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SEMANTICALLY RELATED WORDS IN THE DEESE-ROEDIGER-MCDERMOTT PARADIGM MAY ELIMINATE BILINGUAL COGNATE FACILITATION EFFECTS

Ana Beatriz Arêas da Luz Fontes[1*]
[1]Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil

Davi Alves Oliveira[2**]
[2]Universidade do Estado da Bahia, Jacobina, BA, Brasil

Aline Pereira dos Passos[1***]
[1]Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil

Li-Hao Yeh[3****]
[3]Chung Yuan Christian University, Taiwan

Abstract

This study investigated if bilingual language coactivation would be observed in the context of the Deese-Roediger-McDermott paradigm. Portuguese-English bilinguals listened to 12 lists of semantically associated words that related to either a cognate or a noncognate critical lure. Participants were instructed to recall as many words as they could and to type them on the computer keyboard. Then, they performed a recognition test with words from the study phase of the recall test, as well as critical lures and unstudied words. Statistical analyses showed a small but statistically significant difference in the recall of studied words between conditions. No differences were observed in the recognition. We suggest that participants relied more on verbatim than gist trace, which may have reduced language coactivation effects.

Keywords: false memories; DRM paradigm; bilingualism; language coactivation.

[*] Adjunct professor of Modern Languages at the Universidade Federal do Rio Grande do Sul and a permanent member of the Languages Graduate Program (Programa de Pós-Graduação em Letras). She holds a Ph.D in Cognitive, Social, and Neuro Psychology from the University of Texas at El Paso. She coordinates the Bilingual Language Processing research group (Processamento de Linguagem Bilíngue - ProLinGue) research group and is a member of the Bilingualism and Cognition Lab (Laboratório de Bilinguismo e Cognição - LABICO). Email: ana.fontes@ufrgs.br. https://orcid.org/0000-0002-8075-5256.

[**] Doctoral student at Programa de Pós-Graduação em Difusão do Conhecimento (PPGDC – UFBA, UNEB, IFBA, UEFS, LNCC, SENAI CIMATEC), holds a Master's degree in English (Programa de Pós-Graduação em Inglês: Estudos Linguísticos e Literários – UFSC), a Bachelor's degree in Letters (UNEB), a Technician degree in Informatics (IFBA) and is a Professor at Universidade do Estado da Bahia (UNEB, Campus IV, Jacobina, BA). https://orcid.org/0000-0001-6834-0579.

[***] Currently a Master's student in Psycholinguistics at Universidade Federal do Rio Grande do Sul (UFRGS) and holds a degree in English Language (UFRGS). She has been a private English teacher for four years. https://orcid.org/0000-0003-1576-6255.

**** Received his Ph.D. at 2011 from University of Texas at El Paso. From 2011 to 2012, he was an Assistant Professor at NMSU - Carlsbad. Since 2012 he has been an Assistant Professor of Psychology at Chung Yuan Christian University. His research interests include Bilingualism and Cognitive Psychology. He may be contacted at lhyeh@cycu.edu.tw. https://orcid.org/0000-0002-9004-6592.

Introduction

Whether bilinguals activate words from both their languages when performing single-language tasks, a phenomenon which has been termed language coactivation, has been a recurring research question in psycholinguistics for nearly 40 years now (Gerard & Scarborough, 1989; Caramazza & Brones, 1979). The question has been asked about bilingual reading, as well as oral and written production (Branzi, Calabria & Costa, 2018; Iniesta, Paolieri, Serrano & Bajo, 2021; Palma & Titone, 2020). It has been tested in single-word and sentence contexts (Arêas da Luz Fontes, Brentano, Toassi, Sittig & Finger, 2020; Lauro & Schwartz, 2017; Libben & Titone, 2009; Preuss, Arêas da Luz Fontes, & Finger, 2015; Toassi & Pereira, 2019). It has also been investigated in different directions: the influence of the L1 on the L2 versus the influence of the L2 on the L1 (Szubko-Sitarek, 2011; van Hell & Dijkstra, 2002). More recently, studies with multilinguals have added more layers to the investigation of direction, with research looking at how the L3 may influence processing of the L1, for instance (Barcelos & Arêas da Luz Fontes, 2021; Pinto & Arêas da Luz Fontes, 2020; Pickbrenner, 2014; Toassi, Mota & Teixeira, 2020). The question about language coactivation has been addressed through multiple tasks and paradigms as well. Researchers have used tasks such as lexical decision, picture naming, translation recognition, semantic judgment, and word dictation to try to understand how bilinguals access words in their lexicon (Arêas da Luz Fontes et al., 2020; Cassol Rigatti & Arêas da Luz Fontes, 2022; Colomé & Miozzo, 2010; Iniesta et al. 2021; Lameira, Bezerra, Toassi, Cravo & Carthery-Goulart, 2023; Wiener & Tokowicz, 2019). Neuroimaging studies have been fundamental for taking such studies a step further and showing how bilinguals' languages are organized in the brain (Abutalebi & Clahsen, 2022; Sulpizio, Del Maschio, Fedeli & Abutalebi, 2020; Strijkers, Costa, & Thierry, 2010).

