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Excitatory and inhibitory priming by attended and ignored non-recycled words with monolinguals and bilinguals

Ewald Neumann, Ivy K. Nkrumah and Zhe Chen

Department of Psychology, University of Canterbury, Christchurch, New Zealand

ABSTRACT

Experiments examining identity priming from attended and ignored novel words (words that are used only once except when repetition is required due to experimental manipulation) in a lexical decision task are reported. Experiment 1 tested English monolinguals whereas Experiment 2 tested Twi (a native language of Ghana, Africa)-English bilinguals. Participants were presented with sequential pairs of stimuli composed of a prime followed by a probe, with each containing two items. The participants were required to name the target word in the prime display, and to make a lexical decision to the target item in the probe display. On attended repetition (AR) trials the probe target item was identical to the target word on the preceding attentional display. On ignored repetition (IR) trials the probe target item was the same as the distractor word in the preceding attentional display. The experiments produced *facilitated (positive) priming* in the AR trials *and delayed (negative) priming* in the IR trials. Significantly, the positive and negative priming effects also replicated across both monolingual and bilingual groups of participants, despite the fact that the bilinguals were responding to the task in their non-dominant language.

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Visual selective attention entails the ability to respond to a subset of targeted information while ignoring irrelevant distracting information. Determining how relevant information is selected from among distractors in the stimulus environment remains an imperative issue in cognitive psychology. There is evidence that in selective attention both relevant and irrelevant information is initially activated in parallel, followed by enhancement of target information while distractor information is suppressed (Cerf et al., 2010; Neumann & DeSchepper, 1991; Tipper, 1985). To explore the suppression of irrelevant information, Tipper (1985) presented participants with sequential pairs of trials, a prime followed by a probe, with each trial consisting of two superimposed objects, one printed in green and the other in red. The task was to name the green object while ignoring the red one. In contrast to neutral control conditions, they found *positive* (facilitation) identity and semantic priming effects, the former when the target objects in the prime and probe trials were the same, and the latter when they were semantically related. In addition, response times were considerably longer, compared to control conditions, when the ignored object on the prime display was the same as, or semantically related to, the subsequent probe target. These latter effects were dubbed *negative priming* (Tipper, 1985).

Two main rival theories purport to explain the mechanism(s) behind negative priming effects. Along with an inhibition-based account there is also a memory-based account known as episodic retrieval theory (e.g., Neill, 2007; Neill & Mathis, 1998; for reviews see Frings, Schneider, & Fox, 2015; Mayr & Buchner, 2007). Despite involving different mechanisms, these two theories often make the same predictions regarding the outcome of experiments that include attended repetition (AR) (positive priming) and ignored repetition (IR) (negative priming) manipulations (Neumann & Levin, 2018). In inhibition accounts a lingering attention-based activation of targets and inhibition of distractors accounts for positive and negative priming. In episodic accounts, however, the presentation of a target prompts the automatic retrieval of the most current previous encounter (episode) with that stimulus resulting in positive priming if it was a previous target and negative priming if it was a previous distractor, because of the compatibility or incompatibility of episode response codes. Because there is no need to inhibiti a language that is always the target, these two theories make the same predictions in the present within-language experiments. A more detailed treatment of the memory-based theory is preserved for the General Discussion, which provides a broader context for evaluating the two theories.

Negative and positive priming effects have been extensively researched (e.g., Frings, Wentura, & Wühr, 2012; MacLeod, Chiappe, & Fox, 2002; Neumann & DeSchepper, 1991; Ortells & Tudela, 1996). One of the inconsistencies

CONTACT Ewald Neumann ewald.neumann@canterbury.ac.nz Department of Psychology, University of Canterbury, Private Bag 4800, Christchurch, New Zealand

in the negative priming literature provides a major focus of the present investigation. The inconsistency relates to whether negative priming can be produced with experimentally novel words; that is, words that are used only once except when repetition is required due to experimental manipulation, in which case the words are encountered exactly twice within an experiment. Malley and Strayer (1995) investigated the effects of stimulus repetition on negative priming using prime and probe words that appeared only once in the experiments except to fulfil the AR and IR manipulation. The task was to name the target word (printed in red) while ignoring a distractor word (printed in white). AR positive priming was found in the conditions where prime and probe target words were the same, but IR negative priming did not occur in conditions where the prime distractor was the same as the probe target. In other experiments, when a limited pool of words was used, and these words were repeatedly presented as both targets and distractors, the results produced IR negative priming, but no positive priming in the AR condition.

Intriguingly, when Malley and Strayer (1995, Experiment 5) mixed the novel and repeated words conditions within the same block, *positive priming* was found in the novel word IR condition (Grison & Strayer, 2001; Strayer & Grison, 1999). To account for their findings, Malley and Strayer proposed that negative priming effects occur only when "two highly activated items are presented in tandem and compete for a response" [p. 665], as would be the case with a small pool of recycled words. According to these researchers, when words are repeatedly used, their activation levels would be heightened, and negative priming would occur because selection difficulty in the prime display is high. That is, when the distractor is highly activated, its representation is more likely to compete or interfere with the representation of the target, and it is in such situations that the conditions for producing negative priming are met. In contrast, when words are used only once, their activation levels are relatively low, because the novel distractor word in the prime display is less likely to compete strongly with the target word. In this situation, the conditions necessary for IR negative priming to emerge are unmet and negative priming does not occur. Moreover, Malley and Strayer's Experiment 5 results showed that even positive priming can emerge in the IR condition when the degree of competitiveness between target and distractor prime words is minimised.

