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Bilingual Versus Monolingual Performance Within Memory Suppression

Santiago David
Claremont McKenna College

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Santiago David

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Abstract

Bilingual participants have been argued to have a cognitive inhibitory advantage over monolinguals resulting in a faster ability to inhibit information. However, the advantage has not been studied using the item-method within the Directed Forgetting (DF) paradigm, which is suggested to cause inhibition through remember and forget instructions. As the DF paradigm uses a recall and then recognition task format, the current study also investigated the possibility of retrieval-practice effects of the recall task on recognition. By utilizing the item-method with recall and no-recall conditions, the possible bilingual cognitive advantage, role of inhibition in DF, and potential retrieval-practice effects were investigated. I recruited 73 students (25 bilingual) at a southern California college who participated in exchange for course credit. Participants completed a Directed Forgetting learning task, followed by either a recall or Stroop task, then a recognition test, and finally the LexTALE-Esp as a language proficiency measure. Suppression was measured through 'To Be Remembered' (TBR) and 'To Be Forgotten' (TBF) words. Compared with TBF, TBR had increased recall and recognition rates, and produced a retrieval-practice effect (e.g., faster recognition response times and higher recognition accuracy rates for words recalled). Bilingual participants showed no advantage relative to monolinguals. These results call into question the role of inhibition in DF, show an important confounding variable of retrieval-practice in previous methodologies, and extend the research showing no evidence of a bilingual advantage.

Keywords: bilingual advantage, Directed Forgetting, inhibition, retrieval-practice

Introduction

During the early 1900's the prevailing thought was that being bilingual disadvantaged individuals, leading to decreased mental capacity and intelligence (Goodenough, 1926). Beginning in the 1960's when Peal and Lambert (1962) found bilingual children outperformed monolingual children on both verbal and non-verbal tests, citing greater "mental flexibility", the long-standing belief changed and the topic of bilingual advantages became increasingly researched and promoted. The bilingual cognitive advantage has since been studied across different domains – most clearly seen when comparing children across various tests, such as the Dot Matrix and Backward Digit Recall tasks (which measure working and short-term memory) (Blom et al., 2014). Studies have found bilingual advantages in older populations as well. Friesen et al. (2015) researched a bilingual advantage of visual attention within the young adult population, finding bilinguals performed significantly faster during a visual search task.

The bilingual advantage may also be present in inhibition. When found, a bilingual inhibitory advantage has been suggested to occur due to inhibiting information faster than monolinguals (Blumenfeld & Marian, 2011). As a result of this, monolinguals show more residual inhibition while bilinguals are able to return to a baseline state faster post-inhibiting, typically shown through slower response times (RTs) by monolinguals, even if accuracy does not differ (Blumenfeld & Marian, 2011). In the Directed Forgetting (DF) paradigm, stimuli are instructed to either be remembered or forgotten (Bjork, Laberge, & Legrand, 1968) and participants are required to switch between encoding and inhibiting. Returning to baseline following inhibition of a 'forgotten' word may result in faster and more successful future inhibition and may increase focus on remember items for bilingual participants. By contrast, monolinguals may have compromised encoding because of residual inhibition. Thus, these processing differences and tradeoffs may result in higher recall rates and recognition accuracy for bilinguals on remember items, but lower rates for forget items than monolinguals.

Different elements of bilingual inhibition have been evaluated using tasks such as the Flanker, Go/ No-Go, Simon, and Stroop. The Flanker and Go/ No-Go focus on response inhibition (the ability to suppress actions), the Simon measures interference resolution, and the Stroop uses cognitive interference (the discrepancy between the color named and the color of the word) (Duñabeitia et al., 2014; Luk et al., 2011; Salvatierra & Rosselli, 2011). While not as common within bilingual literature, another primary method of evaluating inhibition has been the Directed Forgetting paradigm. Within the paradigm, the Think/No Think (T/NT) method, item-list method, and item-method are the most commonly used formats. Both the T/NT and item-list methods focus on response inhibition as they are cue dependent, while the item-method focuses on inhibition at the point of encoding since each cue is given the instructions of either ‘To Be Remembered’ (TBR) or ‘To Be Forgotten’ (TBF) during the learning stage (Anderson & Hanslmayr, 2014). The present study uses the item-method to evaluate whether a bilingual cognitive advantage exists. In addition, the study will also seek to better understand the role of inhibition across those populations within the DF paradigm.

Support for the presence of inhibition within Directed Forgetting has been seen across different experiments. In neural studies, the right dorsolateral prefrontal cortex (DLPFC) plays a crucial role in performing cognitive tasks such as working memory, which is important for selecting items to either encode or inhibit during the study phase of the DF paradigm – with previous findings in Directed Forgetting suggesting high working memory capacity (WMC) individuals being better able to encode, and later retrieve, TBR items than low WMC individuals (Marevic et al., 2018). Greater activity in the DLPFC has been shown to be a predictor of decreased activity in the left hippocampus, a key area of semantic memory encoding, during forget trials (Rizio & Dennis, 2013). According to the default mode network hypothesis, however, as DLPFC activity increases, so should activity in the hippocampus (Anderson & Hanslmayr, 2014). Thus, the results support an argument for an active inhibition process within DF. In behavioral studies, slower RTs and lower accuracy rates during the recognition task for TBF words compared to TBR words have also been presented as indications of inhibition of ‘forget’ items (Fawcett & Taylor, 2008).

Contrary to an inhibition account for directed forgetting, for many years interference was proposed to be the primary mechanism explaining the differences between remember and forget items in the DF paradigm. However, it has been suggested that by using the item-method, which has been utilized since 1965 (Muther, 1965), the potential for an interference effect during encoding diminishes, as each cue is studied independently instead of being paired with other stimuli. Interference, may occur during the recall phase at the point of retrieval even within the item-method due to the multitude of stimuli making retrieval of each stimulus more difficult, regardless of word instruction. However, interference is less likely to occur within the recognition task as participants are asked to identify individual words as new or previously studied. Waldhauser, Lindgren, and Johansson (2012) argued words that are truly suppressed, or inhibited, should not be recognized because those items were never encoded initially. If items are not inhibited, however, they should be recognizable – even if interference during encoding or retrieval is present. If interference were responsible for performance in this paradigm and that interference were the same for TBF and TBR stimuli, no recognition differences should be observed between TBF and TBR words.