Such a robust body of research has consistently found that bilingual lexical access is non-selective (see Kroll, Bice, Botezatu & Zirnstein, 2022, for a review). This means that even when bilinguals need to use only one of their languages for a given language task, both are activated, in parallel. Although a consistent finding, some factors, such as proficiency, seem to reduce the degree to which both languages are coactivated. In a recent study, Cassol Rigatti and Arêas da Luz Fontes (2022) presented evidence pointing to an attenuation of language coactivation and suggested, in accordance with Schwartz (2020), that it may be time for researchers to focus their attention to the limits of language coactivation.

The present study aligns with that thought. We asked whether evidence of language coactivation would be observed in the Deese-Roediger-McDermott (DRM) paradigm (Roediger & McDermott, 1995). In other words, we wanted to know the extent to which bilinguals would coactivate their languages during the presentation of semantically related words, and if such coactivation would be strong enough to produce different false memory rates for critical lures that were cognates in comparison to critical lures that were noncognates. We also investigated whether self-rated proficiency in English auditory comprehension would be a predictor of such effect.

False Memories and the DRM Paradigm

In 1959, Deese created a procedure that tested the production of false memories through word lists in a single trial, free recall paradigm. He created lists which contained words semantically associated to a critical non-presented word – which we call here a critical lure. For instance, the words *pin, thread, sewing, sharp* would be presented, with the intention of having participants recall the critical lure *needle*. As a result, some of these lists of words induced the participants to produce false memory (e.g. *needle*), that is, to recall words that were not studied before.

Later, in 1995, Roediger and McDermott replicated Deese's method, using the lists that succeeded at producing high levels of false memory in recall trials, and also added new words to the lists. In addition, they added recognition tests after the recall phase, in which participants would judge whether they had seen the words in the recall test, or not. This procedure was an enhanced version of Deese's paradigm, and it has been called since the Deese-Roediger-McDermott (DRM) paradigm. In the original 1995 study, participants recalled and recognized non-presented words at about the same level they recalled and recognized presented words. The results also showed that "the false-alarm (false memory) rate for the critical non-presented items was much higher than for the other related words that had not been presented" (Roediger & McDermott, 1995, p. 806). This paradigm provides a clear demonstration of how word associations affect memory accuracy (Roediger, Balota, & Watson, 2001). Activation of one concept can trigger the related concepts associated with it and the incorrect activation of a concept can trigger false retrieval (Otgaar, Howe, Muris, & Merckelbach, 2018).

Fuzzy trace theory explains the mechanism underlying the retrieval of accurate versus false memories (Reyna, Corbin, Weldon, & Brainerd, 2016). According to this theory, memory retrieval involves both verbatim and gist traces. Verbatim trace is the accurate, factual representation of the information, whereas gist trace is the general idea of the information (Reyna, 2012). Individuals are capable of processing information in both verbatim and gist traces, but there is a tendency to encode the information as gist, instead of verbatim (Reyna et al., 2016). When a task demands the processing of the information to match the exact representation, verbatim traces are used and the distracting information that shares similar meaning is rejected. On the other hand, when a task requires the retrieval of meaning, there is reliance on both the verbatim traces and meaning-consistent gist traces (Reyna, 2012). Verbatim traces are more prone to forgetting and interference effect, and false memories mostly tend to rely on gist traces of the information (Reyna et al., 2016). In the DRM paradigm, the semantic similarity between the list of words and the critical lure may lead to reliance on gist traces instead of verbatim traces (Roediger et al., 2001).

The DRM paradigm, originally developed in English, has been replicated in several languages (e.g. Dutch: Van Damme and d'Ydewalle, 2009; Portuguese: Albuquerque, 2005; Spanish: Beato and Díez, 2011; French: Dubuisson et al., 2012; Polish: Ulatowska and Olszewska, 2013; Mandarin: Yeh & Lu, 2017). Recently, researchers have started to explore the role of bilingualism on the production of false memories.

Bilingualism and False Memories

Kawasaki-Miyaji, Inoue and Yama (2003) were one of the first authors investigating the production of false memories by bilinguals. In their work, unbalanced bilinguals who had Japanese as the dominant language studied 12 DRM lists, 6 of which were presented in English and 6 which were translated to Japanese. Participants were given a recognition test in which they had to identify the words from the lists they had studied in either the same language (study in English – test in English or study in Japanese – test in Japanese) or in a different language (study in English – test in Japanese or study in Japanese – test in English). The results revealed that participants recognized more words correctly when the language of study and the language of test corresponded, and that there was a greater propensity for false memories when both study and test were in Japanese. The authors discussed the absence of an effect across languages in terms of a lack of proficiency in English, since participants were not raised in an English environment or born in an English-speaking country. Another aspect worth mentioning is that the Japanese lists of words were translated from English. While this may have disregarded the specific semantic associations of the Japanese language, the translated semantic associations appear strong enough to produce more false memories in Japanese than in English.

Similar to Kawasaki et al. (2003), Sahlin, Harding, and Seamon (2005) also translated DRM lists from English, but in this case, into Spanish. However, the participants of Sahlin et al. (2005) were bilinguals who had a more balanced level of proficiency than those of Kawasaki et al. (2003), since they had learned both languages, English and Spanish, at home since birth. Another difference between the two studies lies in the procedure and materials used by the researchers. Participants in Sahlin's et al. (2005) study would hear the lists for recall (just like in the original experiment testing the DRM paradigm), rather than read them. The researchers were also more careful about the words selected for the experiment: "some words were not used because their membership in a list was based on an idiomatic association that was culturally constrained or language specific (e.g., the needle–haystack association does not exist in Spanish)" (Sahlin et al., 2005. p. 1415). Bilinguals in Sahlin's et al. (2005) studied the lists in one language, and, during the recognition test, they saw words they had heard, non-studied words (e.g. words that were not presented in the recall task), and critical non-presented words (e.g. critical lures) in the same language or in another language. The results revealed higher rates of false memories when there was a match between study and test language, but a significant number of false memories were also found when there was no such correspondence. The researchers concluded that false memories can be observed across languages regardless of whether the test language matches the study or not.