A study by Neumann, McCloskey, and Felio (1999, Experiment 1), however, found a different result when using a large pool of words in an experiment where a word was displayed just once except to fulfil the AR and IR manipulation. Their participants were presented with displays consisting of two words and were required to first name the prime target and then to make a lexical decision to the probe target. They found AR positive priming effects occurred when the prime target was identical to the following probe target, whereas IR negative priming was observed when the prime distractor was the same as the subsequent probe target. DeSchepper and Treisman (1996) have also reported negative priming in experiments that employed a large set of novel shapes. Interestingly, however, they reported that IR negative priming was not found in a similar experiment that used a large set of words. Hence, it remains unclear whether negative priming can be reliably obtained with experimentally novel *words*.

It is worth noting here that Henson, Eckstein, Waszak, Frings, and Horner (2014) observed that people can rapidly form arbitrary associations between stimuli and the overt and covert responses they make in the presence of those stimuli. This includes responses not only to targeted prime stimuli, but also nontarget prime distractors in traditional negative priming tasks. To avoid the consequences of such stimulus–response bindings in priming, they recommended using a large pool of stimuli, combined with naming or perceptual identification of the prime, together with a different task such as classification of the probe. Under these circumstances each stimulus would be associated with a unique response that is not repeated in the probe component of a trial, and so could not modulate priming. These recommendations are especially important in light of the observation that negative priming tasks using small pools of items are extremely susceptible to asymmetric transfer effects from influential companion conditions (Neumann & Levin, 2018). Moreover, Neumann and Levin showed that having only small pools of stimuli creates artefacts that have little relationship to process-pure priming effects, thus distorting the priming effects one should be tracking in experiments designed to discover the mechanisms that underlie priming effects, whether they be positive or negative priming. As far as we know, it is only the Neumann et al. (1999) and the current study that have followed the strictures posited by Henson and colleagues.

In light of the inconsistent results described above regarding negative priming effects with words, the main objective of Experiment 1 was to determine whether AR positive and IR negative priming effects can be observed with a large pool of non-recycled words using a purely monolingual group of participants. The aim of Experiment 2 was to investigate for the first time whether the same results would emerge when the stimuli were in the non-dominant language of a group of bilinguals.

As the cognitive and linguistic processes engaged in the acquisition and use of two languages are different from those involved in monolingual language use (Bialystok, 2010; Treccani, Argyri, Sorace, & Della Sala, 2009; but see de Bruin, Treccani, & Della Sala, 2015), it is unclear whether the results obtained from monolingual speakers can be generalised to bilingual or multilingual speakers. Many important questions that confront bilingual researchers do not usually arise in monolingual discussions. These questions include how two languages are represented in memory, how bilinguals manage to select one of their languages for use, and what the nature of the system is that enables bilinguals to switch back-and-forth between languages in different circumstances without constant errors (Kroll, Bobb, & Hoshino, 2014). In the present study, we investigate whether priming effects produced by attended and ignored novel words are expressed differently in bilinguals compared with monolinguals when bilinguals use their second language (L2) in a selective attention task. Specifically, we explore whether and how the additional processing complexity involved in language selection in bilinguals in Experiment 2 would impact positive or negative priming results differently from the pattern of results produced by monolinguals in Experiment 1.

Experiment 1

As mentioned earlier, previous research is equivocal on whether negative priming could occur in an experimentally novel *word* IR condition. Whereas Strayer and colleagues (e.g., Grison & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999) showed that negative priming was contingent on stimulus repetition when *words* were used as stimuli with colour as the selection cue, Neumann et al. (1999) found robust negative priming effects using non-recycled words with letter case as the selection cue. Experiment 1 examines identity negative and positive priming effects using a variant of the identity priming task used by Neumann et al. (1999). Experimentally novel words were used with native English-speaking monolingual respondents. In contrast to Neumann et al.'s Experiment 1, which included a mixture of monolinguals and bilinguals, the present experiment screened participants to ensure that only monolinguals were included. This was done to try to confirm the earlier findings with a group that did not have the possibly complicating factor of bilingual activation. Participants named the lower case target word in the prime trial, then performed a lexical decision task via manual key pressing to the lower case target item in the probe trial. If negative priming is conditional on stimulus repetition as stated by Strayer and colleagues, then no negative priming should be obtained in the IR condition relative to the control condition. Conversely, if Neumann et al.'s findings are corroborated, then significant negative priming should be observed. Testing a purely monolingual group of participants is important because it eliminates the potential complicating factor of bilingual semantic activation, thereby helping to confirm and to generalise the effects reported in Neumann et al.'s study.

In addition to a different and specifically monolingual population, there were a number of other methodological differences between the Neumann et al. (1999) study and the current study. For example, a completely different and larger pool of words was used in the present study. In addition, different computer equipment and experiment generation software were used (e.g., MacIntosh desktop computer vs. Hewlett–Packard laptop, MacLab vs. E-prime experiment generation software, keyboard response input vs. PST Chronos response box), along with different methods of stimuli randomisation and counterbalancing.