Other researchers have studied other potential mechanisms within the DF paradigm. Ecker, Lewandowsky, and Oberauer (2014), for example, proposed a memory decay insofar as items weaken or are lost due to time. Importantly, a 4-minute recall task appearing between the study period and recognition test may cause a loss of memory, especially if an item is not rehearsed or encoded into long-term memory. If a word is not recalled during the 4 minutes of the recall task, sufficient time can elapse for the memory of a word's initial study period to be forgotten by the beginning of the recognition task – causing it to appear inhibited when it has truly been completely forgotten or is temporarily inaccessible for a different reason. Selective rehearsal – whereby participants use maintenance rehearsal until the instruction is presented, and then continue rehearsal of the stimulus if it is a TBR word in order to transfer it to long-term memory – has also been argued to be the primary mechanism responsible for accuracy and response time differences among TBR and TBF words within the item-method (Tan et al., 2020). This may be possible because the process participants use during the learning stage is not explicitly known. Therefore, it is unclear whether participants are actively inhibiting words when given the forget instruction, selectively rehearsing TBR items, or simply ignoring TBF words, such as by looking away from the screen.

If Directed Forgetting is contingent on inhibition, there are two main explanations as to why a bilingual inhibitory advantage would be expected. The first is the advantage results from managing two languages that are activated simultaneously (Kroll, 2008). With bilinguals having greater experience managing linguistic competition resulting from parallel language activation, this ‘cognitive training’ may result in better inhibition abilities (Blumenfeld & Marian, 2013). Support for resolving linguistic competition has been found at both the auditory and lexico-semantic levels (Giezen et al., 2015) and across different networks, such as the alerting, orienting, and executive control attentional networks (Costa el al., 2008).

The second explanation is that bilinguals and monolinguals recruit different neural mechanisms for inhibition (Abutalebi & Green, 2016). Evidence has shown that bilinguals may recruit a more extensive network and may show more brain activation than monolinguals for trials requiring suppression of interference – such as suppressing TBF words to focus on TBR words – but not for response inhibition (Luk et al., 2010), resulting in faster RTs for the bilingual population. The suppression of interference will be explored in the present study as the item-method focuses on inhibition of ‘to be forgotten’ words instead of response inhibition.

Recently, the cognitive benefits of bilingualism have become less clear. Of 46 reviewed studies published from 2004-2018 on bilingualism and cognitive control, roughly 55% showed bilingual advantages, 28% showed mixed results, and 17% found bilingual disadvantages (van den Noort et al., 2019). These discrepancies in results have also been seen within inhibition (Bialystok, Craik, & Luk, 2008; Desjardins & Fernandez, 2018). Therefore, it is possible that a bilingual disadvantage will be observed. This may occur if English is the second language (L2) for bilinguals as previous research has found lower recall rates for bilinguals using L2 as compared to their native language (L1) – as less mastery of L2 results in greater difficulty completing recall tasks (Francis & Gutiérrez, 2012). As no study has directly compared bilingual L2 recall versus monolingual, it is possible bilinguals would have worse recall rates.

There is also reason to believe that bilinguals may show neither an advantage nor a disadvantage within the DF paradigm, as a bilingual inhibitory advantage may not exist. While evidence for no advantage is reported less often than evidence for an advantage, research disputing these benefits is continuing to grow within the literature. For example, in a comparison of 252 monolingual and 252 bilingual (Basque-Spanish) children, no significant differences in inhibition ability on both verbal and non-verbal Stroop tasks were seen (Duñabeitia et al., 2014). More recently, in a study of 11,000 participants and multiple language profiles, no evidence for a bilingual advantage was found across twelve cognitive tests measuring inhibition, working memory, problem solving, and planning, except for a minor advantage on a Digit Span test – which measures working memory and attention (Nichols et al., 2020). In attempting to understand why this discrepancy occurs, meta-analyses and systemic reviews have controlled for factors such as small sample sizes, lenient analyses, and publication bias (Paap et al., 2015) which appear to eliminate the bilingual advantage (Lehtonen et al., 2018).

Differing results in studies evaluating the bilingual advantage may also arise from other factors. One possibility is the influence of the age of acquisition of the second language. Two mechanisms have been proposed to be affected by age of acquisition. The first states that acquisition of L2 by the 'critical period' modifies cognitive development – causing the bilingual advantage – in a way that later acquisition cannot (Kaushanskaya & Marian, 2007). Previously this 'critical period' was suggested to be by the time one reaches 7 years of age (Johnson & Newport, 1989). The second possibility is early acquisition results in increased exposure to L1, L2, and parallel language activation – resulting in more cognitive training than if acquired later on (Kaushanskaya & Marian, 2007). In the case of adolescents and young adults, both early-acquisition (5-year-old) and late-acquisition (9-year-old) bilinguals have been shown to out-perform monolinguals on tests such as a flanker task, with the early-acquisition also outperforming the late-acquisition group (Luk et al., 2011). An early acquisition advantage for cognitive control and task accuracy is present even when holding language fluency statistically constant and across all ages, including in comparing groups who learned both languages simultaneously and groups who learned their second language at 3 years of age (Struys et al., 2015), supporting the hypothesis that the earlier one becomes bilingual, the stronger the cognitive benefits will be. These results have been replicated across different languages (Tao et al., 2011).

The discrepancy of findings exploring the bilingual advantage may also be due to varying performance across different ages. While results indicating a bilingual inhibitory advantage on a Simon task have been found among older bilinguals (roughly 60 years of age), the difference has not been seen between younger (26-year-old) bilinguals and monolinguals (Salvatierra & Rosselli, 2011).