In contrast to the previous studies, Anastasi, Rhodes, Marquez, and Velino (2005, Experiment 2) used DRM lists in Spanish that were created by native Spanish speakers, enabling the maintenance of natural semantic associations of the language. These lists were then used to investigate the production of false memories in Spanish-English bilingual individuals who used Spanish more frequently at home and English at work and with friends. Participants read aloud words displayed on a computer screen in both languages and then performed a recognition test in which they were instructed to select only words that appeared in the same language previously studied. Bilinguals recognized an equivalent number of words presented in the study list in English and Spanish, but produced a greater number of false memories in English than in Spanish, which was not expected. The authors explained that experience and linguistic exposure were not tested in the experiment, and the greater effect of false memories in the second language may have occurred due to their immersion in an English context primarily, which may result in a change of dominance from the native language to the second language.

In Anastasi's et al. (2005) study, bilinguals studied the DRM lists in each of their native languages (English and Spanish), and they should indicate, later in the recognition test, if they had studied those words in a specific language. In contrast, in the study by Marmolejo, Diliberto-Macaluso and Altarriba (2009), bilinguals studied DRM lists in Spanish and English, but they were asked to do the recognition test regardless of the study language. These participants were fluent in both Spanish and English, but reported English as their dominant language. They should indicate whether they had studied that word before, with a yes or no answer, and to point out how confident they were about their response. Again, the results showed that bilinguals recognized a greater number of words presented on the list when the study and recognition test were performed in the same language. In addition, bilinguals produced more false memories and reported a higher index of misconfidence when the languages of study and test were different than when they were the same.

These results highlight the importance of compatibility between the language used in encoding and retrieval of information. In other words, when the encoding language and the retrieval language were compatible, participants recalled and recognized more studied words. In contrast, there was a higher frequency of false memories and misconfidence in recognition when the languages differed at encoding and retrieval.

The study by Arndt and Beato (2017) adds evidence to the discussion that bilinguals activate concepts across languages in studies of false memories. More specifically, these authors suggest that proficiency and dominance in a language have an effect on the automaticity of access to concepts in bilingual memory. In their study, Arndt and Beato (2017) conducted three experiments demonstrating that Spanish-English bilinguals produced more false memories when tested in their native/dominant language than in their non-dominant language. In addition, bilinguals who were more proficient in the second language produced more false memories than the less proficient. The authors suggest that these results are consistent with research that suggests that greater proficiency in the second language increases the automaticity with which lexical representations activate conceptual representations in bilingual memory.

In addition to proficiency, the nature of the relationship between the items on the DRM lists seems to influence the production of false memories by bilinguals. Recently, Bialystok, Dey, Sullivan, and Sommers (2020) compared monolinguals and bilinguals, who spoke different languages as a second language, in three experiments. Bilinguals in this study were either simultaneous or non-English-dominant bilinguals. In the first, in the study phase, participants listened to phonologically related lists of words in English. In the follow-up recognition test, bilinguals produced more false memories than monolinguals. In the second experiment, participants listened to lists of semantically related words. Different from the first experiment, results from the recognition test showed that monolinguals were more susceptible to creating false memories than bilinguals. In the third experiment, participants were divided into four groups: monolingual young adults, bilingual young adults, monolingual older adults, and bilingual older adults. Again, there was a change in the task: this time, the lists (semantically related, as in Experiment 2) were read by the participants. In the recognition test, monolinguals generated more false memories than bilinguals, as in Experiment 2, and older adults produced more false memories than younger adults. Taken together, the results from the three experiments suggest an effect of list type, where phonologically related lists of words produce more false memories for bilinguals and semantically related lists do so for monolinguals. This points, perhaps, to a reliance on form, instead of meaning, for bilingual participants performing recognition tests.

The body of research described above demonstrates that bilingualism can influence the production of false memories. However, the described studies are based on the comparison between groups of monolinguals and bilinguals, and on the difference in the creation of false memories between their first and second language. In a novel study, Passos (2018) investigated whether language coactivation would be observed in the production of false memories by Portuguese-English bilinguals performing the task only in their L2, English, which was something not yet tested in the study of false memories. For that purpose, DRM lists were created by asking Portuguese-English bilinguals to associate words to the critical lures, as well as to come up with the critical lures from a set of words, in a norming study. Next, the lists with higher forward and backward association strength were selected and separated into 2 different conditions, according to the type of critical lure: words with cognate translations into Portuguese and words with noncognate translations into Portuguese. Critical lures were matched across condition in both frequency and number of letters. Also, critical lures were considered cognates across languages if they had an orthographic similarity index (van Orden, 1987) of 0,70 or higher. Participants' self- assessed English proficiency across the four abilities was, on average, within the *very good* category; they also reported using the language *regularly* in their everyday lives, and indicated they learned it in formal contexts. Participants read the DRM lists of 12 semantically associated words and performed both recall and recognition tests later. These lists contained both cognates and noncognates, as controlling for such variable would interfere with the control of semantic association. Thus, we prioritized controlling the strength of association of each item to the critical lure, as done in previous research. A greater number of false memories was expected when the critical lures were cognates with Portuguese, compared to noncognate critical lures in both tasks. Only a spurious result was observed: while there were no differences between cognate and noncognate critical lures in the recall test, there was one significant difference in the recognition test, but in the opposite direction. That is, bilinguals recognized slightly more critical lures that were noncognates, than cognates. The authors suggest the increased activation of cognates may create a standout effect, which would help participants correctly reject cognate critical lures in the recognition test.

