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Mechanisms of False Memories in Bilinguals

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Dedication

To my parents, Oscar “Caly” and Maria “Mary”. Dad, although you’re not with us anymore, I know you continue to take care of us. Mom, thank you for all the sacrifices you have made for my siblings and I to get a good education for a better life. To my siblings Brianna and Mario – I know you both will achieve great things. To my partner Eric, who supports me unfailingly and unconditionally, and who always reminds me with “*Believe in the me that believes in the you*”.

MECHANISMS OF FALSE MEMORIES IN BILINGUALS

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Abstract

Research on false memory in bilinguals has discovered that false memories can transfer across languages and occur at a higher rate than for within-language false memories (Marmolejo et al., 2009). However, the exact conditions that cause the stronger between-language false memory effect are not clear, nor is it clear how language proficiency influences the production of false memories. The present study had three goals. First, we tested whether the stronger between-language false memory effect relative to the within-language effect would replicate. Second, we examined whether bilinguals could integrate information across languages to form false memories by implementing a mixed-language condition. Lastly, we investigated whether language proficiency is positively associated with the susceptibility to falsely remembering non-presented critical lures. 96 Spanish-English bilingual participants were administered standardized language assessments and completed a bilingual DRM paradigm task. Participants completed fifteen study-recall cycles (5 within-language, 5 mixed-language, and 5 between-language), and then completed a final yes/no recognition test. As predicted, the stronger false memory effect between languages in both recall and recognition replicated, and there were significant false memory effects for recall and recognition in mixed-language conditions. However, language proficiency and false memory were not significantly associated. These findings support the conclusion that proficient bilinguals can integrate information across their languages via a shared semantic network.

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Chapter 1: Introduction

The events we remember and retrieve from memory may include events that never took place, and our mind can fill in the important details with sufficient automaticity that it can be difficult to deny their fabrication—this phenomenon is known as *false memory. False memories* are recollections of events that are inaccurately remembered or events that did not occur (Roediger & McDermott, 1995). False memories are characteristically episodic as they pertain to personal experiences with a particular time and place of occurrence, however their episodic nature results in misattribution errors (Schacter & Dodson, 2001). Memory is vulnerable to many external factors (e.g., time, suggestion, and other influences) and misattribution involves the distortion of the details that make up the memory (Schacter & Dodson, 2001).

Distinguishing what underlies the distortion of memories has been of interest in false memory literature and has been investigated using different approaches. One of the most common approaches is the Deese-Roediger-McDermott (DRM) paradigm for memory of verbal information (Roediger & McDermott, 1995). The methodology of the DRM paradigm is as follows: participants are presented with lists that contain highly semantically associated words (e.g., *thread*, *pin*, *eye*, *sewing*, *sharp*, *point*, *prick*, *thimble*, etc.) At the end of each list, the participants are asked to recall as many words they can remember. In the original study, participants recalled not only the presented words, but they also recalled *critical lures* at similar rates; these critical lures are words that are not presented at study but are highly associated to the presented words (e.g., *needle*).

False memory research using the DRM paradigm has been extended to explain false memory in bilingual individuals (Marmolejo et al., 2009; Sahlin et al., 2005; Cabeza and Lennartson, 2005; Howe et al., 2008; Kawasaki-Miyaji et al., 2003). One of the main focuses of these studies was to investigate whether the language at encoding and test needed to be the same (within-language) in order for false memories to occur, or if the language being different (between-language) at encoding and test would still elicit the false memory effect. All of these studies compared within-language and between-language conditions and found that false memories transferred across languages (e.g., encoding in English and recalling in Spanish), sometimes to a greater degree than within languages (e.g., encoding and test in the same language) (Marmolejo et al., 2009). However, it is still unclear under which conditions false memories can cross languages and the extent to which language proficiency influences the formation of false memories or their transfer to other known languages.