The similarity between L1 and L2 has also been suggested as an important variable, with more similar languages such as Spanish and Catalan requiring increased cognitive control due to more interference – causing greater cognitive training (Costa et al., 2008). The impact of language similarity has been replicated when evaluating typologically similar (Dutch-English) as opposed to dissimilar (Spanish-English) – as employed in the current study – languages, once again resulting from the increased cognitive training caused by the greater interference of similar languages (Olguin et al., 2019). However, differences between language pairs are not always found, including when comparing with monolingual populations, and have been suggested to be heavily influenced by L2 exposure – with greater exposure leading to enhanced verbal ability (Adesope et al., 2010; Barac & Bialystok, 2012). These findings may also be affected by the lack of a clear definition for determining language similarity. As a result, similarity may be assessed by factors such as lexical similarity or mutual intelligibility, and yield very different comparisons.

While not previously studied in the DF paradigm, retrieval-practice may also influence findings between bilinguals and monolinguals. The use of a recall and recognition test has been a long standing method for measuring performance within the paradigm. Woodward, Bjork, and Jongeward (1973) evaluated the role of rehearsal on both tasks using the item-method. Results showed that recognition performance was enhanced by retrieval of stimuli – which could include free recall – as rehearsal strengthened memory and made items more readily accessible for future retrieval (Anderson, Bjork, & Bjork, 1994). Thus within the item-method, items which are recalled on the recall task are more likely to be recognized during the recognition test. As cues are split into 'to-be-remembered' and 'to-be-forgotten' groups, roughly half of the cues are explicitly encouraged to be recalled while the other half are encouraged to be forgotten. In previous studies this led to large discrepancies in recall ability. In Woodward & Bjork (1971) participants were presented 6 lists of 24 words (12 TBR, 12 TBF). After each list participants performed an immediate recall, and after all 6 lists participants performed a final recall. On average 50.2% (36.1) of TBR and 1.9% (1.4) of TBF words were recalled on immediate testing. On final testing 23.3% (16.8) of TBR and 4.7% (3.4) of TBF words were recalled, highlighting the effect of the instruction. As a bilingual inhibitory advantage would result in less TBF words and potentially more TBR words being recalled than monolingual populations, these differences would result in differing impacts of retrieval-practice on the ensuing recognition task.

By evaluating the effects of retrieval-practice through recall and no-recall conditions the experiment will be able to unconfound recognition and recall to further evaluate if inhibition is truly the mechanism involved (at the points of encoding, recall, and recognition). If results support inhibition, the study will serve to strengthen the measurements used within the paradigm. However if they do not, previous results will again be called into question and further research will be needed to establish the cognitive processes involved. Based on the literature and theories reviewed, the following hypotheses are presented:

Hypothesis 1: If word instruction cues different processes – encoding for TBR and inhibition for TBF – then ‘To Be Remembered’ (TBR) words will have better recall rates, recognition accuracy, and faster recognition RTs than ‘To Be Forgotten’ (TBF) as seen in Waldhauser, Lindgren, and Johansson (2012) due to TBF words being truly suppressed/inhibited.

Hypothesis 2: If there is a Bilingual inhibitory advantage then Bilinguals will have better recall rates, recognition accuracy, and faster recognition RTs than monolinguals. This will be due to either parallel language activation and the subsequent ‘cognitive training’ (Blumenfeld & Marian, 2011) or because bilinguals recruit a more extensive network for interference suppression (Luk et al., 2010).

Hypothesis 3: If inhibition is responsible for recognition accuracy rates and RTs, then recalled words’ RTs and accuracy rates will be equal to those for non-recalled words. However if retrieval-practice is responsible, then recalled words will have faster response times and higher accuracy rates as retrieval-practice will increase memory strength for recalled items (Anderson, Bjork, & Bjork, 1994).

Hypothesis 4: If Hypotheses #1 and #2 are true, then Bilingual TBR items will have higher recall rates, faster recognition RTs, and better accuracy than Monolingual TBR items and the opposite will be the case for TBF items due to bilinguals being better able to suppress TBF words during encoding and focus on TBR – as better suppression of TBF items should increase memory for and speed of access to TBR items.

Hypothesis 5: If a retrieval-practice effect exists and TBR words are recalled at a higher rate than TBF words, then TBR words will have faster RTs and higher accuracy than TBF words on the recognition task. This will be because recalled, primarily TBR, words will receive a ‘memory boost’ while non-recalled, mostly TBF, words will not.

Method

Participants

A total of 73 students (48 monolingual, 25 bilingual) between the ages of 18-22 from a southern California college participated in the study. Participants were recruited through Sona Systems for 0.5 research credits and divided based on language proficiency between monolingual and bilingual (in English and Spanish). As a language proficiency check all participants completed the LexTALE-Esp, created by Izura, Cuetos, and

Brysbaert (2014). The word list for this task can be found in Appendix A. Participants were randomly assigned to either the recall or no-recall condition.

Procedure

The study used a modified version of the item-method Directed Forgetting paradigm as utilized by Gamboa et al. (2017). The present experiment employed a 2 (Language: monolingual versus bilingual) x 2 (Word Instruction: remember versus forget) x 2 (Condition: recall versus no-recall) mixed design to test recall rates, recognition accuracy, and response times.

Stimuli

One hundred and sixty words were selected from the MRC Psycholinguistic Database. To avoid possible confounding variables, all words were controlled for emotional valence, familiarity, complexity, and length. Only neutral, high familiarity words were utilized for the experiment in order to avoid a potential mirror effect of low familiarity items as low familiarity words are encountered less, causing them to be more prominent and easily recognized (Cook, Marsh, & Hicks, 2006).

Eighty words were presented during the Directed Forgetting learning task. As words could not be presented randomly, two word lists were created and were distributed equally across the different conditions. During the task, 40 of the items were randomly assigned as ‘to be remembered’ (TBR) and the other ‘to be forgotten’ (TBF). All 80 trials were used during the recognition task, along with 80 new words. The list of these items can be found in Appendix B.

