prime word is the same as the target probe word. When the experiment was conducted within the same language, all English in this case (27), response times in the AR condition were faster than on trials where the prime and probe target words were unrelated control trials (CO). In contrast to this positive priming effect, response times in the IR condition were slower than on CO trials, thus constituting a negative priming effect. In the cross-language version of this task, requiring prime display target naming in L1 English and probe lexical decisions in L2 Spanish, however, participants were presented with a prime target in one language and a probe target in another language (27). In the AR condition, for example, bilingual participants would overtly name apple in the prime display and make a lexical decision to manzana (the Spanish translation of the word apple). Interestingly, in the between-language task, there was no positive priming effect in the AR condition, only IR negative priming was observed. As such, if the non-target distractor word in the prime was DOG, participants were slower to make a lexical decision to perro (the Spanish translation of the word DOG), compared to the unrelated CO

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condition. Moreover, when these bilinguals were categorized into more and less proficient, on the basis of their proficiency in Spanish (L2), the more proficient showed no hint of positive priming, coupled with amplified negative priming, relative to the less proficient in L2. To account for the absence of positive priming in the more proficient bilinguals, Neumann and colleagues suggested that since they were proficient in their L2, keeping L1 (English language) activated during probe target processing could only hamper making a lexical decision to a Spanish word (27). By globally inhibiting English to avoid this potential conflict, the normal spreading activation between translation equivalents would be attenuated, thereby accounting for the elimination of positive priming. On the other hand, locally inhibiting the conflicting English prime distractor word, coupled with the global inhibition of English, could account for the exacerbation of the negative priming effect evidenced by the more proficient L2 bilinguals.

In addition, it is noteworthy that in Neumann et al.'s study, participants were required to name a prime target English word while ignoring a simultaneously presented English distractor word, and then in the probe display make a lexical decision to a Spanish target word while again ignoring a concurrently presented English distractor word (27). They surmized that having the probe distractor in the same language as the prime stimuli (English) could possibly encourage the incentive to globally inhibit the English language after reacting to the prime target. Keeping the English language active could, after all, make the non-target English word in the probe display extra intrusive or competitive for making a lexical decision to the Spanish target word. Due to the unprecedented between-language selective attention task they used and the uniqueness of their findings, the explanations offered above were necessarily ad hoc. To test whether the reported findings of Neumann et al. were conditional on having the probe distractor in the same language as the prime stimuli, the present study extended their procedure by incorporating two versions of the task (27). In one version the probe target and distractor were in different languages [(Twi and English), similar to Neumann et al.'s study]. In the other version, the probe target and distractor were in the same language (English). This enabled us to determine if having the probe distractor in L1 (the same language as that used for response to the prime) was a necessary condition for inducing the global inhibition of L1 by the more proficient bilinguals. A corroboration here using different words and different bilingual language groups would reinforce the earlier findings and place the explanations for them on much firmer ground. One of the major aims of the current experiments was thus to determine if the same pattern of findings would be obtained in a vastly different bilingual language group.

The present study involved a native language of Ghana, Africa (Twi) with Twi- English bilinguals. Participants overtly named the prime target Twi word [e.g., anwea (Twi word for sand)] while ignoring a simultaneously presented Twi distractor word and then had to make a lexical decision to whether the probe target stimulus was a word or not a word in English, while ignoring a simultaneously presented Twi or English distractor word. The aim was to examine potential positive and negative priming effects across languages in order to test predictions about the mechanisms underlying bilingual language selection and processing and further track them as a consequence of language proficiency. The new manipulation with an L2 English probe distractor word was added to determine if having the probe distractor word in L1 in the Neumann et al. study was a factor responsible for eliminating the cross-language AR positive priming as described earlier (27). If having the probe distractor word in L2 nevertheless results in the elimination of facilitator priming across languages, it would show that it is not necessary to have the probe distractor as an L1 word. Instead, it would indicate that it was the regular alternation between L1 and L2 in the prime and probe displays, respectively, that induces a global suppression of L1 thereby nullifying positive priming from translation equivalents in a task that nonetheless produces cross-language IR negative priming with translation equivalents.

In the next section, we discuss predictions from the two major rival theories (inhibition-based and episodic retrieval) regarding positive and negative priming in a cross language priming task involving selective attention components. As will be seen, it is only an inhibition-based account with two sources of inhibition (one at the global language level and the other at the local distractor word level) that can accommodate cross-language IR negative priming in the same task that fails to produce AR positive priming.

Inhibition based and episodic retrieval models of negative (and positive) priming

Early cognitive theories assume that cognition is largely driven by the activation of abstract mental representations such as those described in Morton's Logogen theory. Within the abstractionist hypothesis, an encounter with a stimulus or an object leads to activation of abstract mental representations of that object, so that its representation becomes more easily accessible (30,31). This heightened accessibility produces faster and more accurate recognition of a repeated object relative to a novel object. An extension of this view, involving selective attention paradigms, suggests that successful object identification and selection is accomplished by an excitatory mechanism that acts to enhance target information, coupled with an inhibitory mechanism that suppresses distractor information (32). By this account, the presentation of distracting stimuli results in the activation of an abstract internal representation of the distracting stimulus which an inhibitory mechanism then suppresses and disengages from the response output. Thus, whereas the attended stimuli remain momentarily activated, the abstract mental representations of ignored stimuli are rendered provisionally less accessible (33-36). Moreover, when people selectively attend to a stimulus, their attention mechanisms concurrently enhance the target, including its semantic neighbors, but actively suppress the representation of the non-target stimulus and its semantic neighbors (32,37,38). This dual process has the merit of highlighting the target on the prime trial, but with the cost of making it more difficult to retrieve the inhibited or suppressed representation of the conflicting non-target if it appears as the target subsequently on the probe trial. As such, positive priming is due to the activation from a recent experience with a stimulus increasing its accessibility, as well as that of its semantic neighbours owing to preactivation, whereas negative priming is due to active inhibition of ignored information during target selection on the prime trial. This inhibition persists over time and the subsequent processing of the ignored non-target prime item (or its semantic relation) would be delayed due to this suppression (39).