The focus of the present study was to investigate the false memory phenomenon in bilinguals using the DRM paradigm. Specifically, the goals of the study were an attempt to a) replicate the stronger false memory effect between-languages compared to within-languages, b) to investigate whether lists that contained a mixture of two languages in the same list change the strength of the false memory effect compared to within-language or between-language conditions, and to c) investigate whether and to what degree language proficiency is associated with the strength of the false memory effect. The present study examined the influence of language proficiency on the storage of conceptual representations within a bilingual's language integrated lexicon, and further investigated under which conditions false memories can cross languages. Furthermore, the present study was the first to a) test the effect of a mixed-language condition on the false memory effect, b) measure participants' language proficiency using standardized language assessments, and c) treat participant's language proficiency as a continuous variable.

1.1 Theories on False Memory

Explanations for the false memory phenomenon have been offered within the frameworks of at least four competing theories: the fuzzy trace theory (Brainerd & Reyna, 2002), the activation-monitoring theory (Roediger, Watson, McDermott, & Gallo, 2001), the associative activation theory (Howe, 2005; Howe et al., 2008) and the global-matching model (Arndt, 2010). It is important to note that the fuzzy trace theory and global-matching models are used to explain a range of memory phenomena and decision-making processes. However, in the case of false memory, these models differ in their explanations for how semantic associations within the lists from the DRM Paradigm can lead to the formation of false memories. Specifically, the false memory effect is explained to be a consequence of encoding-based processes, familiarity-based processes, or recollection-based processes. While all four theories differ in their explanations, there is a similar idea that the false memory effect is a result of the strong association between the presented items and the critical lure because of their corresponding theme.

1.1.1 Fuzzy Trace Theory

The fuzzy trace theory (Brainerd & Reyna, 2002) postulates that two memory traces are formed at the same time during encoding, the verbatim trace and the gist trace. *Verbatim* traces contain surface form details that represent contextual features of an event (e.g. chocolate cake served on paper plates), whereas *gist* traces are based on the general meaning or conceptual information of an event (e.g. birthday party). Verbatim traces are retrieved more efficiently when there is repeated presentation of an item (e.g., *apple*), whereas gist traces become strengthened and are easier to retrieve when presented with several items that share a similar theme or are semantically related (*apple*, *orange*, *grapes*, *pineapple*, *etc*.; *fruit*) (Brainerd & Reyna, 2002). These memory traces are formed simultaneously during experiences of events and are used to explain the occurrence of false memories and what sets them apart from true memories.

Under the Fuzzy Trace Theory explanation, false memories occur in the DRM Paradigm because of the reliance on gist traces rather than verbatim traces. For veridical or true memories, both verbatim and gist memories are critical, whereas false memories are based on gist traces. Because the presented items are semantically associated, the overall theme of the word lists facilitate the retrieval of the gist trace, rather than the verbatim trace. Therefore, an item that has not been studied will have a higher chance of being falsely remembered if it is semantically associated with the gist traces of the studied items or shares the theme of the studied items.

1.1.2 Activation-Monitoring Theory

Activation-monitoring theory (Roediger et al., 2001) borrows from three theories: *implicit associative response* (Underwood, 1965), *spreading activation* (Collins & Loftus, 1975), and *source monitoring* (Johnson, Hashtroudi, & Lindsay, 1993). Activation-monitoring theory assumes that both activation and monitoring occur during encoding and retrieval of stimuli. The activation monitoring theory explains that under the DRM paradigm, participants encode lists of words associated to a common theme, and unbeknownst to participants, semantically related words also become activated due to *spreading activation* in the lexical-semantic system. According to explanations made by the activation-monitoring theory, both encoding-based processes and retrieval-based processes are responsible for the occurrence of semantically related intrusions in the DRM paradigm.

1.1.3 Associative-Activation Theory

Similar to the activation-monitoring theory, the associative-activation theory (Howe, 2005; Howe et al., 2008) explains that false memories occur as the result of spreading activation of a word to its associated concepts within the mental lexicon. Under the DRM paradigm, non-presented items or critical lures are falsely remembered because of activation from the presented list items. Moreover, the associative activation theory postulates that false memories are dependent on the strength of association between the critical lures and presented list items such that a greater association between a lure and list items increases the rate of false memory production. Associative-activation theory differs from activation-monitoring theory as it emphasizes that with greater proficiency and knowledge, activation and retrieval of concepts becomes more *automatic*.