The experiment was carried out in Pavlovia.

Directed Forgetting Task

After identifying as bilingual or monolingual, participants began the DF task. Participants saw 80 words individually for a duration of 1000 ms, each followed immediately by either an ‘r’ or an ‘f’ for 500 ms. Similar to Cano and Knight (2016), participants were instructed to follow the instruction cues on screen and to forget words followed by an ‘f’ and to remember the words followed by an ‘r’ (See Appendix C). A 6000 ms interval for remembering/forgetting followed the instruction. After the interval, the next cue was presented.

Recall/Stroop Task

Following the learning phase participants in the recall condition completed a 4-minute recall block. During this task, participants were asked to recall all the words they remembered from the DF period, regardless of instruction to remember or to forget. Participants typed their recalled words into the computer and pressed enter after each word. Participants within the no-recall condition completed a 4-minute Stroop task to maintain time consistency with the other condition and to prevent rehearsal of studied items.

Recognition

During the recognition task, all TBR and TBF words, along with 80 new terms, were presented in a random order. Participants were instructed to decide if the word was new or previously studied.

LexTALE-Esp

After the completion of the Directed Forgetting task, all participants completed the LexTALE-Esp as a Spanish proficiency check. Within this task 54 Spanish words and

27 non-words were presented. Participants were instructed to distinguish each cue as either a Spanish word or non-word. Participants were instructed to use their best judgement for cues they were unsure of. Following the completion of this task, participants were debriefed, thanked, and compensated for the experiment.

Results

Data Preparation

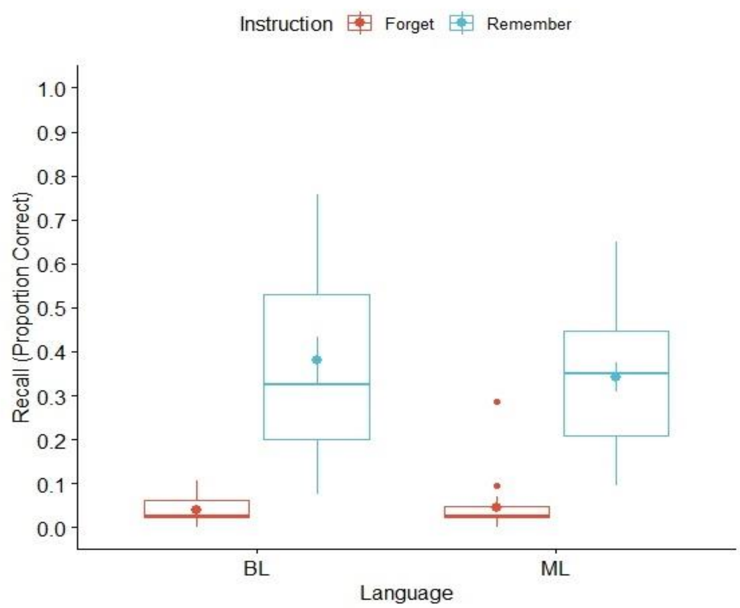
Eight participants (3 bilingual, 5 monolingual) had either exceptionally high recall rates (> 80%) or violated recognition RT boundaries (below 300 ms or above 2500 ms) more than 33% of the time. Roughly 10.2% of trials violated these boundaries and were also removed. A final sample of 65 participants was used.

Recall

A 2 x 2 Mixed ANOVA was performed on Word Instruction (within-subjects) and Language (between-subjects) in order to assess the effect of word instruction and bilingualism on recall performance. A significant main effect of Word Instruction was revealed, M_{TBR} = 33.45%, *SE* = 2.99%, M_{TBF} = 4.15%, *SE* = 0.79%, $F(1,37) = 96.81$, $p < .001$, partial η2 = .72. TBF word performance was found to have violated the assumption of normality following a Shapiro-Wilk Test. However, as instructions explicitly cued forgetting of stimuli, a floor effect was expected to cause a non-normal distribution as seen, with skewness of 3.43 (*SE* = 0.38) and kurtosis of 15.74 (*SE* = .74). No significant main effect of Language between bilingual and monolinguals was noted, $F(1,37) = 1.23$, $p = .27$. Both populations performed similarly on TBF and TBR words, resulting in no significant interaction. Recall performance is presented in a boxplot in Figure 1.

Figure 1

Recall Proportions for Word Instruction and Language



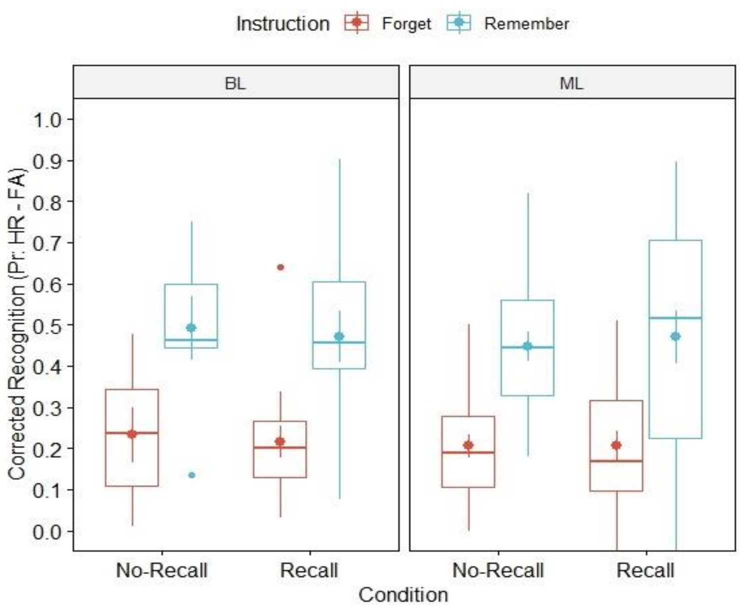
Note. Means and standard errors are represented on the boxplot as a dot with a vertical line.