In the present work, we replicated the previous study and tested the coactivation of the bilinguals' languages in a version of the DRM performed only in the participants' second language. That is, bilinguals performed the DRM paradigm completely in English, but Portuguese activation was investigated by manipulating the type of critical lures: they were either cognates with Portuguese (*piano*-piano) or noncognates (*pencil*-lápis). This time, though, we changed the nature of the stimuli. Instead of visual, participants were presented with auditory stimuli to parallel the procedure used by Roediger and McDermott (1995) in their demonstrations of false recall and recognition with semantic associates. Again, the main objective of the study was to investigate the extent to which bilinguals would coactivate their languages during the presentation of semantically related words, and if such coactivation would be strong enough to produce different false memory rates for critical lures that were cognates in comparison to critical lures that were noncognates. If we consider that the semantic similarity between the words in a DRM list and the critical lure indeed lead to greater reliance on gist traces rather than verbatim traces, as suggested by Roediger et al. (2001), and if we consider that language coactivation triggers semantic information across the bilinguals' two languages (van Hell & De Groot, 1998), then we would expect an even greater reliance on gist information for bilinguals. As a consequence, given that cognates are more strongly activated in bilinguals' lexicons due to their form and semantic overlap across languages, we would expect bilinguals to produce more false memories when the critical lure is a cognate between their languages than when it is a noncognate. This is despite previous findings (Passos, 2018) showing the opposite pattern of results because the great majority of studies testing for language co-activation in bilingual lexical access find cognate facilitation effects (see Lijewska, 2020 for a review). Furthermore, we expected that self-assessed auditory comprehension in English would be a predictor of participants' performance on both recall and recognition tasks as previous studies have shown an effect of proficiency on such tasks when performed in the less dominant language (Suarez & Beato, 2021).

Method

Design

This was a within-subjects design, in which all participants saw both levels of the manipulated independent variable: the cognate status of the critical lure. Dependent variables were binary response of whether the studied items were correctly or incorrectly recalled and recognized, whether the critical lures were correctly or incorrectly recalled and recognized, and whether the unstudied items were correctly or incorrectly recalled and recognized.

Participants

Participants were 31 Portuguese-English bilinguals (22 females and 9 males), all native speakers of Portuguese. Two participants spoke Spanish as their second language and rated themselves higher in that language than in English. Thus, they were excluded. Twenty-nine participants were, therefore, included in the final sample (20 females and 9 males). Of these, four left the language questionnaire incomplete; thus, participants' linguistic background information is based on 25 responses. The average age of the participants was $M = 28.1$ years old ($SD = 5.9$). Participants' proficiency was assessed through a self-evaluation language proficiency questionnaire that enabled them to report their linguistic background. Eighty-one point five percent of the participants learned English in either school or free courses, that is, through instruction. They started learning English approximately at age 11 (SD = 3.2), and had been studying English, on average, for about

182 months (SD = 87.7). Participants' self-assessed proficiency showed scores on the higher end of the 1-7 likert scale, ranging from M = 5. 8 (SD = 1,1) in writing to M = 6,4 (SD = 0.8) in reading. Participants reported watching an average of 2.5 hours a day (SD = 1.3) watching streaming TV in English, and a mean 2.6 hours a day using social media and the internet in English (SD = 1.5). Out of the 27 participants, 11 (40.7%) spoke a third language. More information concerning the participants' experience and usage of the second language are presented in Table 1.

Table 1: *Self-rated proficiency in the four skills and language background information of the Portuguese-English bilinguals (N = 25).*

Skill or language background	*Mean (SD)*
Self-rated proficiency	
Speaking	6.1 (0.8)
Reading	6.4 (0.8)
Writing	5.8 (1.1)
Listening comprehension	6.2 (1.0)
Hours reported using English	
Watching TV or streaming	2.5 (1.3)
Listening to music or podcasts	2.0 (1.6)
Reading for pleasure	1.3 (1.0)
Reading for work or school	2.1 (1.5)
Using social media or the Internet	2.6 (1.5)
Writing for work or for school	1.4 (1.4)
Playing video game or online games	0.7 (1.4)
Age of acquisition of English	11.0 (3.2)
Time, in months, of English study	182.8 (87.7)

Note. Self-rated proficiency was measured on a 1-7 scale, with 1 = very poor, 2 = poor, 3 = limited, 4 = average, 5 = good, 6 = very good, and 7 = excellent.

Materials

Online Platform

The experiment was hosted and completed on the *Lapsi* (Psycholinguistics Laboratory on the Web) platform (https://www.lapsi.davi.solutions), a digital laboratory, which allowed participants to carry out the experiment online.