Associative-activation theory further explains that false memory production between children and adults differs due to the automaticity of activation mechanisms which are dependent on knowledge and proficiency in language. Children have lower proficiency for the concepts in their mental lexicon due to having less experience with accessing the conceptual representations, and therefore there is less activation of critical lures from presented list items (Howe et al., 2009). Previous research demonstrates that young children produce lower rates of false recall compared to adults (Howe, 2008), and the explanation is that children's activation of concepts and their associates is not automatic and requires more effort. Moreover, evidence from bilingual false memory research supports the associative activation theory such that the greater the proficiency in a language, then the stronger the associations between concepts are, thus the greater production of false memory (Arndt & Beato, 2017).

1.1.4 Global-Matching Models

Another explanation was derived by applying *global-matching models* to explain false memories (Arndt, 2010; Arndt, 2012). In global-matching models, studied words are encoded as memory traces composed of item features such as semantics, perceptual details, and contextual information. At retrieval, test items are compared against all other memory traces for similarity, and higher similarity produces a higher activation value. Items with a sufficiently high activation value are classified as studied. Although critical lure items are not studied, and therefore do not truly produce a veridical memory trace, they resemble the studied items enough to produce a high enough activation value to be mistakenly classified as studied items (Arndt & Hirschman,1998).

1.2 Bilingual Memory and Transfer Across Languages

1.2.1 Semantic Memory

Semantic memory encompasses information that has been acquired through a lifetime of experiences, leading to the formation and elaboration of a semantic network. In this network, language has allowed each unique object, or concept to be categorized and identified, according to its meaning and name. The semantic network can be described as a mental lexicon, with a collection of word forms at the lexical level. In the case of understanding and knowing two languages, bilinguals have shared conceptual representations for words and their translation equivalents (e.g., *cat* in English and *gato* in Spanish) (see Altarriba, 1992; Francis, 1999 for reviews).

1.2.2 Episodic Memory

Episodic memory is memory for specific events or occurrences of information. In bilinguals, words that are encoded in one language are accessible through the other language, as long as the encoding and test tasks involve processing the meanings of the words (for a review, see Francis, 1999). For example, Durgunoglu and Roediger (1987) found evidence for strong transfer across languages in both recall and recognition. Studies utilizing repetition priming paradigms have found transfer across languages for concrete nouns, abstract nouns, verbs and adjectives in repetition priming (de la Riva et al., 2012; Francis et al., 2010; Francis &

Goldmann, 2011; Seger et al., 1999; Taylor & Francis, 2017). These studies indicate that verbal episodic memory representations are shared at the conceptual level.

The DRM paradigm relies on both semantic and episodic memory. In the retrieval task, participants are asked to retrieve the words that were studied, making it an episodic memory task. However, the emergence of the false memory for the critical lure is based on the semantic association of the studied words with the critical lure and the formation of a gist trace for the critical lure in episodic memory. Bilingual studies that implemented the DRM paradigm (Roediger & McDermott, 1995) found that false memories transferred across languages (Kawasaki & Yama, 2003; Cabeza and Lennartson, 2005; Sahlin et al., 2005; Howe et al., 2008; Marmolejo et al. 2009). Critical lures were recalled even when the studied items were not presented in the same language during encoding. The false memory effect between languages was also found to have a stronger rate compared to false memories within languages (Marmolejo et al., 2009), further providing evidence for shared semantic associations and semantic representations across languages.

1.3 Effects of Language Proficiency on False Memory

Studies have examined the effects of language proficiency on memory processes in both recall and recognition. Some studies found free recall memory performance to be worse in bilinguals' less proficient language (L2) compared to in their more proficient language (L1) (Francis et al., 2020; Yoo & Kaushanskaya, 2016) but it should be noted that there is some inconsistency in the literature. In recognition memory, Spanish-English bilinguals showed better recognition performance in their less proficient language (L2), suggesting there is an advantage in the L2, like low-frequency words, for recognition memory (Francis & Strobach, 2013). However, the abovementioned language proficiency effects were found for regular recall and recognition memory and therefore it is not clear that these findings would apply to false recall and recognition memory.