Recognition

A 2 x 2 x 2 Mixed ANOVA was performed on Word Instruction (within-subjects), Language (between-subjects), and Condition (between-subjects) to assess the potential main effects of each and of any interactions on corrected recognition accuracy. The following formula was used to calculate Pr, or corrected recognition: Hit Rate (HR) – False Alarm (FA) (Snodgrass & Corwin, 1988). Hit Rate indicates the trials in which previously studied items were correctly identified, while False Alarms indicate trials in which participants claimed new items to have been previously studied. By analyzing corrected recognition we are able to better understand performance, instead of relying on simple accuracy rates, as accuracy does not explain participants ability to distinguish between previously studied and new items. However, as with the previous analysis, only a significant main effect of Word Instruction was noted, M_{TBR} = 46.5%, *SE* = 2.85%, M_{TBF} = 21.14%, *SE* = 1.85%, $F(1,61) = 105.81$, $p < .001$, partial η2 = .63. The findings can be seen in Figure 2.

Figure 2

Corrected Recognition (HR – FA) for Word Instruction, Language, and Condition

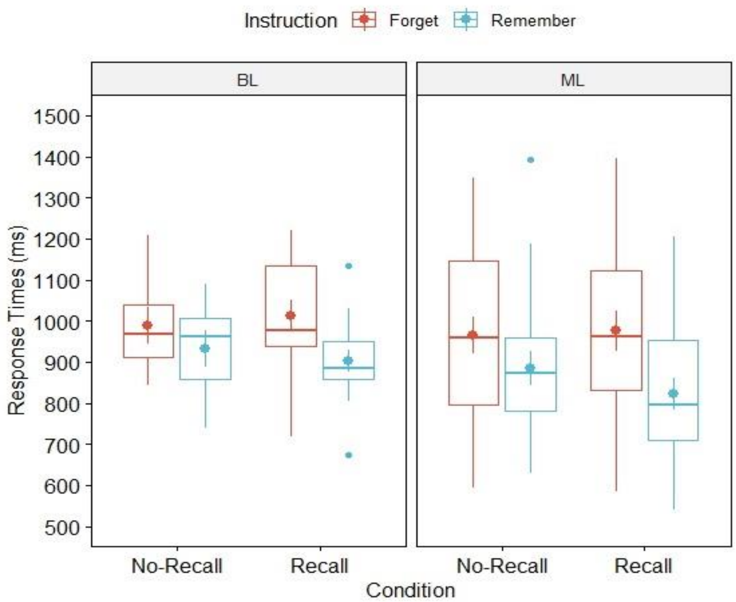


Note. Means and standard errors are represented on the boxplot as a dot with a vertical line.

A 2 x 2 x 2 Mixed ANOVA was performed on Word Instruction (within-subjects), Language (between-subjects), and Condition (between-subjects) to assess the potential main effects of each and of any interactions on recognition RTs. Again, a significant main effect of Word Instruction was revealed M_{TBR} = 874 ms, *SE* = 20.4 ms, M_{TBF} = 982 ms, *SE* = 23.9 ms, $F(1,61) = 29.18$, $p < .001$, partial η2 = .32. No significant main effects of Language, Condition, or interactions were found. Results can be seen below in Figure 3.

Figure 3

Recognition RTs for Word Instruction, Language, and Condition

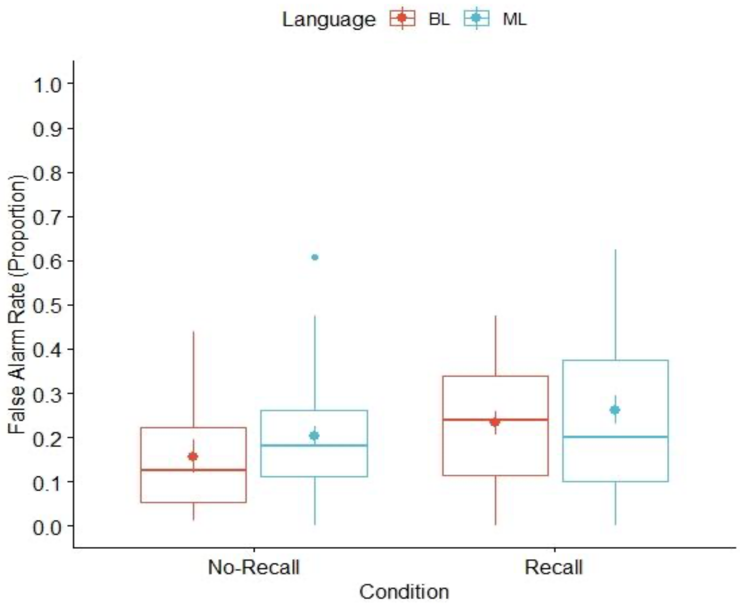


Note. Means and standard errors are represented on the boxplot as a dot with a vertical line. Lower RTs indicate faster responses.

An independent samples t-test revealed higher false alarm rates among recall condition participants (*M* = 25.01%, *SE* = 2.15%) than those in the no-recall condition (*M* = 19.24%, *SE* = 1.85%). However, as both the assumptions of normality and homogeneity of variance were violated, $W(130) = .95$, $p < .001$, the nonparametric Mann-Whitney U Test was used. Results from this test revealed no significant main effect or interaction differences, $U = 1738$, $p = .10$. Rates can be seen in Figure 4.