To emphasise the distinctiveness of binary-processing in inhibitory terms, Neumann and DeSchepper conjectured that whenever selective attention is warranted, an inhibitory mechanism can also operate on encountered relevant information that is no longer needed and likely to become disruptive (21). Such inhibitory inducements parallel the distractor inhibition that apparently causes negative priming effects, except that it is an endogenous form of such inhibition. Endogenous inhibition acts on internally represented information that is apt to interfere with responses to targeted information, whereas exogenous inhibition refers to the suppression of distractors that are visible in the environment. Experimental indices of endogenous and exogenous inhibition are gauged by evidence of the suppression of internal and external distracting non-target information (37,38,40,41).

Based on predictions derived from our earlier English-Spanish cross-language study (27), we posited that endogenous inhibition is applied to the Twi language after the processing of the prime display is finished, because keeping Twi activated would only interfere with the probe lexical decision required in English. Hence, the inhibition or suppression of Twi should curtail any potential spreading activation from the prime target (in Twi) to its translation equivalent (in English) if it becomes the probe target in the AR condition. Moreover, suppression of the Twi prime distractor word, while naming the target, should spread to the distractor's semantic relations in the other language (English), such that if that English translation equivalent then becomes the probe target requiring a lexical decision, as in IR trials, a significant cost in reaction time should occur. Collectively, the local inhibition of the prime distractor word together with global inhibition of the entire prime language should thus produce negative priming in the IR condition, but no positive priming in the AR condition. If the proficiency effects observed by Neumann et al.'s cross-language experiment were also corroborated, this hypothesized outcome should be especially prominent for the more L2 proficient bilinguals for the reasons stated earlier (27).

An alternative to inhibition-based models of priming has been proposed by Neill and his colleagues (25). In the episodic retrieval model performance in selective attention priming tasks is mediated by the retrieval of specific "episodes" or "instances" in memory (42). Episodic representations may contain information about the identity or location of objects and their status as a target ("respond") or distractor ("do not respond"). A participant may therefore recognise a current probe target object as similar to one recently experienced, which would in turn elicit either a compatible or incompatible response tag (43). By this account, positive priming is caused by the retrieval of an episode that is automatically triggered by the onset of the same stimulus (or a conceptually related stimulus) in the probe display that was attended to and responded to in the prime display. This can provide an explanation for why the distractor word "RED", for example, can produce a delay in naming a subsequent red hue, compared to hues of other colors in negative priming versions of Stroop color naming tasks (44,45).

Although the word RED looks nothing like the hue red, their similarity is at a semantic or conceptual level, as would be the case between translation equivalents across languages in bilinguals. As such, in this approach AR positive priming occurs as a result of access to an episodic representation that contains response information that matches, and hence facilitates, the required response. Negative priming on the other hand is provoked by the automatic retrieval of information from the prime display which conflicts with the current correct response (25). Thus when the target encountered in the probe display was a previous distractor, retrieval of recent related information occurs, but the item most likely to be retrieved – the distractor prime stimulus conveys with it a tag that disrupts the response to that same item when it is the probe target. It is the ensuing response conflict between the "do not respond" tag associated with the prime distractor item and the "respond" tag attached to the probe target item that ostensibly accounts for the negative priming delay when it is an identical or closely related item.

The episodic retrieval model is an extension of Logan's theory of automaticity involving obligatory encoding, obligatory retrieval, and instance representation (42,43). In Logan's terms, the conditions for the automatic retrieval of episodes of the type that can produce positive priming effects are quite restricted. For instance, the benefit in repetition priming is often particular to the physical and conceptual format of the initial presentation. Therefore there is little transfer from words to pictures and from pictures to words (43). Hence in order for the episodic model to account for data showing abstract conceptual transfers from pictures to words, a fairly broad similarity gradient is essential, possibly incorporating semantic, lexical, phonological and/or perceptual information in magnitudes that correspond to the demands of the task (39). In episodic retrieval postulations, it is the similarity relationship between prime and probe stimuli that determines whether the prime stimuli are sufficiently similar to the target probe stimulus to elicit the response attached to the prime target or distractor and thus produce either facilitation or delay, respectively. This foundational idea in the memory-based episodic retrieval theory was disconfirmed by the cross-language result reported (27).

More specifically, the theory predicts both AR positive priming and IR negative priming in that experiment as it does in the present cross-language experiment, if it is the case that a conceptually equivalent probe target word is sufficiently similar to a prime distractor to elicit their accompanying response tag. Hence, the straightforward predictions from the episodic retrieval theory are that if positive priming is observed in the AR condition, so should negative priming be observed in the IR condition, and vice versa. It is particularly noteworthy that, in addition to translation equivalence, there is also an additional physical change from upper-to lower-case letters in the IR condition, which if anything should reduce the likelihood of obtaining negative priming, compared to positive priming in the AR condition wherein both are in lower-case. The opposite pattern, however, was observed (i.e., significant IR negative priming in the absence of AR positive priming), which is problematic for the episodic retrieval account and questions its fundamental underpinnings. A replication and extension of our earlier cross-language findings would provide a crucial test of the opposing theories under circumstances in which these accounts make discriminably different predictions about the outcome.