The existing studies investigating the DRM paradigm in bilinguals have mostly focused on self-reported language proficiency (Cabeza & Lennartson, 2005; Kawasaki-Miyaji et al., 2003; Sahlin et al., 2005; Marmolejo et al., 2009; Arndt & Beato, 2017). Moreover, these earlier studies (with the exception of Arndt & Beato, 2017) did not directly compare false memory production for the more proficient language (L1) versus the less proficient language (L2), but rather focused on comparing the elicitation of false memories for within-language and between-language conditions. However, several of these studies reported higher rates of recall and/or recognition in their participants' more dominant language (Kawasaki-Miyaji et al., 2003; Howe et al., 2008; Marmolejo et al., 2009).

To our knowledge, only one published bilingual DRM study used objective assessments to measure language proficiency (Kawasaki-Miyaji et al., 2003). The participants in the Kawasaki-Miyaji et al. (2003) study were fluent in Japanese and English, and the test used as a measure of language proficiency was a digit span test, which was used to calculate language dominance by subtracting English scores from Japanese scores. Based on this test, they classified majority of the participants as being less proficient in English. However, digit span tests are not appropriate measures of language proficiency as they only serve as a tool to measure speed of processing or short-term memory.

1.4 The Present Study

The present study investigated the false memory effect in bilinguals, and further tested the conditions in which false memories transferred across languages. Bilingual participants were assessed for their language proficiency using both self-report and standardized language assessments. During the encoding phase, participants completed study-recall cycles by listening to the word lists and later recalling the words in the instructed language. At test, participants completed a recognition task in either English or Spanish by indicating whether the presented word was studied (e.g., *Yes*) or not studied (e.g., *No*) during the encoding phase regardless of the language in which it was presented.

Although all the models of false memory make similar predictions on the DRM paradigm's false memory effect, the predictions for the current study were framed around the fuzzy trace theory (Brainerd & Reyna, 2002). However, our results are also interpreted with the consideration of the other theories of false memory (i.e., activation-monitoring theory, associative-activation theory, and global-matching models) in the general discussion.

The first goal of the study was to investigate the between-language false memory effect and its greater strength compared to the within-language false memory effect. Earlier studies implementing the DRM paradigm in non-English speaking populations were successful in replicating the false memory effect with word lists that were in languages other than English (i.e., Japanese, Spanish, and Portuguese) (Miyaji & Yama, 2002; Anastasi et al., 2005; Albuquerque & Pimentel, 2005). Researchers developed a bilingual DRM paradigm to investigate whether the false memory effect would transfer across languages. Not only did the false memory effect transfer across languages, studies also found even more robust effects for between-language conditions than for within-language conditions (Marmolejo et al., 2009; Howe et al., 2008).

While the fuzzy trace theory was initially based on a monolingual population, it can be adapted to major concepts established in the bilingual literature. The two memory representations for fuzzy trace theory (Brainerd & Reyna, 2002), *gist* and *verbatim*, can be thought of as two levels of representation for bilingual language representation, the lexical level and conceptual level. The lexical level consists of word form information whereas the conceptual level involves meaning of the words (Kroll & de Groot, 2020).

According to fuzzy trace theory, false memories occur due to the reliance of a gist trace after the verbatim trace has decayed, even when both gist and verbatim traces are encoded at the study phase. The DRM paradigm involves the presentation of various items that a share the same theme, or critical lure, thus the strengthened gist trace. In respect to bilingual participants, the gist traces formed by bilinguals are language-general because the presented items activate conceptual representations in both languages, therefore gist traces are readily accessible at test whereas verbatim traces are only encoded in the language at encoding.

Based on the fuzzy trace theory, we predicted we would observe the between-language false memory effect because of the reliance on language-general gist traces at test. Furthermore, we predicted that we would observe a stronger between-language false memory effect compared to the within-language effect. Because the language at encoding differs from the language at test, verbatim traces would not be available in the test language to help differentiate words that were studied from the critical lure and reject the critical lure.

The second goal was to investigate whether mixing two languages in the same list would change the strength of the false memory effect compared to within-language or between-language conditions. According to the bilingualism literature, bilinguals have an integrated lexicon with a shared conceptual representation. If concepts and semantic associations are language-general, bilinguals should be able to integrate input from their two languages via a shared semantic network at the conceptual or *gist* level when studying a mixed-language word sequence. Because the mixed-language list would present words in English and Spanish, the verbatim traces for the mixed-language list would include language-specific information for half of the studied items.