Figure 4

False Alarm Rates for Condition and Language

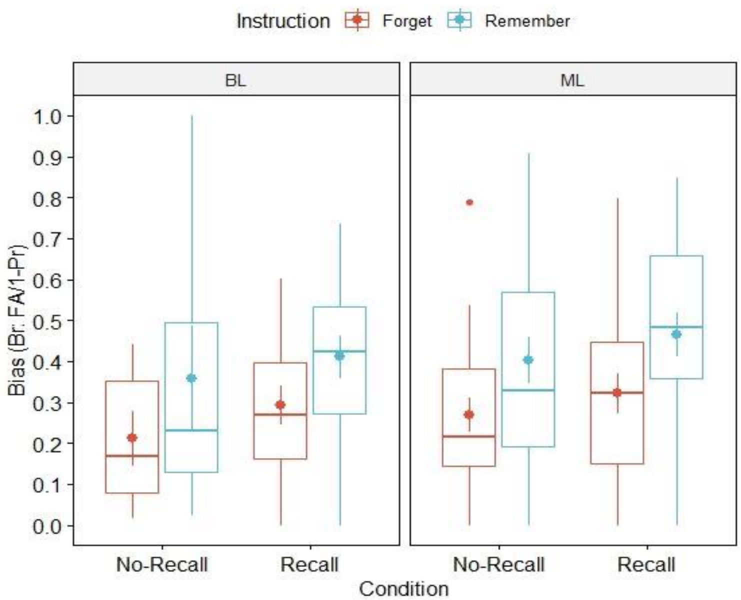


Note. Means and standard errors are represented on the boxplot as a dot with a vertical line.

To better understand recognition performance, bias (Br) corresponding to corrected recognition (Pr) was calculated. Values above 0.5 suggest a liberal bias (increased willingness to claim an item as previously studied) while values below 0.5 suggest a conservative bias (decreased willingness to claim an item as previously studied). Results showed the majority of participants had a conservative bias (M = .35, SD = .24). A 2 x 2 x 2 factorial ANOVA was performed on Word Instruction, Language, and Condition to assess the potential effects of each and of any interactions on Br. Only a significant main effect of Word Instruction was revealed M_{TBR} = .42, SE = .031, M_{TBF} = .28, SE = .025, $F(1,122) = 9.14$, p = .003, partial η2 = .07. The findings can be seen in Figure 5.

Figure 5

Bias for Word Instruction, Language, and Condition



Note. Means and standard errors are represented on the boxplot as a dot with a vertical line.

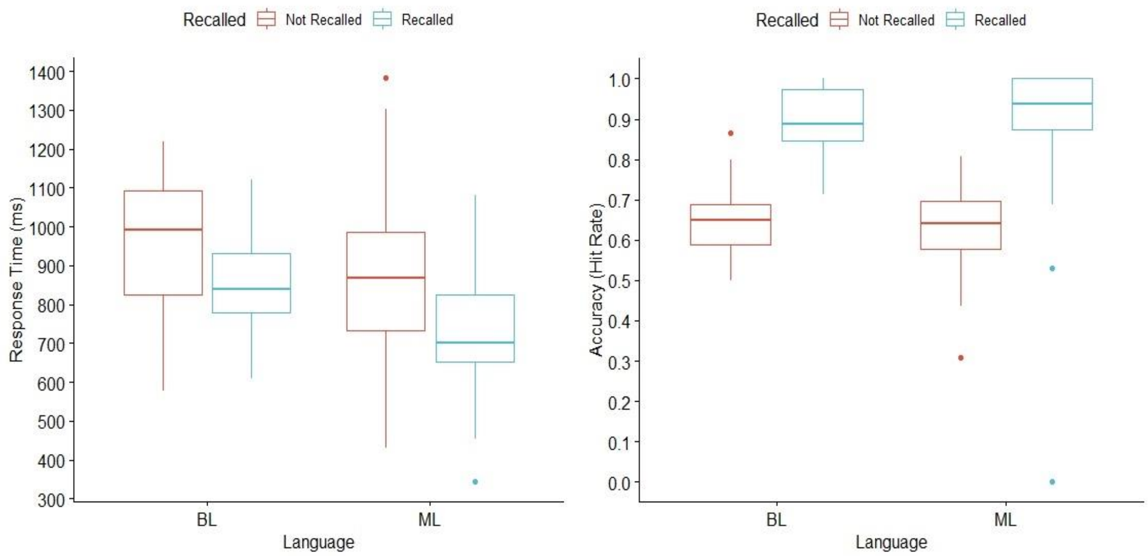
Retrieval-Practice Effects

In order to assess if there were any main effects of Language, Retrieval-Practice, or an interaction between the two, a one-way ANOVA and two paired sample t-tests were performed. No significant main effect of Language was found following the one-way ANOVA. The first paired sample t-test compared recognition RTs between recalled and non-recalled words. Results showed recalled words' RTs (M = 778 ms, SE = 24.5 ms) were significantly faster than non-recalled (M = 934 ms, SE = 30.1 ms), $t(35) = 7.09$, $p < .001$. The second t-test compared recognition accuracy between recalled and non-recalled words. Recalled words' recognition accuracy (M = 89.41%, SE = 1.91%) was significantly higher than non-recalled (M = 64.55%, SE = 1.56%), $t(35) = 16.03$,

$p < .001$. When evaluated together, there is a clear main effect of Retrieval-Practice on recognition accuracy rates and RTs. These results can be seen in Figure 6.

Figure 6

Recognition Response Times and Accuracy Rates for Language and Retrieval-Practice



Note. The graph on the left shows the main effect of Retrieval-Practice on recognition RTs. The graph on the right shows the main effect of Retrieval-Practice on recognition accuracy.

Discussion

The present study investigated a potential bilingual inhibitory advantage within DF. In addition, by measuring retrieval-practice effects the study was able to better understand the mechanisms at play within the item-method. Results replicated previous findings for corrected recognition (Tan et al., 2020; Taylor et al., 2018), recall rates (Macleod, 1999), and bias (Zwissler et al., 2015). Recognition RTs fell between previous results. However, this may be due to different RT exclusion boundaries, allowing for some studies to have faster RTs (Fawcett & Taylor, 2008), while others slower (Macleod, 1999).

Consistent with previous research, Hypothesis 1 was supported as a significant word instruction effect was seen with higher recall rates, recognition accuracy, and faster recognition RTs for TBR over TBF words (Wierzba et al., 2018; Yang et al., 2016). These results suggest the DF manipulation worked as TBF performance was much lower than TBR.