Second language proficiency and inhibitory control

As described earlier, the Neumann et al. study with English (L1)-Spanish (L2) found that the bilinguals designated more proficient in Spanish produced greater IR negative priming than the less proficient who, indeed, did not produce significant negative priming (27). They also reported that neither the more nor less proficient Spanish bilinguals produced significant AR positive priming. The present study attempted to further track the potential link between language proficiency and inhibitory control using cross-language prime target naming, followed by probe target lexical decision tasks in a group of Twi (L1)-English (L2) bilinguals.

Although Neumann et al. first posited the idea of global language inhibition and local distractor word inhibition by demonstrating both of their influences in a cross-language priming task, others have begun discussing the possibility of local and global inhibition as key mechanisms of language control in bilinguals (27,46). As far as we know, however, the present experiment is the first attempted corroboration of these ideas in the context of examining positive and negative priming effects as a function of different levels of language proficiency in L2. An additional factor investigated in the current study that was unexplored in the English-Spanish cross- language experiment is the language status of the probe distractor word. In the Neumann et al. experiment the probe distractor word was always in the same language (L1) as the words in the prime display. As such, it is conceivable that this was responsible for inducing the global suppression of the language used for the prime words. More specifically, having the probe distractor word in L1 may have provided the incentive to inhibit L1 because keeping L1 active would make the probe distractor more competitive or interfering with the probe target. Alternatively, it is also conceivable that the prospective knowledge that there is continual regular alternation between the response requirements for L1 in the prime and L2 in the probe is actually what induces inhibition of L1. The latter hypothesis would be exemplified if the language status of the probe distractor word (L1 *vs.* L2) does not interact with L2 proficiency. This would strongly imply that the probe distractor is simply ignored and that it does not matter what language it is in, irrespective of L2 language proficiency.

Although the design of the present experiment is built upon Neumann et al.'s Experiment 2, there were a number of methodological differences. For example, the median split analysis designed to create distinguishable groups of more and less proficient second language groups was different in the two studies (27). In the earlier English-Spanish bilingual experiment, the criteria for more and less proficient individuals were based on subjective answers by the participants on a Spanish proficiency questionnaire. Additional criteria for designating the subjects as less or more proficient were that less proficient had at least 3, but less than 6, years of formal Spanish training. The more proficient had at least 6 years of formal Spanish training and had spent at least 6 continuous months in a predominantly Spanish-speaking country. For the current study, it was reasoned that an effective way to create an accurate division based on L2 proficiency was to have a multi-faceted teacher rating for each participants' English language proficiency (see Appendix A for a sample of the proficiency questionnaire). In this case, an advantageous circumstance was having direct knowledge about various aspects of L2 proficiency (e.g., speaking, reading, writing and comprehension abilities) for each participant by interactions with the teachers for a minimum of one year. If anything, this should yield a more objective and accurate assessment of each participants' L2 competencies than was the case in the English-Spanish study. In addition, all of the participants in the current study expressed utilization of both Twi and English on a daily basis, whereas not all of the participants in the English-Spanish study used both languages on a daily basis. Other examples of methodological differences involved: a different and much larger word pool in the current experiment, somewhat longer prime display duration in the current experiment (250 ms *vs.* 200 ms), different forms of randomization and counterbalancing of stimuli, different computer equipment (Hewlwett-Packard Laptop *vs.* MacIntosh SE desktop), and a different mode of response collection (Chronos button box *vs.* keyboard input). If the outcome of the present experiment were to emulate the pattern of results from the earlier cross-language experiment, it may be concluded that these methodological differences did not substantially alter the outcome.

MATERIALS AND METHODS

Participants

Eighty-two Twi-English bilinguals from Ghana volunteered to take part in the experiment. Thirty-nine (22 men, 17 women) were sampled from the Colleges of Education and 43 (16 men, 27 women) from the University of Cape Coast. Their ages ranged from 19 to 29 years. Formal teaching of English begins at age six to school children in Ghana, and university courses are taught in English. Self-reports showed that all the participants spoke Twi as a first language (L1) and English as a second language (L2), and they all judged themselves to be reasonably proficient in the English language. They also reported frequent, deliberate switches of spoken language in Twi and English on a daily basis.

Proficiency dichotomization

A 25 item Language Proficiency Questionnaire was prepared to group participants into more and less proficient categories (see Appendix A). Lecturers/instructors in both schools were asked to provide information about the students' English language proficiency levels by rating them on the questionnaire. The questionnaire had five sections and each section measured one core area relating to speaking, reading, comprehension, writing and a general language instructor's knowledge of the ratee's English language competence. L2 proficiency status for a population like Ghana becomes incomprehensive if proficiency judgements are based on speaking or writing alone, so the proficiency questionnaire employed in this study tested four core areas of L2: reading, writing, comprehension, and speaking. Questions on the questionnaire were rated on a 4 point Likert scale ranging from never (1), sometimes (2), often (3), and very often (4). We aggregated scores on each participant's questionnaire and developed a median split for each group.

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

Stimuli

The stimuli were 620 English words randomly selected from (47). Word frequencies varied from 32 to 50 uses per million. The Twi noncognate equivalents of the English words were taken from the Twi-English, English-Twi Hippocrene Concise Dictionary (48). The Twi words used in the experiment, together with their English translations, are shown in Appendices B and C. One-hundred and sixty-eight items from the word pool were used as targets, and the remainder was retained as filler words.