Language History Questionnaire

The Language History Questionnaire (LHQ) (Li, Zhang, Tsai, & Puls, 2014; Li, Zhang, Yu, & Zhao, 2020) consists of a series of questions that explores linguistic data, such as language skills (reading, listening, writing, speaking), age of acquisition, frequency of language use through self-reports. The participants rated their proficiency on a scale of 1 (*very poor*) to 7 (*excellent*) in the four skills. Their self-assessed scores in listening comprehension were used as the measure of proficiency in data analyses as our task depended on participants' ability to understand auditory stimuli. Also, this measure correlated strongly and positively with mean proficiency across the four abilities (r = 0,85). Frequency was measured by asking participants to estimate how many hours a day they spent doing a variety of activities in English, such as listening to music, playing video games, etc. This question was measured on a scale from 0 to 5, in which 0 = "I don't do this activity"; 1 = "up to one hour"; 2 = "up to 2 hours"; 3 = "up to 3 hours"; 4 = "up to 4 hours" and 5 = "more 5 hours".

Stimuli

Stimuli were auditory and were selected from a previous study by Passos (2018). In short, 12 lists were created, each containing 12 words (144 words total), in addition to the 12 critical lures (one for each list). The critical lures were either unambiguous cognate words or unambiguous noncognate words. The forward and backward associative strength between the critical lures and the words on the list were previously measured and controlled in Passos (2018). Variables such as frequency, length, concreteness, and cognateness were not controlled for in the semantically associated lists of words as such control would drastically reduce the number of items available to compose the lists. Also, previous studies did not control for such variables. Nonetheless, because the amount of cognates in these lists could lead to null effects, we added orthographic similarity as a predictor in our models (see Results section). The same study also controlled the frequency of occurrence of the critical lures in English between the conditions. See examples in Table 2. The complete list of stimuli is available on Appendix A.

Table 2: *Example of stimuli used in the DRM paradigm.*

Critical lure	List items
Cognate	
actor	movies, television, script, Oscars, character, actress, artist, role, Hollywood, fame, stage, celebrity
Noncognate	
brick	wall, concrete, build, hard, material, base, shelter, mud, protection, layer, foundation, cube

Recall test

In preparation for the recall test, all words of all lists were recorded by a Portuguese-English bilingual woman who had never had any contact with the participants. She recorded the lists on her cellphone, and later the stimuli were edited in the *Audacity* app (https://www.audacityteam.org/). In the study phase of the recall test, participants heard each word of a given list, one at a time. The words were presented with an interval of two seconds between them. Participants heard each word only once. Since the study was carried out online, participants were instructed to just listen to the words and to not write them down as they heard them. At the end of each list, participants saw a screen with the word "RECALL", which indicated they should type on the computer keyboard all the words they remembered hearing. They had up to one and a half minutes to type as many words as they could recall, in no particular order. They pressed the Enter key or clicked on the "Continue" button when they finished and a new list started; this procedure continued until they finished all 12 lists. The lists were presented in random order across participants, but the items within the lists were always presented in the same order, from stronger to weaker backward semantic association.

Recognition test

Stimuli were written lists of words, selected both from the recall test and from Roediger's (2001) study. The conditions of the recognition test were the same as the recall test, but this time the critical lures were also added in the test. Based on the procedure presented in Marmolejo, Diliberto-Macaluso, and Altarriba (2009), three lists from each of the two conditions (6 lists total) were selected for the recognition test, and words in positions 1, 6 and 11 of these lists, which had been presented in the recall test, were chosen to compose the recognition test. Thus, there were 3 studied words from each of the selected lists, adding up to 18 studied words. The six critical lures associated with these lists were also presented in the recognition test. Furthermore, another 24 unstudied words were selected from Roediger's (2001) study, 12 of which were critical lures and 12 that were words associated with each of these critical lures. These were all noncognates. Participants were presented with 48 words in total. Words were visually presented in the computer screen in groups of 12 (4 groups of 12 words). Participants had to select and click on one of two buttons ("Yes" and "No"), presented below each word, whether they had seen it during the study phase of the recall test, or not. They were presented in the same order across participants.

Procedure

Participants were sent an individual email with a link to access the research instrument. We sent them alphanumeric codes through which we identified them later. This ensured their participation was anonymous. After registering in *Lapsi,* the platform where the experiment was hosted, they agreed to the consent form. Next, they answered 18 questions in the *Language History Questionnaire.* Afterwards, participants received the following instructions about the recall test:

"In this recall task you will listen to lists of words. Please be sure the volume of your computer is loud enough for you to understand the words properly. Each list will start with a presentation of a plus sign (+) in the middle of the screen. This sign indicates a new trial. When you are ready to start a trial, press the spacebar to start hearing the list of words. After you listen to all the words in the list, a RECALL screen will appear and you should type as many words as you can remember from the list you just heard.

Table 3: *Descriptive Statistics of Participants' Responses to Both Experimental Conditions in the Recall and Recognition Tests*

Variable	**Correct**		**Min.**	**Max.**
	M	**SD**		
Recall				
Cognate				
Studied	45.37	9.92	26	66
Unstudied	1.93	2.42	0	9
Critical lure	0.44	0.64	0	2
Noncognate				
Studied	46.37	9.53	24	64
Unstudied	1.85	2.12	0	9
Critical lure	0.33	0.55	0	2
Recognition				
Cognate				
Studied recognized	7.85	1.35	5	9
Studied non recognized	1.11	1.34	0	4
Critical lure	1.04	0.90	0	2
Noncognate				
Studied recognized	7.70	1.26	5	9
Studied non recognized	1.30	1.26	0	4
Critical lure	1.11	0.89	0	3
Unstudied				
Recognized	2.48	2.12	0	8
Non recognized	21.56	2.22	16	24

Note. N = 29.