Revisiting the Bilingual Advantage

The most important finding from the study is that no bilingual advantage was seen at any point. As a result, Hypotheses 2 and 4 were not supported. This finding goes against previous research within inhibition (Blumenfeld & Marian, 2013; Giezen et al., 2015) and calls into question the existence of a bilingual cognitive advantage, at least within the DF paradigm. However, there are multiple possibilities as to why this was not found.

The first is that the advantage does not exist. As stated in the introduction, recent research has continued to find less evidence of differences between bilinguals and monolinguals across various cognitive measures (Nichols et al., 2020). Why this is occurring is not exactly clear but it may be due to an increased willingness to publish null results and papers showing disadvantages. Whereas ten years ago when the trend was to explore the different elements of the advantage, reevaluation and reflection on these results is now an emerging part of the field. It may also be due to more robust constructs and measures – reducing the likelihood of false positives. While the central limit theorem, as proposed by Pierre-Simon Laplace, calls for a sample size of at least 30 participants per condition, the number is still susceptible to finding differences where none may exist. When the advantage was initially being investigated, in most cases, studies consisted of 30-40 participants per condition, often ranging in factors such as age and education (Bialystok et al., 2004) – which have been seen to cause differing results (Salvatierra & Rosselli, 2011). Current studies consist of much larger sample sizes and control for confounding variables such as background and age of acquisition among participants (Duñabeitia et al., 2014).

The second possibility is the paradigm activates a different segment of inhibition. While the item-method is believed to cue inhibition at encoding – inhibiting interference of TBF items – it is possible the inhibition is occurring at the points of recall and recognition. In this case, response inhibition (inhibiting TBF responses) would be the mechanism used. Whereas a bilingual advantage – recruiting a more extensive network than monolinguals – has been found during interference inhibition, it has not been seen for response inhibition (Luk et al., 2010). Thus, while a bilingual inhibitory advantage may exist, no difference would be expected between monolinguals and bilinguals in this case.

It is also possible that inhibition is not the process used in the item-method. Therefore, a bilingual inhibitory advantage would not show. However, as the bilingual advantage has been suggested across other cognitive domains it would potentially still be expected. Given this, it is important to study the mechanisms used within DF in order to better understand why an advantage was not seen and the true cognitive processes the findings are a result of.

A final explanation is due to the sample used. However, the choice of English-Spanish bilinguals is not suspected to be the cause of the null result as previous research has found the inhibitory advantage within this population (Blumenfeld & Marian, 2013). Since participants self-identified as either bilingual or monolingual it is possible that monolinguals identified themselves as bilingual. While the study did employ the LexTALE-Esp as a proficiency measure, participants were not re-categorized based on performance. This decision was made as the test only evaluated visual proficiency (i.e. reading/writing). A low score would not reflect total proficiency, as many bilinguals may speak English and Spanish but not read or write one of them. Due to the nature of the study, further proficiency measures were not able to be utilized. However, when comparing high scoring LexTALE-Esp bilinguals versus monolinguals, no significant differences were noted across any performance measure. Therefore, I propose that the sample is not responsible for the null result.

Retrieval-Practice Effects

In support of Hypotheses 3 and 5, significant retrieval-practice effects were found as recalled words had higher accuracy and faster response times on ensuing recognition trials than non-recalled words. These findings are in line with the established literature on retrieval (Anderson, Bjork, & Bjork, 1994; Woodward, Bjork, & Jongeward, 1973) and have a significant impact on the item-method, showing retrieval-practice is a confounding variable that is clearly present. Since previous studies using the item-method, with a recall then recognition format, have not taken retrieval-practice effects into account, it is unclear to what extent the retrieval-practice has affected recognition performance. This effect may not have been accounted for previously because there are no significant differences between populations to indicate a retrieval-practice effect on mean recognition accuracy and RTs – as seen in Figures 2 and 3. However, as shown in the present study, this is not true at the individual level, as there are clear accuracy and RT differences between recalled and non-recalled words. I propose general results do not differ across condition because the benefit received for recalled words and the punishment of non-recalled words create a regression toward the mean effect, causing the data to appear normal when comparing the entire population.

In addition, it appears that simply using a recall task reduces the conservative bias of participants. This means participants do not approach the recognition test with the same thresholds they initially start out with, and may not be indicative of what their true recognition performance would be. I submit two possibilities for why this occurs. One reason may be participants become more self-aware of the fact they do not recall many words, so they automatically adjust the thresholds towards less conservative levels. The second possibility is that the difficulty of the recall task causes a threshold adjustment that the Stroop does not.

Retrieval-Practice or Inhibition?

Together, the retrieval-practice results further call into question the mechanisms used within the DF paradigm. As stated in Hypothesis 3, if inhibition was responsible for recognition performance, then recalled words' RTs and accuracy rates should have been equal to that of non-recalled words. Since this is not seen, I submit recognition performance is in large part affected by retrieval-practice, not inhibition. As previously discussed, there may be more explanations for why a word may not be recognized, such as memory decay and selective rehearsal (Ecker, Lewandowsky, & Oberauer, 2014; Tan et al., 2020).

Further, as this study only focused on evaluating the role of retrieval-practice during recall, it is unclear what other mechanisms may be responsible at different points in the study. For example, in addition to recalled words receiving a ‘memory boost’ from being recalled, it has also been suggested that non-recalled items become less accessible – a process known as Retrieval-Induced Forgetting (RIF) (Anderson, Bjork, & Bjork, 1994). While not investigated in this experiment, it is possible that lower TBF performance may be a result of RIF.

Importantly, while the study phase seeks to induce directed forgetting through the use of remember and forget instructions, it is not clear if this is how participants approach the task. Therefore while Hypothesis 1 was supported as a significant main effect of word instruction was seen, the mechanisms cued are not known.

Limitations

Several limitations in the study must be acknowledged. The first is the low and unequal number of participants across conditions. Unfortunately, due to the circumstances and campus closure, the study had to be translated from an in-person study to online. This resulted in a total data collection period of only three weeks. However, as previous research has suggested small sample sizes are more likely to find a bilingual advantage it is interesting that results indicated no presence of one (Paap et al., 2015). Given that the population came from a small school setting, it is also possible that participants discussed the study amongst each other despite instructions not to.