Ninety-six pronounceable English non-words were created to fulfill non-word conditions (e.g., agple - instead of apple). The number of letters in letter strings was similar for word and non-word targets to prevent ease of discriminability between probe targets and distractors. The three priming conditions were: attended repetition (AR - wherein the probe English target was the Twi translation of the prime target word - (e.g., safoa (Twi word for key) - key); control condition (CO - wherein prime and probe stimuli had no relationship); and ignored repetition condition (IR - wherein the target probe English word was the translation of the ignored prime Twi word (e.g., MFONINI (Twi word for photo) - photo).

In the experiment, there was a slight difference between the task responded to by participants from the College of Education (CoE) and those from the University of Cape Coast (UCC). The CoE group had primes (both target and distractor) always in L1 (Twi) and the target probes in L2 (English), but the distractor probes in L1; whereas the UCC group had the primes (both target and distractor) in L1 and the probes (both target and distractor) in L2. (Tables 1 and 2). Thus in the CoE group, participants named a Twi prime target word while ignoring an uppercase Twi distractor word, and then made a lexical decision to an English probe item while ignoring an uppercase Twi probe distractor word. The UCC students named a Twi prime target word while ignoring an uppercase Twi distractor word, and then made a lexical decision to an English probe item while ignoring an uppercase English probe distractor word. The logic was to examine if the language of the probe distractor has any influence on whether the hypothesized elimination of the cross-language facilitation is dependent on having the probe distractor word in L1 (the language required for response to the prime target word), as specified earlier. Sample trial couplet sequences for each group are presented in Figure 1. All other stimuli, presentation parameters, and conditions of the experiment were the same for both groups.

TABLE 1

Sample of conditions for word/non-word trials in CoE experimental group

Condition	Prime Display	Probe Display
Attended Repetition	ABAKƆN	star
	nsoroma	GYIDIE
Control Condition	asɛm	promise
	BƆSUO	NTAKRA
Ignored Repetition	KURUWA	cup
	adwuma	SAFOA
Non-word Condition	TOA	schudent
	afunumu	ADWENE

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

TABLE 2

Sample of conditions for word/non-word trials in the UCC experimental group

Condition	Prime Display	Probe Display
Attended Repetition	AKWADAA	linguist
	ɔkyeame	BUTTER
Control Condition	asɛm	LEMON
	BƆSUO	kitchen
Ignored Repetition	OBUBUANI	lame
	adwuma	KEY
Non-word Condition	TOA	pewdor
	afunumu	BRAIN

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

Each condition (AR, CO, and IR) of the experiment consisted of 24 trials, plus 72 non-word trials. Prime and probe non-target distractors consisted of real words in both "word" and "non-word" trials. Along with the 72 target words for the conditions of interest, additional words served as fillers in the role of target and/or distractor stimuli (e.g., the prime distractor in the AR and CO condition, the prime target in the IR condition, the prime target and distractor in the non-word condition (see Appendix C). The 72 probe target words were randomly assigned into sets A, B, and C of 24 words in each of the three conditions (AR, CO and IR) and systematically rotated for the purpose of counterbalancing. This yielded 3 versions of the experiment and participants were randomly assigned to each version. As such, each word that appeared for example as a probe target in the AR condition also appeared as a target in the CO and IR conditions in the other two versions, respectively. Hence, probe target words to which lexical decision response times to the AR, CO, and IR conditions were perfectly counterbalanced across participants. The entire sets of 72 word and 72 non-word trials were arranged in random order and the same order appeared for all participants

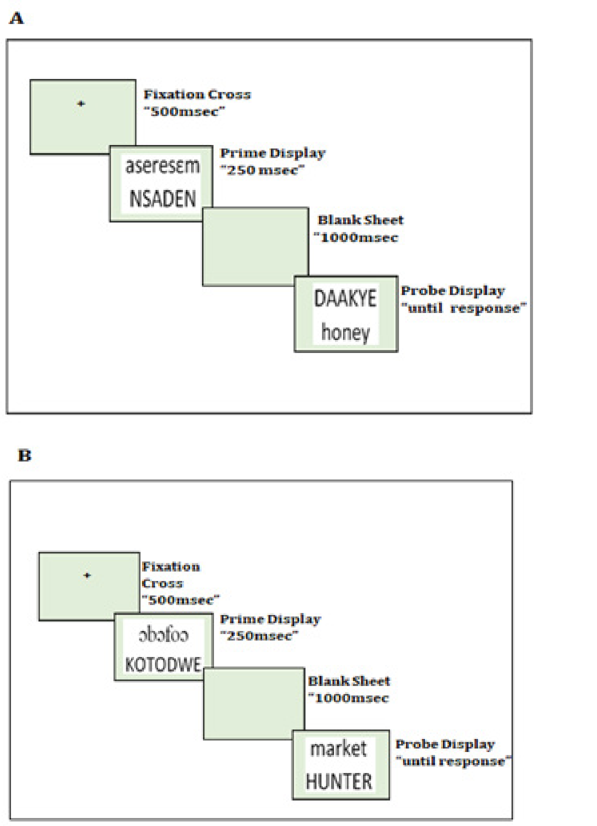

Figure 1) A) *Sequence of stimulus in a trial couplet for the CoE group. The probe distractor was a Twi word. B) Sequence of stimulus presentation in a trial couplet. For the UCC group. The probe distractor was an English word. Note that in the experiments the distance between the closest edges of the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

irrespective of the counterbalancing version. Each target or distractor word was presented only once in a prime-probe couplet except to satisfy the AR or IR condition. The aim of which was to curtail any possible carry-over effects from the repetition of words, thus helping to elicit pure priming effects. The experiment was deliberately designed with a low ratio of trials representing each condition. This was deemed especially important for AR trials, which comprised 1/6th of the total trial couplets, because as relatedness proportion increases, respondents are apt to formulate expectancies and benefit by speeded performance when repetition is predicted (49). Similarly, the logic underlying the 72 non-word trials (equaling the number of word trials) was to eliminate any bias toward responding "word" or "non-word" (28). There were 24 practice trial couplets (12 word and 12 non-word trials) that were not repeated in the main experiment.