Method

Participants

The participants were 39 English-speaking monolingual students (29 men and 10 women) from the University of Canterbury, New Zealand. Their ages ranged from 18 to 28, with a mean age of 22. Self-reports indicated that none of the participants could speak more than a few words in another language and they all reported normal or corrected-to-normal vision.

Stimuli and apparatus

The stimuli consisted of 620 three-to-thirteen letter words from the word norms of Francis and Kucera (1982). Word frequencies ranged between 32 and 50 uses per million. One hundred and sixty-eight words were randomly selected to act as targets and the remaining as filler words. Ninety-six English pronounceable nonwords were also created (e.g., *pawdar* instead of *powder*) for the nonword condition. String length for "word" and "nonword" stimuli were kept similar so there was no predictive relationship between string length and the word versus nonword category.

Two hundred and sixteen words were randomly selected and assigned to 1 of the 3 groups (72 each): nontarget primes, nontarget probes, and probe targets. The probe target words were randomly and equally distributed into sets 1, 2, and 3, with 24 words in each of the 3 conditions of interest: AR, IR, and control (CO). Participants were assigned at random to one of the three groups for the purpose of counterbalancing. Group 1 had Set 1 as AR trials, Set 2 as IR trials and Set 3 as CO trials; Group 2 had Set 1 as CO trials, Set 2 as AR Trials and Set 3 as IR trials; and Group 3 had Set 1 as IR trials, Set 2 as CO trials and Set 3 as AR trials. The entire trial sets of 72 word and 72 nonword trials (nonword trials were the same for all groups) were arranged in a random order, and the same order was then employed for all the participants irrespective of group. For instance, if the probe target word "bird" was presented on the 20th trial for Group 1 in the AR condition, it was also presented on the 20th trial for Groups 2 and 3 in the IR and CO conditions, respectively. Across participants, this resulted in the target words being exactly matched across conditions. The filler words were similarly matched, for the same stimuli were used in all the versions. Because each probe target was paired with the same distractor word and in the same position in the trial sequence for all participants regardless of group and condition, this ensured that we could attribute the priming effects, if found, to our experimental manipulation of the relationship between the prime and probe trials rather than to some extraneous factors such as the specific stimuli used in a condition or their positions in the trial sequence.

The experiment consisted of 144 prime–probe trial couplets, with 50% of the probe trials requiring a "word" response and the remaining 50% requiring a "nonword" response. We used equal proportions of "word" and "nonword" trials, because if the nonword ratio is less than half of the total trial couplets participants may be biased to produce a word response when a nonword is presented (see Altarriba & Basnight-Brown, 2007). Only 16.7% of the total trial couplets (i.e., 24 trial couplets) were AR trials. This was to ensure that we would obtain an uncontaminated estimate of priming effects, for there is evidence that an increase in prime–probe target relatedness induces participants to form expectancies, and this in turn would affect their performance (e.g., Neely, 1991; Neumann & Levin, 2018; see also Altarriba & Basnight-Brown, 2007; Neely, O'Connor, & Calabrese, 2010). The IR and CO conditions also each consisted of 16.7% of the total trial couplets. The AR, CO, and IR manipulations were only used for the word condition, not for the nonword condition. Prime target, prime distractor, and probe distractor were always words in both the word and nonword conditions. Furthermore, each individual target or distractor word appeared only once in a prime–probe display except to fulfil the AR or IR condition. The experiment was preceded by 24 practice trials similar to those in the main experiment. No practice words or nonwords were used in the main study.

Each trial consisted of a black fixation cross, followed by a display that consisted of two vertically aligned letter strings: the target word written in lowercase letters and the distractor word written in uppercase letters. Both letter strings were printed in black (Calibri, font size 11) on a white background. The width of the letter string ranged from 1.4 cm (1.6 degrees of visual angle) to 5 cm (5.7 degrees of visual angle), and the distance between the closest edges of the letter strings was 1 pixel. Increasing attentional selection difficulty is known to enhance the probability of observing negative priming effects (see Langley, Overmier, Knopman, & Prod'Homme, 1998; Tipper, 1985). Therefore, target and distractor items were presented one above the other pseudo randomly, such that the target was on the top for half of the trials and at the bottom on the remaining trials. Moreover, the location of the prime words was varied so that the two stimuli were equally likely to be displayed in the middle, or marginally towards the left or right of centre. Probe stimuli were centred on the screen at all times in order to encourage diffuse maintenance of attention toward the mid-portion of the display screen.

The experiment was performed on a 15.6 inch Hewlett–Packard (HP) laptop computer. All programming was done with E-Prime 2.0 software programme (Psychology Software Tools, Inc., 2012). For the lexical decision task in the probe trials, participants made manual responses on a 5-button PST Chronos response box, which features milliseconds accuracy across machines (Psychology Software Tools, Inc., 2012). The two leftmost buttons of the response box were activated and designated for the "word" and "nonword" responses, respectively. Both response latencies and accuracy were recorded, and reaction times were measured from the onset of the probe display to the press of the response button. For the prime trials, participants made oral naming responses to the target stimulus on each trial. These responses were monitored for errors from behind the participant using a pre-generated response sheet that contained a sequential list of the prime target words. Because trials on which naming errors were committed may indicate that selective attention to the prime target word was unsuccessful, they were later removed from the statistical analyses.