This is a memory test, so please pay attention and try your best at remembering the words. You should only type them or write them down after you hear the entire list. Following these instructions is really important for the reliability of our experimental results. You will have one and a half minutes to type all the words you can recall. Afterwards, a new trial will begin with a plus sign, a new list will be presented, and a RECALL screen will follow, and so on.

You will first have a chance to complete practice trials to get familiar with the task. After those trials, the experiment will begin. When you are ready, press the spacebar."

Participants then completed two practice trials and saw a screen that indicated the end of practice and asked them to press the spacebar to continue. When they finished all 12 lists, a screen announced it was the end of the recall test and instructed them about the recognition test. The instructions were the following:

"This is a memory recognition test related to the recall test you have just completed. On this recognition test, you will read each word below and decide whether you have seen it during the recall test you have just finished. If you believe you have seen the word before, please select 'yes'. If you believe you have not seen the word before, please select 'no'."

The entire experiment was about two hours long. When participants finished all parts of the experiment, they were thanked again for their participation on the computer screen. Data was saved automatically on the platform's server and later downloaded, organized. and analyzed.

Results

We first ran descriptive analyses for each level of the independent variable, considering the total number of correctly recalled and recognized items, the total number of incorrectly recalled and recognized critical lures, and the total number of incorrectly recalled and recognized unstudied items as well as totaling both conditions (See Table 3).

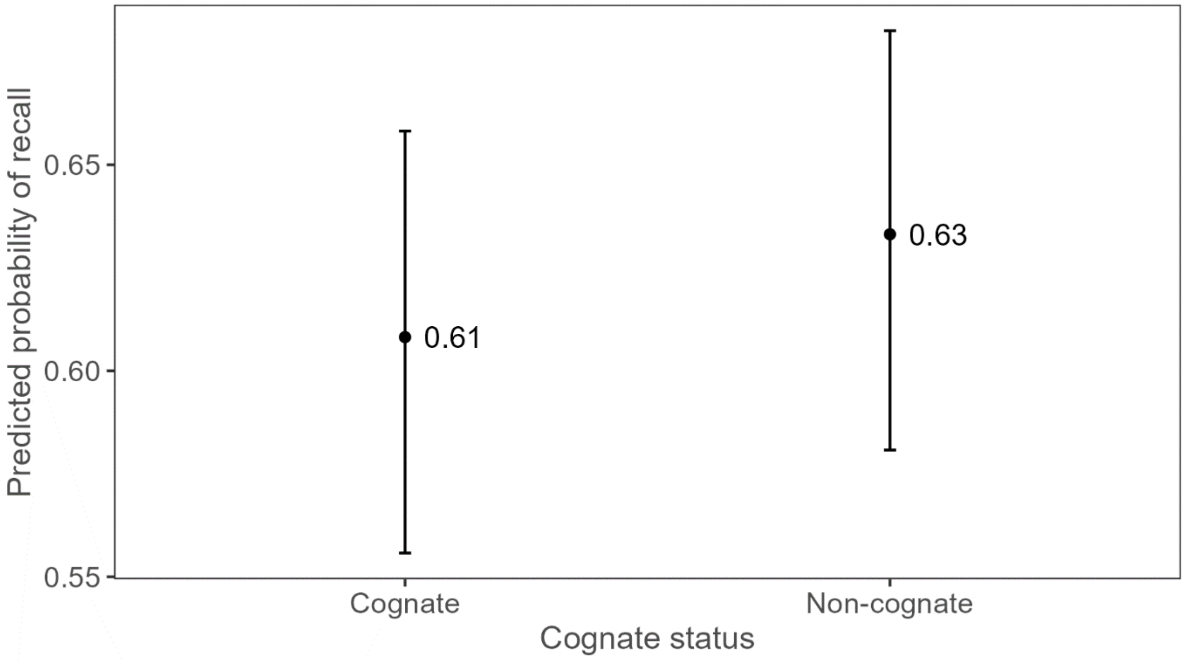
In general, looking at both conditions together, participants performed well in both tests, correctly recalling studied items at an average rate of 64%, and correctly recognizing studied items at an average rate of 86%. Furthermore, their rates of incorrectly recalled and recognized items were low: 16% in the recall test and 10% in the recognition test. Finally, participants produced false memories at very low rates. In the recall test, the average rate was 3.2%, while in the recognition test it was 3.6%. Crucial for the objective of the present study, descriptive statistics show very small differences between the cognate and the noncognate conditions in all dependent variables for both tests.

Next, to assess the differences for each dependent variable, mixed-effect logistic regression analyses were performed, using manual forward stepwise selection of predictors, with a significance level of α = .05. All the models were fit with random intercepts for participants. Models with random slopes and with random intercepts for items failed to converge in preliminary tests, so only the random intercepts for participants were kept in the final analyses. The analyses were executed employing the programing language and statistical environment R (R Core Team, 2023).