Apparatus and stimuli presentation

Testing was carried out on a 15.6 inch Hewlett-Packard (HP) laptop computer. All programming was done with E-Prime 2.0 software (50). A 5-button PST Chronos response box, which features milliseconds accuracy across machines, was used for recording lexical decision reaction times (Psychology Software Tools, Inc., 2012). The two leftmost buttons were activated and designated "word" and "non-word". A response sheet that contained the prime target words was used to monitor the naming of primes. Word length for both Twi and English stimuli ranged between three to fourteen letters. All word stimuli were printed in lowercase (target) and uppercase (distractor) black letters (Calibri, font size 11) on a white background. Non-word letter strings served only as probe targets and were always in lowercase black letters. The distance between the closest edges of the top and bottom letter string was 1 pixel width. The width of the words covered approximately 1.4 cm (1.6 degrees of visual angle) for the shortest to 5 cm (5.7 degrees of visual angle) for the longest. Prime displays were presented either centred, or slightly to the left or right of centre, in equal proportions on the computer screen, because research shows that varying stimulus position helps to increase the magnitude of negative priming by taxing attentional selectivity more than when static stimulus positions are held (51). The distance between the left and right words from the centre was about 1.5 cm (1.7 degrees of visual angle). Probe stimuli were displayed at the centre of the screen at all times.

Design and procedure

A mixed design was employed. The between-subjects variables were probe distractor (Twi *vs.* English) and proficiency (More *vs.* Less). The within-subjects variable was priming condition (AR *vs.* CO *vs.* IR). Each participant was tested individually in a session lasting about 45 minutes in a dimly-lit room optimised for low noise. They sat at approximately 50 cm from the computer screen. Instructions emphasised strict accuracy as well as quick reaction time. Participants underwent the practice trials repeatedly if necessary, to become familiar with the task before starting the main trials. They were instructed to overtly name the prime target word (lowercase letters) and subsequently decide whether the probe target (lowercase letters) was a correct English word or not. Lexical decisions to probe target items were made by pressing the "word" button with the index finger of the right hand, and the "non-word" button with the middle finger of the right hand.

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

RESULTS

Cut-off scores of 30% naming errors or 30% lexical decision errors were pre-set in order to exclude participants with large numbers of errors. However, no one exceeded these error rates so the analysis was carried out on the 73 participants (35 belonging to CoE and 38 to UCC). Non-word trials were not included in the analysis. Only those probe trials in which both the prime and probe targets were correctly identified were included in the calculation of the mean RT. The mean RT for each participant was then converted into the adjusted RT, or AdjRT [AdjRT=RT/(1-% error)]. The AdjRT technique controls for speed-accuracy trade-offs (37,52,53) and it is considered a more sensitive and accurate gauge of processing than just RTs alone. Refer to Figure 2 for the AdjRT results as a function of priming condition and L2 proficiency. The error bars show the within-subjects standard error of the means (54). The mean RTs and error rates are shown in Appendix D.

Before formal analyses are conducted, it is important to point out that the clearest distinction between the less and more L2 proficient bilinguals is in the neutral control condition where the error bars do not overlap, as can be seen in Figure 2. This is how it should be if our median split analysis successfully created two discernibly different groups in L2 proficiency. The benefit in the AdjRT in the control condition for the more proficient bilinguals is because they are more efficient in processing the probe target when there has not been any priming manipulation.

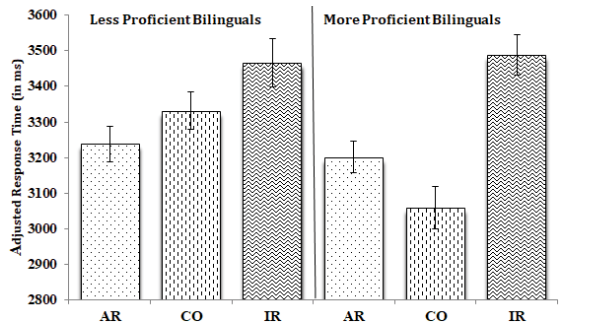

Figure 2) *Adjusted mean response latency (in milliseconds) as a function of Attended Repetition (AR), Control (CO), and Ignored Repetition (IR) conditions for less and more proficient bilinguals in L2. Error bars indicate within-subjects standard errors.*

A 2 × 2 × 3 mixed analysis of variance (ANOVA) was conducted on the AdjRT data, with probe distractor (L1 *vs.* L2 word) and proficiency (more *vs.* less) as between-subjects factors and priming condition (AR *vs.* CO *vs.* IR) as the within-subjects factor. A significant main effect of priming was found [F (2, 138)=10.68, MSE=1852872, p=0.001, η_p^2=0.13], indicating significant differences among the three priming conditions. In addition, there was a marginally significant interaction between language proficiency and priming [F (2, 138)=2.68, MSE=465595, p=0.07, η^2_p = 0.04. No other effects reached significance. Due to the specificity of our a priori hypotheses that, relative to the less proficient bilinguals, the participants with more proficiency in L2 would show amplified negative priming but no positive priming, we next conducted two separate ANOVAs: one comparing the results from the AR and CO conditions, and the other from the CO and IR conditions.