Design and procedure

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

Participants were tested individually in a dimly-lit room. The testing session lasted about 40 min, and the viewing distance was approximately 50 cm. Participants were instructed to verbally name the lowercase target word in the prime stimulus display. When the probe display appeared, they made a lexical decision as to whether the lowercase target item was a correct English word or not. Speed and accuracy were emphasised and participants were encouraged to ignore the uppercase distractors as best as they could. On each pair of trials, before the prime trial, there was a 500 ms fixation cross in black at the centre of the screen. This was immediately replaced by the two prime words, exposed for 250 ms, followed by a blank screen for 1000 ms while the participant named the lowercase target word. This was followed by the probe trial consisting of a distractor word and a target item, which remained on the screen until the participant made a word or nonword decision to the lowercase target item. This sequence recurred throughout the experiment. A sample of the trial couplet sequence is displayed in Figure 1.

Results and discussion

Trials in which the participant made a naming error or a lexical decision error were not included in the reaction

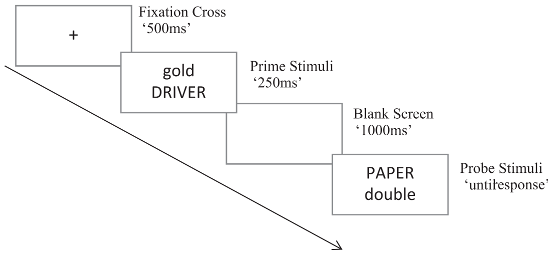

Figure 1. Sequence of stimuli presentation for Experiment 1. Note that the distance between the closest edges of the top and bottom item in each display was 1 pixel width.

time (RT) data analyses. On such error trials the participant might not have successfully selectively attended to the target item. Hence the RT analyses were conducted only on those trials where both naming and lexical decision responses were correct. Nonword data were not analysed and are not presented below. Individual data sets that contained 30% or more naming or lexical decision errors were also excluded from RT analyses. Two participants met the criterion and their data were removed. Thus the analyses were conducted on the remaining 37 participants. The mean RT data are shown in Figure 2. A repeated-measures analysis of variance (ANOVA) was conducted on the RT data. A significant effect of priming was found F (2, 72) = 29.69, MSE = 14430, p < .001, η_p^2 = .45. All subsequent t-test results are two-tailed. Planned comparisons further showed that the participants were faster in the AR condition (M = 993, SD = 325.9) than in the CO condition (M = 1148, SD = 420.2), t (36) = 5.25, p < .001, d = .86, demonstrating positive priming. In addition, they were slower in the IR condition (M = 1200, SD = 455.1) compared with the CO condition (M = 1148, SD = 420.2), t (36) = 2.56, p = .02, d = .42, demonstrating negative priming.

Error rates for probe lexical decision errors were analysed in a similar way. The priming effect was again significant [F (2, 72) = 5.01, MSE = 16.68, p = .01, η_p^2 = .12]. Consistent with the RT data, the participants showed a significant positive priming effect, and a marginally significant negative priming effect. Planned t-tests confirmed that relative to the CO condition (M = 3.5%, SD = 3.48), the

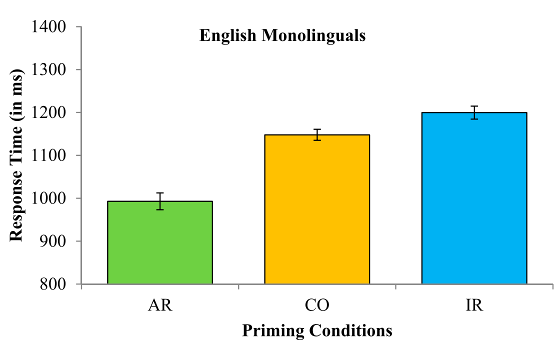

Figure 2. Mean median response latency (in milliseconds) as a function of AR, CO, and IR conditions in Experiment 1. Error bars indicate within-subject standard errors.

error rate was lower in the AR condition (M = 1.8%, SD = 4.03), t (36) = 1.88, p = .03, d = .31. The difference between the CO and IR (M = 4.8%, SD = 4.90) conditions approached significance, t (36) = 1.34, p = .09, d = .22. This pattern of data shows no evidence of speed-accuracy trade-offs.

Experiment 1 revealed substantial negative and positive priming effects in the IR and AR conditions, respectively. These results challenge the assumption that when words are used as stimuli negative priming occurs only under the condition of high stimulus repetition. Instead, our results corroborate Neumann et al.'s (1999) findings, indicating that negative priming effects can be observed in conditions where non-recycled words are used. However, given the widespread assumption described earlier that repeated recycling from a small set words is needed for negative priming to occur, it would decisively strengthen our case if our results were replicated and extended with a uniquely different group performing the task in their non-dominant language. Given the many purported differences between monolinguals and bilinguals in general (Bialystok & Feng, 2009; de Bruin et al., 2015), and between Twi and English in particular (we will elaborate on this later), it is unclear whether the two groups would show the same pattern of data. This question was explored in Experiment 2.

Experiment 2

Experiment 2 was designed to extend the results in Experiment 1 using Twi-English bilinguals. Twi is the most prominent indigenous language in Ghana, 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). Twi has 22 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. There are numerous other differences between Twi and the English language (for details, see Nkrumah & Neumann, 2017). In Experiment 2, the participants were all native speakers of the Twi language and generally proficient in the English language. Most Ghanaians begin to acquire English around age 6 when they enter school where it is used along with Twi in the classroom until students graduate from high school. The university students who participated in Experiment 2 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.