In the DRM paradigm, the language-general gist traces would be the main cause for the elicitation of false recognition of the critical lures, at least to the level observed in within-language conditions. Following the same logic postulated by fuzzy trace theory, we predicted that the false memory effect for the mixed-language condition would be between the within-language conditions and between-language conditions. Because verbatim traces are encoded for items in both languages, there would be half of the verbatim traces available to correctly reject the critical lure at test.

The third goal was to investigate whether and to what degree language proficiency is associated with the strength of the false memory effect. The present study assessed participants' language proficiency using a standardized objective language assessment (WMLS-R; Woodcock et al., 2005). A composite score for oral language was obtained for each participant and this score was included in the analyses as a continuous variable. To our knowledge, the present study is the first bilingual false memory study to measure participants' language proficiency using a standardized language assessment.

According to the bilingualism literature, word forms have stronger links to conceptual representations in the more proficient language (L1) due to a lifetime of exposure and usage. If words in the L1 have stronger conceptual representations, the gist traces formed will be stronger for L1 words. We hypothesized that higher language proficiency would increase the recall and recognition of non-presented critical words. Therefore, it was predicted that participants would falsely recognize more critical lures when the presented associates were studied and retrieved in the more proficient language (L1).

Chapter 2: Methods

2.1 Power and Sample Size

To have 80% power to detect medium differences between conditions, the sample size requirement for the first and second goal was 86 for the effect of test language and 28 for the effect of encoding language and the interaction between encoding language and test language. For the third goal, to have 80% power to detect a medium correlation, the required sample size was 84. For counterbalancing considerations, a multiple of 24 was required, and therefore the sample size was 96 participants.

2.2 Participants

Participants were 96 (69 females, 26 males, one bigender) Spanish-English bilingual students who were enrolled in psychology courses at the University of Texas at El Paso. Participants were compensated with extra credit on their courses for their participation in the experiment. The median age of participants was 20 ($SD = 4.3$) and 99% reported they were of Hispanic ethnicity. Participants self-reported a mean age of acquisition for English of 6.7 years old, and a mean age of acquisition for Spanish of 1.8 years old.

Because the experiment required participants to be bilingual, participants were administered standardized objective language assessments in both English and Spanish (Woodcock et al., 2005) to assess for their language proficiency. Two subtests (Picture Vocabulary and Verbal Analogies) were administered and used to compute a composite Oral Language proficiency score for each participant. This composite Oral Language proficiency score was converted to an age equivalency score which represents the age at which a given raw score on the language assessment is normative. The age equivalency scores for English and Spanish were used to classify each participant's language proficiency and participants had to score an age equivalency of 8 years old or greater to qualify for the study. The mean language assessment score for the English Picture Vocabulary assessment was 13 (*SD* = 5) and 17 (*SD* = 9) for the English Verbal Analogies assessment. The mean language assessment score for the English Oral Language composite score was 14 (*SD* = 5). The mean language assessment score for the Spanish Picture Vocabulary and Verbal Analogies assessments were 12 (*SD* = 2) and 20 (*SD* = 9), respectively. The mean language assessment score for the Spanish Oral Language composite score was 14 (*SD* = 5).

2.3 Design

The experiment utilized a 3 (encoding language) x 2 (test language) mixed design for the free recall study cycles, and a 3 (encoding language) x 2 (test language) mixed design for the recognition test. The encoding language condition was manipulated within subjects, with one set of lists presented in English, another set presented in Spanish, and the third set presented in mixed language (half English and half Spanish). A fourth set was reserved to provide words for a set of non-studied foil lists to serve as comparable items for the recognition test. The test language was manipulated between subjects, with half of the participants tested in English, and the other half tested in Spanish. Accuracy was measured in both free recall and recognition tests.

2.4 Materials

2.4.1 Experimental Word Stimuli

The experiment utilized normed English and Spanish associative lists that have been shown to elicit the false memory effect in both recall and recognition tests (Marmolejo et al., 2009). To ensure enough lists were available for each of the experimental conditions, additional English and Spanish normed associative lists were selected from another set of norms (Anastasi et al., 2005). A total of 20 lists were acquired from both the aforementioned studies for the present study, with 5 lists for each experimental condition.