Attended repetition *vs.* control condition

Mean AdjRT's were entered into a 2 (L1 *vs.* L2 probe distractor word) x 2 (More *vs.* Less L2 proficient) x 2 (AR *vs.* CO) mixed ANOVA. The main effect of priming was not significant [F (1, 69)=.27, MSE=34177, p=.60, η_p^2 = 0.00], indicating there was no overall AR positive priming effect. In addition, no significant main or interaction effects were observed for the probe distractor factor (p=.26 and .73, respectively), indicating that the language (L1 or L2) of the probe distractor had no effect on the processing of the probe target. The only statistically significant effect was the interaction between priming and proficiency [F (1, 69)=4.13, MSE=519006, p<0.05, η_p^2 = 0.06]. The source of this interaction stems from the more proficient in L2 producing somewhat slower responses in the AR condition (3202 msec) relative to the CO condition (3059 msec), whereas the less proficient in L2 produced somewhat faster responses in the AR condition (3239 msec) relative to the CO condition (3332 msec).

To clarify the priming by proficiency interaction, we conducted t-tests for dependent means for the more and less proficient groups separately. Although the less proficient participants produced a tendency towards positive priming (93mec), the effect was not significant [t (37)=1.21, p =.12, d=.20]. The more proficient in L2, on the other hand, produced a tendency toward slower responses (142ms) in the AR condition relative to the control condition. The effect was marginally significant [t (34)=1.60, p =.06, d=.27]. This pattern of data is consistent with the L2 proficiency analyses and results reported by Neumann et al. (27). Most notably, as in the earlier study, the pattern of data from the more proficient group is consistent with the notion that inhibition is applied globally to the prime language after the prime trial when the prime language is no longer needed for the lexical task. For these participants the prospective knowledge that the upcoming probe response requires L2 serves to globally inhibit their L1 in order to avoid interference from the now irrelevant language, thus eliminating any hint of spreading activation between AR translation equivalent concepts. These results are entirely consistent with the finding reported by Neumann and colleagues (27). Moreover, the absence of any probe distractor effects suggests the probe distractors are effectively ignored. More importantly, this verifies that regardless of whether the probe distractor word is in L1 or L2 it is the anticipated regular alternation beween L1 and L2 in each prime-probe couplet that eliminates AR positive priming by inducing the more proficient in L2 to inhibit L1 to avoid potential interference from L1 when responding to the L2 probe target word.

Ignored repetition *vs.* control

A 2 (L1 *vs.* L2 probe distractor word) × 2 (More *vs.* Less L2 proficient) x 2 (CO *vs.* IR) mixed ANOVA was also conducted on the mean AdjRT's data. The main effect of priming was significant [F (1, 69)=14.03, MSE=3068999, p<.001, η_p^2 = 0.17], with longer RT in the IR condition (3477 msec) than in the CO condition (3201 msec). In addition, no significant main or interaction effects were observed for the probe distractor factor (p=0.18 and 0.82, respectively), indicating again that the language (L1 or L2) of the probe distractor had no discernible effect on the processing of the probe target. The interaction between priming and proficiency was significant [F (1, 69)=3.84, MSE=839445, p<0.05. η_p^2 = 0.05]. No other effects were significant. Due to the specificity of our hypotheses predicting a greater magnitude of negative priming for the more proficient in L2, and to clarify the priming by proficiency interaction, we again conducted two separate paired t-tests, one for the more proficient and the other for the less proficient bilinguals. The less proficient participants produced a tendency towards negative priming (135 msec), however, this was not statistically significant [t (37)=1.23, p=.11, d=.20]. The more proficient participants on the other hand, produced a statistically significant impairment (429 msec) in the IR compared with the CO condition [t (34)=3.93, p<.001, d=0.66]. These results for the more and less proficient in L2 participants are again consistent with the findings reported in the cross- language English-Spanish by Neumann and colleagues and will be explored further in the broader context of the Discussion section below (27).

DISCUSSION

Together with findings by Neumann et al., the current findings provide a novel perspective for investigating bilingualism and the consequences of second language proficiency in modulating two mechanistic sources of inhibitory control (27). For the more proficient in L2, this was demonstrated by the behavioral cost causing the complete elimination of cross-language facilitatory priming between translation equivalent concepts in the attended repetition condition by global inhibition of a language that becomes irrelevant and potentially interfering for responding to the probe display. Despite no positive priming, this was coupled in the same tasks with enhanced negative priming between an ignored prime distractor word and its translation equivalent concept in the ignored repetition condition for the more proficient L2 bilinguals. From our perspective, it is the local inhibition of a competing prime distractor word, coupled with the global inhibition of the language used in naming the L1 prime target, which produces exaggerated negative priming impairment for the more proficient L2 bilinguals. Hence, the reason the AR and IR AdjRTs are quite similar between the less and more proficient is due to a specific impairment in the AR condition for the more proficient whereby any potential benefit of positive priming is completely eliminated; whereas the specific impairment they suffer in the IR condition is due to the amplification in the cost of negative priming. As hypothesized, both of these patterns are due to the greater efficiency in global language suppression and local prime distractor word suppression, respectively, by the more proficient bilinguals.

Specific implications for the inhibition-based theory

In the current cross-language selective attention context, the results provide strong support for the inhibition-based account of negative and positive priming. Overall, the study did not produce significant positive priming effects in the attended repetition condition wherein the prime and probe targets were translation equivalents, irrespective of whether the probe distractor shared the same language as the prime or was presented in the same language as the target probe. However, negative priming effects were produced in the IR condition where the probe distractor was the translation equivalent of the ignored prime. This was particularly the case for the bilinguals who were more proficient in their L2, and this was the same regardless of whether the language of the probe distractor was an L1 or L2 word.