Contemporary research has broadened our understanding of the way we think about bilingualism and its implications for language and cognition. First, the two languages of the bilingual are always active (e.g., Chen, Bobb, Hoshino, & Marian, 2017; Van de Putte, Baene, Brass, & Duyck, 2017). The parallel activation of the two languages is assumed to give rise to competition that imposes demands on the bilingual to control the language not in use to achieve fluency in the target language. Secondly, there are consequences of bilingualism that affect the dominant as well as the non-dominant language. Thus, the native language changes in response to second language use. The consequences of bilingualism appear to reflect a reorganisation of brain networks that hold implications for the ways in which bilinguals negotiate cognitive competition more generally (see Kroll et al., 2014). This suggests that the nature of bilingual language representation and processing is different from those of monolinguals. Since the bilingual experience is different from those of monolinguals, it is unclear whether priming effects produced in Experiment 1 would generalise to a bilingual group of participants who engage in the same task, but in their L2, rather than their dominant language.

With regard to Experiment 1, it might be speculated that the conflict between target and distractor prime words could potentially be stronger when these words are in the native (dominant) language, than is the case in Experiment 2 wherein the words are in the weaker (non-dominant) language of the participants. This would suggest that the negative priming effect would be more likely to emerge in Experiment 1 than Experiment 2. On the other hand, as pointed out by an anonymous reviewer, it might be the case that performing a lexical task in the probe increases the salience of lexical information in both experiments, which would strengthen the interference by prime distractors and thereby increase conflict, leading to the recruitment of an inhibitory mechanism. In addition, the overall complexity of the task may be heightened in Experiment 2, compared to Experiment 1, due to the necessity of dealing with less familiar words from the non-dominant language in Experiment 2. This added complexity might induce greater focal concentration onto the target stimuli, which has been adduced as a contributing factor in obtaining negative priming (Pritchard & Neumann, 2009, 2011), thus potentially yielding negative priming. In any case, in terms of testing the issue of whether once presented prime words can produce negative priming, the present experiment can attest to the robustness of such an effect, if it occurs, despite having the stimuli and responses in the non-native language of participants.

If similar patterns of results are observed in Experiment 2, as were observed in Experiment 1, it can be concluded that negative priming is not dependent on stimulus repetition regardless of the language characteristics of respondents, and even regardless of whether responding involves a dominant or non-dominant language. To our knowledge this is the first priming experiment to investigate both positive and negative priming effects in the non-dominant language of bilingual participants. It is also one of the first experiments to investigate priming effects using an indigenous African language with non-WEIRD participants who are not from Western, Educated, Industrialised, Rich, and Democratic societies, hence contributing an original new addition to the bilingual literature (see Nkrumah & Neumann, 2017).

Method

Participants

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

Stimuli and apparatus

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

Design and procedure

The design and procedure were the same as those used in Experiment 1. Participants took approximately 60 min to complete the experiment. Compared to Experiment 1, participants in Experiment 2 were less familiar with computerised tasks and made responses in their non-dominant language, which could contribute to longer response times and thus the longer duration of Experiment 2.

Results and discussion

No individual participant's data contained 30% or more naming or lexical decision response errors. Hence the analyses were conducted on all the 40 respondents. As before, the nonword data were not analysed. The mean RT data are shown in Figure 3. A repeated-measures ANOVA on the RTs showed a significant effect of priming, F (2, 78) = 10.14, MSE = 162,658, p < .001, η_p^2 = .21. As in Experiment 1, planned t-tests were further performed to establish

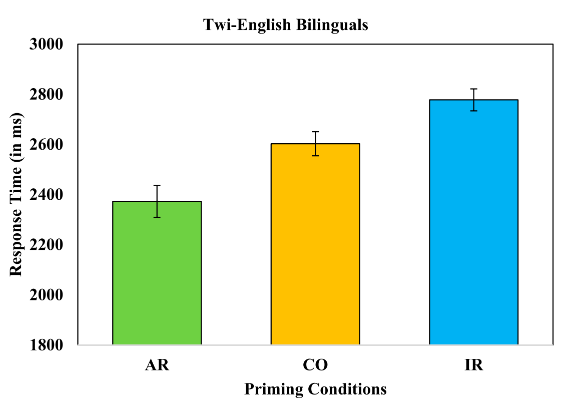

Figure 3. Mean median response latency (in milliseconds) as a function of AR, CO, and IR conditions in Experiment 2. Error bars indicate within-subject standard errors.

whether in contrast with the CO condition, the participants produced a significant facilitation effect in the AR condition and a significant delay in the IR condition. The results confirmed that compared with the CO condition ($M = 2603$, $SD = 1187.8$), RT was faster in the AR condition ($M = 2373$, $SD = 1290.4$), $t\ (39) = 2.20$, $p = .02$, $d = .35$, and slower in the IR condition ($M = 2778$, $SD = 1294.76$), $t\ (39) = 2.73$, $p = .01$, $d = .44$.

Error rates were analysed in a similar way. The effect of priming was not significant [$F\ (2, 78) = 1.47$, $MSE = 10.33$, $p = .24$, $n_p^2 = .04$]. Thus, the interpretation of the RT results was not compromised by potential speed-accuracy trade-offs.