The second limitation is that the study was carried out online. While it is hoped that participants provided their full attention and effort to the study, there is no way to know. With the experiment containing a study period, it is essential that participants stay focused to provide accurate results. In addition, the test environment could not be controlled as virtually every participant was in a different location.

A third limitation is that the study was unable to accurately identify bilinguals. While initially the study had planned to use the Language Experience and Proficiency Questionnaire (LEAP-Q) to gain a full language profile of participants, when moved online the LEAP-Q could not be added (Marian et al., 2007). Due to this, factors such as age of acquisition, percentage of time spoken, proficiency across reading, writing, speaking, and listening were unable to be measured. These measures would have allowed for better distinction of the populations and possibly would have prevented self-misidentification among participants. Instead, the study relied on self-identification and the LexTALE-Esp as a proficiency measure. As participants could only select monolingual or bilingual, it is also possible that participants who identified as bilingual spoke more than two languages.

Future Studies

Moving forward, studies should continue to evaluate the role of bilingualism on cognitive abilities. While a bilingual cognitive advantage was not found in this study, it is still possible that one exists. Therefore, future studies should continue to evaluate the advantage through replication and expansion into new domains – such as auditory inhibition – using various measures – such as EEGs. Further language profiles should also be evaluated as this study only looked at monolinguals versus English-Spanish bilinguals.

The DF paradigm, and specifically the item-method, should be further studied to understand the true mechanisms used at the points of encoding and retrieval. Research should investigate recognition accuracy and RTs more closely using measures such as Signal Detection Theory. The methodology should also be further analyzed to understand the full impact of retrieval-practice effects. If retrieval-practice is in fact a strong confounding variable, future studies should move away from the study-recall-recognition format. Potentially, by comparing performance on multiple inhibition tasks, such as the Flanker Task and Stroop test, along with the item-method, the role of inhibition will be better understood within the DF paradigm.

Conclusion

This study serves as an important benchmark as being one of the first to compare bilingual versus monolingual performance within the Directed Forgetting paradigm. Results strongly support recent findings of no bilingual cognitive advantage. These results should not be taken lightly as they disagree with years of previous research.

Importantly, this study also serves as one of the first to evaluate the methodology used within the item-method. Results show there has been a clear retrieval-practice effect present that has previously not been accounted for. These findings not only call for reevaluation of previous studies, but also for further understanding of the item-method. While for many years the DF paradigm has been believed to be an inhibition measure, the present study does not find conclusive evidence for this. As research continues to find support for the presence of other cognitive processes, such as selective rehearsal (Tan et al., 2020), it is important to truly understand and establish the mechanisms involved.

While this study initially expected to find a bilingual advantage using a well established method, I now finish by emphasizing the need for further evaluation. If a bilingual cognitive advantage does exist, research must continue to investigate what causes it to be present. However if it does not exist, a more in depth examination is needed as to why it has been previously reported in order to avoid future false positives. In a world that is increasingly multilingual, it is crucial to understand the cognitive differences that may come with it.

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Appendix A

LexTALE-Esp Word List

Non-Words:
Abracer
Actuacionar
Alardio
Antar
Arsa
Brecedad
Cadallo
Capiyo
Cartinar
Cintro
Decar
Empirador
Escuto
Esposante
Fatacidad
Flamida
Floroso
Grodo
Hacido
Lampera
Pauca
Plaudir
Rompedo
Temblo
Terzo
Tropaje
Vegado

Words:
Acantilado
Alegre
Alfombra
Asesinato
Atar
Aviso
Barato
Besar
Bisagra
Bizcocho
Cabello
Camisa
Candado
Canela
Cenefa
Clavel
Cuchara
Engatusar
Estornudar
Flaco
Fomentar
Frondoso
Ganar
Granuja
Guante
Hacha
Helar
Hervidor
Hormiga
Jilguero
Lacayo
Loro
Martillo
Matar
Merodear
Musgo
Nevar
Orgulloso
Pandilla
Pellizcar
Polvoriento
Pozo
Prisa
Pulmones
Rabino
Rebuscar
Regar
Secuestro
Seda
Tergiversar
Torpe
Yacer
Yunque
Zapato

Appendix B

Directed Forgetting Word List

Count	Gentle	Number	Record	Speak
Course	Glass	Object	Remark	Spoon
Cover	Glove	Office	Repeat	Spring
Dance	Grass	Order	Reply	Square
Degree	Globe	Ounce	Report	Staff
Desire	Greet	Owner	Result	Solve
Dinner	Ground	Paint	Return	Stand
Dirty	Group	Piano	Relay	State
Doctor	Lunch	Purse	River	Still
Dollar	Major	Party	Ruler	Stone
Dozen	Match	Pilot	Season	Store
Dream	Matter	Pencil	Second	Storm
Dress	Mature	Penny	Sense	Story
Drink	Maybe	People	Shape	Street
Extra	Member	Period	Sheet	String
False	Memory	Person	Shirt	Style
Famous	Mimic	Phone	Short	Summer
Final	Method	Pillow	Shout	System
Favor	Minute	Place	Scarf	Table
First	Mirror	Pearl	Simple	Teeth
Fixed	Modern	Plant	Single	Thing
Flame	Moment	Plate	Sleep	Three
Float	Money	Pocket	Sleeve	Thumb
Floor	Month	Pound	Scout	Ticket
Flower	Mouth	Public	Slope	Tired
Freely	Music	Quart	Small	Towel
Fresh	Nerve	Quick	Smell	Window
Friend	Nickel	Quiet	Smoke	Worker
Front	Never	Radio	Smooth	World
Fruit	Noise	Reach	Sound	Wrote
Future	Notes	Really	Space	Years
Garden	Notice	Reason	Spare	Zipper

Appendix C

Graphical Representation of the Item-Method Directed Forgetting Task