First, we analyzed a possible effect of proficiency (i.e., self-rated listening comprehension scores) on the recall of studied words and critical lures. The model showed no statistically significant effects of proficiency (β = 0.14, p = .161, 95% CI = [-0.06, 0.33]); thus, proficiency was not added in the next steps. We also analyzed a possible effect of orthographic similarity on the recall of studied words to address the concern that items on our lists included both cognates and noncognates, which could lead to null effects. The model showed a statistically significant effect of orthographic similarity (β = -0.13, p = .049, 95% CI = [-0.25, -0.00]). To analyze the differences between the cognate and noncognate conditions controlling for the effect of orthographic similarity, we ran a final model with both cognate status and similarity as predictors of correctly recalled studied items. This model showed a statistically significant effect of cognate status (β = 0.11, p = .012, 95% CI = [0.02, 0.19]), and the effect of orthographic similarity reduced and was not statistically significant (β = -0.11, p = .089, 95% CI = [-0.24, 0.02]). Considering that cognate status and similarity are positively correlated, we can interpret this result as evidence that the effect of cognate status is stronger than the effect of orthographic similarity. Another model was fit to analyze the effect of cognate status on the recall of critical lures. First, we also analyzed a possible effect of orthographic similarity on the recall of critical lures, and the model showed no statistically significant effect (β = -0.17, p = .657, 95% CI = [-0.93, 0.58]). Thus we did not include this variable as predictor in the final model, which had cognate status as the single predictor, and which also showed no statistically significant effects (β = 0.34, p = .179, 95% CI = [-0.16, 0.85]). Thus, participants did not differ in the production of false memories between critical lure conditions.

As Figure 1 shows, the difference between the cognate and noncognate condition in the recall of studied items, although significant, is small and in the opposite direction of the expected one. We had expected a higher rate of false memories when the semantically associated items led to a cognate critical lure. Possible explanations for this finding are presented in the discussion section.

Figure 1: *Predicted probability of recall of studied words*



Finally, we analyzed a possible effect of proficiency on the recognition of studied words and critical lures. Like the analysis of recall, the model showed no effects of proficiency on recognition (β = -0.03, p = .691, 95% CI = [-0.13, 0.20]). We also analyzed a possible effect of orthographic similarity on the recognition of studied words and, unlike the analysis of recall, the model showed no statistically significant effects (β = -0.32, p = .076, 95% CI = [-0.67, 0.03]). Thus, the model built to analyze differences between conditions had only cognate status as predictor and showed no statistically significant effects as well (β = -0.01, p = .954, 95% CI = [-0.24, 0.22]). Again, participants produced similar rates of false memories in both conditions.

Discussion

The objective of the present study was to investigate the extent to which bilinguals would coactivate their languages during the presentation of semantically related words, and if such coactivation would be strong enough to produce different false memory rates for critical lures that were cognates in comparison to critical lures that were noncognates. To test such premises, Portuguese-English bilinguals heard lists of semantically associated words that related to either a cognate or a noncognate critical lure. Participants were assessed in both recall and recognition tests. Results showed a difference only in correct recall of studied items: lists with noncognate lures had a higher rate of correct recalls than lists with cognate critical lure. As the analysis show, this effect cannot be explained by the presence of more orthographically similar words on these lists. Still, this could be a frequency effect as we were not able to control for word frequency within the lists; we only did so at the critical lure level. Future research should address this possibility.

Most importantly, there were no significant effects in the critical lures. That is, across the recall and recognition tests, participants produced a comparable rate of false memories in the cognate and noncognate conditions. This was not expected, as we believed the semantically related words would more strongly activate cognate critical lures, resulting in a higher number of false memories. There are a few possible explanations for this finding.

It may be that language coactivation does not resist the spreading activation resulting from the presentation of semantically related items in a single language. Perhaps such lists create a type of context, a high constraint one, which is able to eliminate language coactivation (Lauro & Schwartz, 2017; Libben & Titone, 2009; Schwartz & Kroll, 2006; Titone, Libben, Mercier & Pivneva, 2011). This finding is in line with Passos (2018), who also did not observe reliable effects of cross-language activation in the DRM paradigm when participants read the lists of words. Our results also suggest that participants may have relied more on verbatim traces of memory retrieval, which represent the accurate, factual description of the information. As verbatim traces depend on form, instead of meaning, the present findings are somewhat related to the results of Bialystok et al. (2020). They found that phonologically related lists of words produce more false memories for bilinguals, compared to semantically related lists, suggesting a reliance on form, instead of meaning, in their performance on the DRM.

A final possible explanation for the lack of differences between the production of false memories in the cognate and noncognate conditions concerns what has been called the bilingual L2 advantage in recognition memory (Francis & Strobach, 2013). That study showed that bilingual recognition is more accurate in the less fluent language (L2) than in the more fluent language (L1), which is the case of the Portuguese-English bilinguals who participated in the current study. According to the authors, this finding is attributable to the greater episodic distinctiveness of L2 words. So, it may be the case, specifically for the recognition test, that bilinguals were really good at monitoring the source of their memory and thus produced a low rate of false memories. Also, because they made use of such enhanced distinctiveness of English words, it did not matter whether the critical lures were cognates or noncognates: they could tell them apart from the studied words.