Consistent with Experiment 1, Experiment 2 also produced substantial negative and positive priming effects in the IR and AR conditions, respectively. Thus despite presenting the task in the non-dominant language of the Twi-English bilinguals, negative priming effects were again observed. This suggests that sufficient conflict existed between prime target and distractor words to elicit suppression of the nontarget word. Apparently, even when only the weaker language of bilinguals is used for the stimuli in the task, there is universality in the way languages are modulated that can override language-specific or cultural differences. Clearly, the pattern of the results in Experiments 1 and 2 was nearly identical, despite the overall longer RTs in Experiment 2, which might be expected when bilinguals perform a task in their non-dominant language and the participants are less familiar with computerised tasks. An open empirical question that we are currently pursuing involves what happens in a cross-language experiment when the prime words are in the non-dominant or weaker language but the probe items require a switch to the dominant language.

General discussion

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

The present results are consistent with Neumann et al.'s (1999) study with large pools of non-recycled words, but inconsistent with Strayer and colleagues' (Grison & Strayer, 2001; Kramer & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999) claim that negative priming only occurs with repeated stimulus presentations involving a small pool of words. Strayer and colleagues argued that experimentally novel distractors fail to strongly interfere with responding to the target item because the activation levels of novel words are low, hence the inhibition-based modulation mechanism is not engaged to the degree required for producing negative priming. Although our results differ from theirs, we agree with their proposal that the activation level of the prime distractor is an important factor in the manifestation of negative priming effects. Our results should not be viewed as evidence against the findings of Strayer and colleagues. Instead, they should be taken together with their's to get a better sense of the sorts of task parameters that can modulate the manifestation of negative priming effects.

More specifically, a threshold level of competition between target and distractor stimuli must be exceeded and consistently maintained throughout an experiment before negative priming effects are likely to be observed (e.g., Pritchard & Neumann, 2004, 2009, 2011; Schooler, Neumann, Caplan, & Roberts, 1997). One possible explanation for the observed difference between the present results and those of Strayer and colleagues (e.g., Malley and Strayer, 1995; Strayer & Grison, 1999) could be differences in selection difficulty between the studies. In their experiments, targets and distractors differed in colour, and colour was used as a selection cue. Because colour is a very salient object feature, it should be easy to distinguish the target from the distractors due to "pop-out effects" (e.g., Treisman & Gormican, 1988). When words are used in such an easy selection situation, Strayer and colleagues have shown that a particular word must be experienced several times as a target first before becoming a prime distractor in an IR condition in order for it to produce a negative priming effect. It makes good sense that in an easy selection scenario, some perceptual fluency (Jacoby & Dallas, 1981) must develop for a given word, before it can become competitive enough with a target stimulus in a prime display to elicit the degree of inhibition necessary to produce negative priming. By contrast, in the present experiments, targets and distractors were closer together, shared the same colour, and the selection cue was letter case. Compared with colour difference between words, difference in letter case makes them harder to discriminate. This would lead to greater competition between target and distractor words, thereby inducing more extensive suppression of the distractor during the prime trial, ultimately resulting in the observed negative priming effect when a distractor became the target in the probe trial.

Our results are consistent with previous research, which shows that selection difficulty increases the chances of obtaining significant negative priming effects because more conflicting distractors require a greater degree of inhibition (Pritchard & Neumann, 2004, 2009). For instance, it has been shown that negative priming is only observed in children when anticipation of conflict in target selection is present throughout the experiment (Pritchard & Neumann, 2011). Other studies have also demonstrated the important role of conflict difficulty in target selection for eliciting negative priming effects (e.g., Frings & Wühr, 2007; Gamboz, Russo & Fox, 2000).

Another factor that may have contributed to the finding of negative priming in the present experiments is the high attentional demand required to perform the tasks. In each prime–probe couplet, participants first named the target in the prime trial, and then made a lexical decision in the probe trial. Having to shift response on every trial would require continuous attentional focus, inducing participants to pay close attention to the tasks at hand. The close proximity of the target and distractor and their spatial uncertainty would also increase the attentional demand of the tasks. These factors made target selection difficult, thus inducing a heightened selective state in an experiment-wide manner, resulting in the negative priming effect. Previous studies have shown that the magnitude of negative priming tends to increase when attentional state is heightened (e.g., Moore, 1994; Pritchard & Neumann, 2011; Tipper & Cranston, 1985). Our results are thus consistent with the notion that a high degree of competition between target and distractor words is required to induce significant NP effects in the absence of stimulus repetition.

Implications for episodic retrieval and inhibition-based theories of negative and positive priming

One enduring debate in cognitive psychology is whether negative priming effects are driven by episodic (memory) retrieval mechanisms or distractor inhibition processes. The present experiments were not designed to distinguish between the two theories, and the results are consistent with both theories. From the distractor inhibition perspective, the act of attending to a target stimulus activates the mental representation of that stimulus as well as those of its semantic neighbours (e.g., *room* and *building*). This accelerates the processing of that stimulus on a subsequent encounter relative to a neutral stimulus that has not been encountered before (e.g., Houghton & Tipper, 1994; Neumann, Cherau, Hood, & Steinnagel, 1993; Neumann & DeSchepper, 1991, 1992; Tipper, 1985). In addition, selecting for target information is associated with suppression of the nontarget stimuli. When the prime is encountered the mental representations of both the target and nontarget items are concurrently activated, and the nontarget item is then inhibited in order to aid in selecting the target. The inhibition applied to the nontarget is assumed to persist and impair response latency to that item (and potentially its close semantic relations) when it appears as the probe target requiring a response. To account for positive priming in the present paradigm, the distractor inhibition theory purports that the presentation of the target word on the prime trial (e.g., stick) activated the mental representations of that word, and this activation lingered and facilitated the response to the word "stick" when subsequently encountered owing to preactivation. Similarly, the internal representations of the ignored prime distractor word (e.g., GOAT) was inhibited during the selection of the target, and this inhibition persisted and delayed the response to the word "goat" when it appeared as the probe target requiring a lexical decision, hence negative priming.