The robust negative priming effects observed in the IR *vs.* CO trials coupled with no positive effect in the AR *vs.* CO trials are consistent with the inhibition hypothesis. What might account for this? The nature of the present tasks required a regular alternation of languages which changed systematically and predictably between primes and probes throughout the task. Hence, after naming the prime target in Twi in the present paradigm, the Twi language as a whole becomes irrelevant and potentially disruptive, especially for those more adept in their second language. Because participants know that the ensuing probe task is in English, keeping the Twi language system activated could impair the subsequent task of making a lexical decision to the English probe target. Consequently, global inhibition of the Twi language system is induced, thus preventing any potential spread of activation from one language to the other, which nullifies any benefit for a translation equivalent probe word in the other language (55). In addition, a local form of inhibition is applied selectively to the Twi prime distractor word, during naming of the prime target. In this case, it is evident that the inhibition spreads to its translation equivalent in English and consequently delays processing of that word if it becomes a translation equivalent probe target word. The cumulative effect of global inhibition of the irrelevant language and selective inhibition of the prime distractor word is manifested in the large negative priming effect, coupled with the total absence of positive priming by the more proficient L2 bilinguals.

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

The role of L2 proficiency in inhibitory control

The overarching aim of the current study was to explore the role of L2 proficiency in shaping the mechanism underlying bilingual lexical selection and processing. We hypothesised that if the proficiency effects predicted by Neumann et al.'s cross- language experiment are substantiated, then the IR negative priming effect should be especially strong for the more proficient bilinguals, and that AR positive priming was more likely to be eliminated in the more proficient than the less proficient participants (27).

In conjunction with the same results reported and predicted by Neumann et al.'s bilingual study, we propose that more proficient participants are induced to inhibit their L1 language (Twi) when the upcoming lexical decision response required a different language (English) (27). Hence, after requiring Twi to name the prime target, a global inhibition of the now irrelevant Twi language ensues, rendering priority to the forthcoming relevant language (English). In our view, this accounts for the elimination of positive priming, as well as the magnified negative priming recorded in the more proficient, compared to the less proficient group. On the other hand, the less proficient participants appear to be more dependent on their Twi (L1) language to respond to the probe task in the English (L2) language. They might access the meaning of L2 (English words) via the L1 (Twi words) such that completely inhibiting one language is less likely to occur. After naming the prime target (Twi), a less proficient participant may be unable to entirely suppress the Twi language system, because it may be necessary for processing the upcoming English task. For less proficient participants successful L2 processing might be contingent on keeping both the L1 and L2 languages active, and this may help account for their trend toward positive priming in the AR condition, coupled with the nonsignificant negative priming effect in the IR condition (3). Less proficient bilinguals may be more inclined to rely on their native language as a type of crutch when accessing their second language, whereas more proficient bilinguals may employ a global form of inhibition to suppress the potential interference from L1 when it becomes irrelevant for a response requiring L2 (27,56,57). The more proficient bilinguals thus appear to be able to isolate their languages more efficiently than their less proficient counterparts, such that once the response to a prime L1 (Twi) is accomplished; L2 (English) activation is prioritised. In our view, the above descriptions help to explain the complete pattern of AR *vs.* CO and IR *vs.* CO priming as a function of L2 proficiency.

For the reasons given above, the potential AR positive priming and IR negative priming effects were showing more extensive impairment in the more proficient individuals, compared to the less L2 proficient individuals. As was the case in the earlier cross-language experiment, only the CO condition appears to have been dealt with more easily by the more proficient, compared to the less proficient, L2 participants (27). This is as it should be, because it is only the control condition that would not suffer the consequences of the posited inhibitory influences affecting the AR and IR conditions. Thus, despite using different methods for establishing the median split analysis, our earlier and the present study's results reinforce one another and suggest that distinguishable more and less L2 proficient groups were established in both of these cross- language experiments.

An important implication from the convergence of findings between the present study and the earlier English-Spanish study 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 (27). The mechanisms involved also appear to be quite general cognitive mechanisms that are shared in common with findings in other selective attention studies, especially those involving negative priming effects (37). Due to the novelty of our findings, future cross-language experiments pursuing positive and negative priming effects as a function of L2 proficiency should be rigorously pursued with the present selective attention paradigm. In this pursuit, it would also be beneficial to test different bilingual language groups with even more objective measures of second language proficiency to help verify the convergence of the current findings with those reported in our earlier cross-language priming study.

Problems for the episodic retrieval model

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

As a result of its backward acting nature, positive and negative priming effects produced by the episodic retrieval model depend largely on the extent to which the probe display target serves as a retrieval cue for the target or distractor word in the previous prime display. Thus one way to examine the episodic retrieval model is to manipulate prime-probe similarity because episodic retrieval is determined by the similarity of context between encoding and retrieval episodes (58,59). The important point in this framework is that negative and positive priming should be maximized to the extent that probe targets share similarity with either the prime target or prime distractor. The greater the similarity, in both cases, the more likely the attached tag would be elicited.