Another finding from the present study is that English proficiency was not a predictor of participants' performance in any of the dependent variables. This is not expected as previous research (see Suarez and Beato, 2021 for a review) has shown that language dominance and L2 proficiency influence bilinguals' performance in the DRM paradigm. In the present study, we did not compare first and second, or dominant and non-dominant languages, so we cannot directly compare our study to the literature in this sense. Our findings do suggest that when participants perform the DRM in the L2 only, proficiency does not seem to matter. This interpretation should be taken carefully, though, as the range of listening comprehension scores in our sample varied only from 4-7, on a scale from 1-7. That is, there was little variation in participants' L2 proficiency within the participants.

In comparison to previous studies that tested bilinguals in their second language, our study also differs greatly in the percentage of false memories produced. While in the recall test our participants made about 3% of incorrect recalls of critical lures, bilinguals in Anastasi et al. (2005) and Marmolejo's et al. (2009) incorrectly recalled critical lures at a rate of 22% and 19% to 46% (depending on the test condition), respectively. Similarly, in the recognition test, bilinguals in our study incorrectly recognized critical lures at a rate of about 35%. Other studies reported higher rates of incorrectly recalled critical lures, ranging between 43% to 87% (Anastasi et al., 2005; Marmolejo et al., 2009; Kawasaki-Miyaji & Yama, 2003; Bialystok et al., 2020). The only exception here is the study of Arndt and Beato (2017), in which the rate of false memories in the recognition test was lower than in our study: it ranged from 13% to 15%, depending on the test condition. Such comparisons raise the possibility that participants in our sample were indeed more dependent on verbatim traces, when compared to other studies.

Regarding the percentage of correctly recalled studied items, our study again differs from the literature. Our participants correctly recalled studied items at a rate of 63%. Bilinguals in Marmolejo et al. (2009) correctly recalled items from the study phase at rates ranging from 31% to 56%, depending on the condition of the test, while in Anastasi et al. (2005), participants recalled about 39% of studied items. These numbers show higher rates of correct recalls of studied items in our sample, compared to previous studies. This is another piece of evidence suggesting greater reliance on verbatim trace for bilinguals in our sample.

Nonetheless, our results compare to the literature in regards to correctly recognized studied items. Previous research presented rates ranging between 57% to 86% for such items, when bilinguals were tested in their L2. Here, participants correctly recognized previously studied items at a rate of 86%.

Taken together, our results concerning correctly recalled and recognized studied items suggest high accuracy in the tests, especially in comparison to other studies. This may be explained by fuzzy-trace theory, as suggested, or it may be explained by methodological limitations.

For instance, because our data was not collected in the laboratory, where we would have been able to keep an eye on participants' behavior, we are unable to tell whether participants were indeed following the instructions of the tests. It is possible that participants were writing down the words as they heard them, thus eliminating the chances for false memories. When looking at individual data, we identified two individuals who had 100% correct responses and excluded them from analyses. Still, it is possible that other participants were only partially following instructions and writing down some of the words only to avoid "getting caught". In the future, data collection should take place in the lab, to avoid such possibility. In addition, because each recall test took place immediately after its correspondent list, the words may have been still readily available in memory for correct recall.

Other methodological issues that may have had an impact on the results involve our DRM lists. Although the lists were created based on sample data from the same population of participants as those of the present study, it may be the case that the semantic associations amongst the items were not strong enough to produce false memories. We were careful to ensure that semantic associations were socially and culturally bound for our sample of Portuguese-English participants; still, there is some variation in the strength of forward and backward associations amongst the lists, which could have reduced the chances for our lists to induce the critical lures. Along the same lines, we may not have had a sufficient number of items on the lists although other studies have had evidence of false memories with 12-list items (Marmolejo et al.,2009).

Statistical issues may also have influenced our results. We have a small sample and a small number of items in the recognition test. In the future, using another procedure for the development of the recognition task might yield different results.

Despite all limitations, the present study introduces a novel way to test language coactivation. To our knowledge, no other study has tested bilingual cross-language activation in such a way. Thus, we contribute to the 40+ years of research in the area by recycling an established paradigm, the DRM, and using it to ask research questions in a different area. Furthermore, although the evidence supporting bilingual language coactivation is vast and robust, we presented results showing that there may be situations, or tasks, that eliminate it.

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Appendix A

Stimuli used in the experiment, including cognate and noncognate critical lures, as well as the semantically related words in each list.

Critical lure	Condition	List of items
actor	cognate	movies television script oscars character actress artist role hollywood fame stage celebrity
diet	cognate	fat diabetic calories fit food eat weight healthy vegetables carbohydrates nutrition nutrients
hero	cognate	marvel superman powers dc brave savior fearless courageous mask fly duty help

piano	cognate	classical music orchestra Beethoven instrument keyboard notes talent harmony fingers songs strings
poet	cognate	poem literature writer rhyme rhythm inspiration emotions passion novel dreamer culture faker
symbol	cognate	icon code representation mark message concepts avatar riddle idols font brand badge
beauty	noncognate	beautiful pretty handsome makeup elegance beast eyes natural inner stereotypes fair radiate

brick	noncognate	wall concrete build hard material base shelter mud protection layer foundation cube
danger	noncognate	risk criminals caution beware accident toxic explosive warning burglar hazard safety distress
farmer	noncognate	plantation agriculture chickens harvester countryside cows lands horse apple organic field orange
holy	noncognate	sacred bible jesus god saint religion miracle church christ trinity pray cross

rabbit	noncognate	bunny easter alice animal carrot fluffy ears chocolate white eggs jumps teeth