The episodic retrieval account argues that the presentation of a stimulus automatically induces the retrieval of the most current episode connected with that stimulus (Neill & Valdes, 1992; Neill, Valdes, Terry & Gorfein, 1992). Positive priming is conditional on the matching congruence ("respond" "respond") between the processing information present at the probe display and at the prime display (e.g., Fox & De Fockert, 1998; Neill, 1997). Regarding NP, the previous distractor and its tag ("do not respond") are automatically retrieved once the target probe is encountered which generates conflict because of the incongruous requirement for the target probe ("respond"). The cost of resolving this conflict results in negative priming. With regard to the present paradigm, in the AR condition, the target in the prime trial was also the target in the probe trial. The stimulus–response binding that occurred in the prime trial was retrieved in the probe trial, and response was facilitated, hence positive priming. In the IR condition, the stimulus–response binding that occurred in the prime trial was different from the stimulus–response binding in the probe trial. Resolving this mismatch took time, hence negative priming.

A clear difference between these two theories relates to the direction in which they each operate. In the inhibition theory distractor inhibition works in a "forward" direction, beginning at the prime display and continuing to the subsequent probe trial (see Frings et al., 2015). The activation of the internal representation of the prime target item "carries forward" and facilitates response when the same item or its semantic relation appears as the next probe target. Similarly, inhibition applied to the ignored prime "persists" and impairs response when the same item or its semantic relation appears as a probe target. Although the distractor inhibition account contends that spreading activation and inhibition occurs with identical and semantically related stimuli, there is evidence that semantic negative priming effects are usually smaller than identity effects (Fox, 1995). Furthermore, some authors have reported no evidence for semantic negative priming for words, which has triggered debates on whether semantic negative priming actually exists (e.g., Chiappe & MacLeod, 1995; MacLeod et al., 2002). In episodic retrieval theory, on the other hand, memory retrieval works in a "backward" direction with the probe trial target acting as a memory retrieval cue to access the prime response tag. Despite these differences both theories would make similar predictions for the within-language experiments reported here. Neumann et al. (1999, Experiment 2; and Nkrumah & Neumann, 2017, Experiments 2 and 3) have, however, provided differentiating predictions between the episodic retrieval and inhibition-based accounts, using a cross-language versions of the present paradigm. They found clear evidence of IR negative priming of translation equivalents across the languages in the same task that produced no evidence of AR positive priming of translation equivalents. This occurred even though the AR prime and probe shared the additional similarity of both being in lower case, whereas the IR prime distractor was presented in upper case and the probe target in lower. According to the strictures of the episodic retrieval theory, since there was closer similarity between prime and probe targets in the AR condition, than the prime distractor and probe target in the IR condition, it should have led to a greater likelihood of obtaining AR positive priming than IR negative priming – the opposite of what was observed.

From our perspective, the findings described above imply, instead, that two forms of inhibition were in operation: one at the local prime distractor word level and the other at the prime global language. The former leads to cross-language IR negative priming and the latter leads to the elimination of cross-language AR positive priming, because the prime language becomes irrelevant and potentially distracting for responding in the language required for the probe target word. While the negative priming effect can be explained by the local inhibition of the prime distractor word spreading to its translation counterpart in the other language or by incompatible response tags in episodic retrieval theory, the elimination of AR positive priming is rendered inexplicable by the latter theory. According to the episodic retrieval theory AR positive priming should be more likely to occur across languages than negative priming, because there are two sources of positive priming (activation of the prime target word and compatible response tags), each of which could produce facilitatory priming, whereas there is only one source for impaired responding in negative priming (incompatible response tags). By this logic, and the closer structural similarity between prime and probe target words in the AR condition, elicitation of the "do not respond" tag in the IR condition should be *less* likely than the elicitation of the compatible "respond" tag in the AR condition.

Although there are variants of the original episodic retrieval theory (e.g., assuming the incidental retrieval of the executed prime response, e.g., Frings, Rothermund, & Wentura, 2007; Rothermund, Wentura, & De Houwer, 2005), the issues they address are tangential to the basic flaw in the episodic retrieval theory in cross-language experiments with bilinguals (Neumann et al., 1999, Experiment 2; Nkrumah & Neumann, 2017, Experiments 2 and 3). The current experiments, on the other hand, strongly support Henson et al.'s (2014) recommendation that future negative priming experiments should incorporate large pools of items that require different kinds of responses to prime and probe stimuli. This recommendation is critically important because when small pools of stimuli are used, such as variants of the flanker task with only four stimuli (as in some experiments by Rothermund and colleagues) with each one mapped on to a particular response, one observes what may be interpreted as incidental stimulus–response (S–R) binding effects that can impact both target and distractor prime stimuli. Although such binding effects may be interesting in themselves and easily replicable, they have little or nothing to do with "priming". In fact, they make establishing the underpinnings of priming (i.e., what priming experiments should be designed to do) more difficult (see Neumann & Levin, 2018). Fortunately, ostensible S–R binding effects are avoided in experiments like ours, which require different responses to primes and probes, and adhere to Henson et al.'s other recommendations, as well. The variants of the original episodic retrieval theory would thus not apply in paradigms like ours, and discussing them would detract from our main findings and conclusions. It is worth noting that Neumann and Levin (2018; see also Levin & Neumann, 1999) provide a clear-cut demonstration of how artefacts are generated in negative priming experiments that use small pools of stimuli, and why such experiments hamper identifying the mechanism(s) that underlie process-pure priming effects.