Although initially 23 candidate lists were identified, norming was done to ensure that associates within each list were not highly associated with the critical lures of other lists. The 20 lists were determined after a norming study was conducted using Qualtrics. Minor modifications were made for the following lists: *bread*/*pan*, *dance*/*baile* (*bailar*), *river*/*rio*, *sleep*/*dormir*, *slow*/*despacio*, and *soft*/*blando*, *sleep*/*dormir* (Marmolejo et al., 2009). Minor modifications were also made for the following set of lists: *high*/*alto*, *foot*/*pie*, and *doctor*/*doctor* (Anastasi et al., 2005). Additionally, Spanish words that were not consistent with local usage were replaced with corresponding words for the same concepts that are most often used in the El Paso-Ciudad Juárez community. See Appendix A for the lists utilized in the experiment.

Sound files for all stimulus words (including critical lures) were recorded by a female native bilingual speaker of English and Spanish using Praat software (Boersma & Weenink, 2018). Each of the 20 lists contained 12 presented words and the non-presented critical lure. Each word and critical lure in the list had a sound file in both English and Spanish. The sound files were used to create language pure lists in English and in Spanish. The sound files were also used to create lists that contained the words English and Spanish in alternating order for the mixed-language condition. Two versions of the mixed language lists were created to account for any potential order effects. The 20 associative lists were randomly divided into 4 sets of 5 lists for each encoding condition and for the non-studied foil lists set. The assignment of lists to encoding conditions was counterbalanced across participants. Assignment of items to languages in the mixed lists was counterbalanced across participants using. Assignment and counterbalancing were done using a Latin square.

2.4.2 Language Background

Participants were required to complete demographic and language background questionnaires. The language questionnaire addressed participants' self-reported language background (e.g., age of acquisition), usage and subjective ratings of proficiency. The demographic questionnaire gathered information such as gender, age, ethnicity, race, education level, parent education level and socioeconomic status.

2.4.3 Apparatus

Stimuli were presented using Qualtrics. The list stimuli were presented auditorily in each study sequence, with a two second interval between consecutive words in the list. Word stimuli for the recognition test were presented visually. Participants that participated remotely completed the experiment using their personal laptops or desktops. Participants that participated in person completed the experiment on iMac desktops in the laboratory. Responses for the free recall study cycles were recorded using a handheld voice recorder for later transcription and verification.

2.5 Procedure

The experiment was administered remotely or in person. Participants that completed the experiment remotely accessed the experimental session by joining a Zoom meeting created by the experimenter after the participants signed up for the study. Remote participants were tested individually by a bilingual experimenter while on the Zoom meeting. At the beginning of the remote experimental session, participants were instructed to complete the experiment in a quiet room without distractions. Participants received a link to the experimental form and shared their screen with the experimenter. In-person participants were tested individually by a bilingual experimenter in a quiet testing room. After informed consent, the experimenter administered the language assessments in both English and Spanish.

After completing the language assessments, participants were then given instructions for the encoding phase of the experiment. The encoding phase consisted of the free recall cycles. The experimenter instructed the participant that they would need listen to the words attentively and remember them, because they would not be able to replay the words. Participants were then instructed that after listening to the set of words, they would need to complete a free recall task by recalling aloud all the words from the list they had just heard in the language specified to them. Participants first completed a practice trial to familiarize themselves with the task, then continued onto the actual experimental study-recall cycles. There was a total of 15 lists for the free recall phase of the experiment, each list containing 12 words. The lists were blocked by encoding language and the order of conditions was counterbalanced, with 5 lists presented in English, 5 lists presented in Spanish, and the remaining 5 lists presented in mixed language sequence. Half of the participants were randomly assigned to recall the lists aloud in English, and the other half recalled the lists aloud in Spanish.

After the 15 free recall study cycles were completed, participants were instructed on the recognition memory task. The experimenter explained to the participant that a series of words would appear on the screen, and that they would need to indicate "Yes" if they studied the word in either English or Spanish, or indicate "No" if they did not study the word during the free recall study phase. Participants first completed a series of practice items to familiarize themselves with the task before completing the actual recognition task. From each of the 15 studied lists, and each of the 5 non-studied lists, three list words (from positions 4, 6, & 8) and the critical lure made up the recognition task. Thus, the recognition task consisted of 80 words. For half of the participants, all words in the recognition task appeared in English, and for the other half they appeared in Spanish, consistent with the language they were assigned for the free recall task.