In effect, episodic retrieval theory would predict both positive and negative priming outcomes in cross-language tasks, although, if anything, there should be a greater likelihood of obtaining an AR positive priming effect than an IR negative priming effect. It is important to note that the presence of either of these effects would necessitate an intimate conceptual connection between a word from one of the languages to the translation equivalent of that word in the other language. More crucially, however, in a test of the predictions from episodic retrieval, there should be a reduced likelihood of demonstrating IR negative priming than AR positive priming. Because the uppercase non-target in the prime becomes the lowercase target in the probe in the IR condition, there is an additional contextual change between prime and probe words compared to the AR manipulation in which both prime and probe targets are in lowercase letters. Hence the IR condition should provide a less effective retrieval cue, according to the dictates of the episodic retrieval account. It is thus problematic for the episodic retrieval account that a non-target prime distractor had enough influence on the probe target to induce negative priming, but the attended prime target was not sufficiently "similar" to the identical probe target to produce positive priming. While it may be possible for the episodic retrieval account to accommodate other findings regarding positive and negative priming in selective attention tasks, it is clearly the case that in the present cross-language study inhibitory processes are overriding any potential influence from episodic retrieval processes (60).

Although it is beyond the scope of the present article to discuss in detail, it should be pointed out that the dissociation we observed between AR positive and IR negative priming effects also contradicts a major pre-theoretical assumption in the selective attention literature. As articulated by Christie and Klein, it is generally assumed that attended information should always produce stronger priming effects than ignored information in selective attention tasks, such as negative priming paradigms that include a positive priming manipulation (61). This pre-theoretical assumption, held by most selective attention researchers, should be re-evaluated in light of the present findings (62). It seems intuitively obvious that attending to something should be more likely to have a larger impact on priming, compared to something that has been ignored, but this intuition should henceforth be questioned. In the cross-language context it is the non-target, ignored information that is having the greater impact on modulating the priming effects.

Broader theoretical implications

There are a number of additional potentially important theoretical and empirical implications of our cross-language priming. For instance, previous studies have attempted to draw parallels between selective attention and memory research by way of an inhibitory or suppressive information processing mechanism they might share in common (20,21,41). As described earlier, this inhibitory mechanism is thought to suppress distracting, non-target words in certain negative priming tasks. A similarly described active inhibitory mechanism has also been posited to accommodate two different memory phenomena, encompassing retrieval induced forgetting (41,63-65). If the same active inhibitory mechanism is involved in reducing or eliminating interference effects from no longer relevant words in each of these cases, it would help advance and unite both the selective attention and memory literatures through a shared adaptive processing mechanism.

For example, another way to accommodate the elimination of positive priming across languages in a task that nevertheless produces negative priming across languages is to think of it as the reaction time (RT) analogue to the "no-think" component of the think/no-think phenomenon in the memory literature (64-66). Recall that the T/NT task involves a reminder to an unwanted memory of a previously encountered word and instructions to suppress the thought of that word (without mentioning the word itself) from awareness. Similarly, in regard to our cross-language priming tasks, participants are simultaneously induced not to think of a language that is attended in the prime display and a non-target distracting word as they become irrelevant and potentially distracting prior to the onset of the probe display. Rather than being instructed not to think about a word, however, as in the T/NT task, in the cross-language selective attention tasks participants are being induced not to think about a language on the one hand and a conflicting word on the other by the regular alternation between languages, and the non-target status of the ignored prime word.

Because the current study together with our other cross-language experiment provide strong evidence of suppressive processing at both a local and a global level for more proficient L2 bilinguals, such participants in particular should show evidence of inhibitory processing that is potentially detectable on an almost trial by trial basis (27). The observable behavioural priming effects should therefore become valuable tools for providing alternative ways of evaluating the neurobiological role of GABAergic metabolism whenever inhibitory information processing is being exploited in order to efficiently suppress unwanted memories whether they stem exogenously from the environment in a selective attention task or endogenously in a memory task. Schmitz and colleagues recently observed that hippocampal GABA (a chemical neurotransmitter substance that implements neural inhibition) contributes to stopping unwanted memories (66). They showed that GABAergic inhibition of hippocampal retrieval activity forms the key link in the volitional inhibitory control underlying thought suppression and impaired memory for suppressed content. Their evidence for a mechanism enabling inhibitory control over specific memories via GABAergic inhibition of local hippocampal activity could in turn provide the underpinning mechanisms for the lack of AR positive priming combined with intact IR negative priming in our cross-language paradigms with more and less proficient bilinguals (27). Linking these purportedly suppressive selective attention and memory phenomena within a neurobiological framework would be a worthwhile pursuit, because one of the main goals of cognitive psychology is to establish genuine information processing mechanisms that are closely aligned with the actual neurophysiological mechanisms of the brain (37,40,67). Mutual verifications from suppressive priming effects with words and no-think memory effects with words could help establish for the first time a psychologically real information processing mechanism that is functionally responsible for temporarily purging unwanted memories or thoughts.

CONCLUSION

The results reported here corroborate and extend the study by Neumann et al. (27). Each of these studies directly tested differentiable predictions from an active inhibition perspective in contrast to the episodic retrieval account via cross-language priming tasks with bilinguals.

The inhibition-based account more successfully accommodated the collective findings. What is fundamentally amiss in the episodic retrieval theory is the prediction that the likelihood that the AR condition should produce positive priming is greater than the likelihood that the IR condition should produce negative priming. Instead, our findings suggest that local and global forms of inhibition have critical roles in bilingual lexical selection and processing and can operate simultaneously within the same task. The overall outcomes, and in particular the demonstrated effect of L2 language proficiency indicate that bilingual language processing can be regulated by two sources of active inhibition: one stemming from the global suppression of a language that becomes irrelevant and potentially distracting, and another that acts on a local word level that suppresses a competing word (68). These results provide a step toward understanding how proficient bilinguals are able to vacillate between their languages with such fluid dynamics. They also extend our understanding of inhibition phenomena and how they might be used to track the crucial roles of L2 proficiency in modulating bilingual language representation and memory processes. Future work will be needed to get a more complete understanding of how this language control transpires and what exactly differentiates less from more proficient bilinguals in their second language.

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