In our view, the absence of positive priming across languages, in a task that nevertheless produces negative priming, is due to the *language* of the priming words becoming globally inhibited, which prospectively suppresses interference from that language when responding in the other language as required by the probe target word. Since participants prospectively know that there is consistent alternation between their languages from prime to probe, keeping the prime language activated would be detrimental to making a lexical decision about a word in the other language. The language for the prime is thus rendered intrusive and dealt with by inhibitory control of the potentially intrusive mental representations, which stops such unwanted memories from producing AR positive priming.

There are several additional potentially important theoretical and empirical implications of the present study. For example, previous studies have attempted to draw parallels between selective attention and memory research via an inhibitory or suppressive information processing mechanism they may share in common (Anderson & Spellman, 1995; Neumann, et al., 1993; Neumann & DeSchepper, 1992). As described earlier, this inhibitory mechanism is thought to suppress distracting, nontarget words in certain negative priming tasks. A similarly described active inhibitory mechanism has also been posited to accommodate two different memory phenomena: *retrieval induced forgetting* (RIF, Anderson & Spellman, 1995; Buckley & Neumann, 2018) and the "no-think" component of the *Think/No-think* (T/NT) task (Anderson & Green, 2001; Anderson et al., 2004). Establishing that a similar or perhaps the same active inhibitory mechanism is involved in reducing or eliminating interference effects from no longer relevant words in each of these cases 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 a reaction time (RT) analogue to the “no-think” component of the T/NT phenomenon in the memory literature (e.g., Anderson & Green, 2001; Anderson et al., 2004; Schmitz, Correia, Ferreira, Prescot, & Anderson, 2017). 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. With regard to the cross-language priming tasks, participants are simultaneously induced not to think of a *language* that is attended in the prime display and a nontarget distracting *word* when they become irrelevant and potentially distracting prior to the onset of the probe display. Rather than being instructed not to think about a word, as in the T/NT task, people 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 nontarget status of the ignored prime word as required by the task itself.

The current study together with our cross-language experiments (Neumann et al., 1999; Nkrumah & Neumann, 2017) provide evidence of suppressive processing at both a local and a global level, potentially detectable on an almost trial by trial basis. The resulting priming effects should, therefore, become particularly 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. Anderson and colleagues (i.e., Schmitz et al., 2017) observed that hippocampal GABA (a chemical neurotransmitter substance that implements neural inhibition) contributes to stopping unwanted memories. They showed that GABAergic inhibition of hippocampal retrieval activity forms the key link in the volitional inhibitory control underlying thought suppression and, crucially, the memory for suppressed content. Their evidence for a mechanism enabling inhibitory control over specific memories via GABAergic inhibition of local hippocampal activity could provide an underpinning mechanism for the lack of AR positive priming combined with intact IR negative priming in our cross-language paradigms (Neumann et al., 1999; Nkrumah & Neumann, 2017). Establishing a firmer linkage among these purportedly suppressive selective attention and memory phenomena within a neurobiological framework should be intensively pursued.

One of the main goals of cognitive psychology according to Pylyshyn (1984) is to establish genuine information processing mechanisms that are only one or two steps removed from actual bio physiological mechanisms of the brain. Mutual verifications from suppressive priming effects with words and no-think memory effects with words could help establish for the first time such a psychologically real information processing mechanism, functionally responsible for temporarily purging unwanted memories.

Conclusion

The present experiments reported negative and positive priming effects with large pools of non-recycled words. The results suggest that a word encountered only once as a distractor, but never as a target, can nonetheless be significantly impaired if it appears as a subsequent probe target, as evidenced by negative priming effects. For the first time, this was shown to be the case even when bilinguals perform the task in their non-dominant language. These findings extend the work of Neumann et al. (1999) and provide additional evidence that repeating words multiple times prior to becoming a distractor is not a necessary condition for obtaining negative priming with words. Collectively, the picture emerging from this work is that both AR positive priming and IR negative priming are clearly capable of being produced with non-recycled words, as long as prime and probe words are within the same language. This helps dispel one of the myths about negative priming that the effect is larger and more likely to be observed when a small pool of recycled words is used (Grison & Strayer, 2001; Kramer & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999). Intriguingly, using the same paradigm as the present experiments, but with cross-language manipulations with bilinguals (Neumann et al., 1999; Nkrumah & Neumann, 2017), only the IR negative priming effect remained intact, whereas AR positive priming completely disappeared. The current research strongly suggests that inhibitory control of momentarily irrelevant or conflicting information is a more ubiquitous and robust form of cognitive control than previously thought (see also Li, Neumann, & Chen, 2017; Wu & Thierry, 2017).

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