Afterwards, participants completed the demographic and self-report language background questionnaires. The participants were then debriefed on the purpose of the experiment.

Chapter 3: Results

3.1 Coding

Participant's responses during the study-recall cycles were marked using response sheets to keep track of the recalled presented list items and critical lures. A presented list item was scored correctly if it was recalled in the requested language and shared the root word, regardless of the plurality, verb tense, and gender if recalled in Spanish. For an example of verb tense, the item *swimming* was scored as correct, when the presented list item was *swim*. For an example of gender, for recall in Spanish, the responses *gatitos*, *gatita*, *gatitas* were all scored correctly in the Spanish recall condition for the list item *gatit*o. Critical lures were scored similarly to presented list items, disregarding plurality, verb tense and gender. Although the present study took an intermediate approach compared to Marmolejo et al. (2009) when coding participants' responses during the study-recall portion, our findings were consistent with the bilingual false memory literature.

3.2 Recall

False recall for the non-presented critical lures was measured as the proportion of lure items from the presented lists recalled in the requested language. Veridical or true recall was measured as the proportion of presented items recalled in the requested language. These recall proportions are given in Table 1. To address the first and second goals of the study, two 3 (encoding language) x 2 (test language) mixed ANOVAs were performed, one for false recognition and one for veridical recognition. Planned pairwise comparisons were conducted to compare false recall of non-presented critical lures for each of the three studied conditions.

3.2.1 False Recall

As shown in Figure 1, the proportion of false recall for critical lures from presented lists was significantly higher in the between-language condition (*M* = .377, *SD* = .238) than in the within-language condition (*M* = .226, *SD* = .248), *F* (1, 94) = 24.358, *MSE* =.091, *p* = .000, η^2_p = .206. The proportion of false recall for critical lures in the between-language condition was significantly higher than in the mixed-language condition (*M* = .296, *SD* = .249), *F*(1, 94) = 7.313, *MSE* = .086, *p* = .008, η^2_p = .072. The proportion of false recall of critical lures was significantly higher in the mixed-language condition than in the within-language condition, *F*(1, 94) = 8.613, *MSE* = .056, *p* = .004, η^2_p = .084. The main effect of test language was not significant, nor did it interact with the effects of the encoding language condition, *p*s > .2.

3.2.2 Veridical Recall

As shown in Figure 1, the proportion of veridical recall for presented items from presented lists was significantly higher in the within-language condition (*M* = .549, *SD* = .135) than in the between-language condition (*M* = .408, *SD* = .113), *F*(1, 94) = 148.137, *MSE* = .013, *p* = .000, η^2_p = .612. The proportion of veridical recall for presented items from presented lists was significantly higher in the within-language condition (*M* = .549, *SD* = .135) than in the mixed-language condition (*M* = .468, *SD* = .129), *F*(1, 94) = 63.423, *MSE* = .010, *p* = .000, η^2_p = .403 . The proportion of veridical recall for presented items from presented lists was significantly higher in the mixed-language condition (*M* = .468, *SD* =.129) than in the between-language condition (*M* = .408, *SD* = .113), *F*(1, 94) = 22.085, *MSE* = .016 *p* = .000, η^2_p = .190. The main effect of test language was not significant, nor did it interact with the effects of the encoding language condition, *p*s > .2.

3.3 Corrected Recognition

False recognition for the nonpresented critical lures was measured as the proportion of false alarms to critical lures from the presented lists. Veridical or true recognition was measured as the proportion of hits to studied items from the presented lists. To correct for individual biases, corrected recognition scores were obtained for false recognition and veridical recognition by subtracting the proportion of the non-studied items condition from each of the three encoding language conditions. Recognition proportions are given in Table 2. To address the first and second goals of the study, two 3 (encoding language) x 2 (test language) mixed ANOVAs were performed, one for false recognition and one for veridical recognition.

3.3.1 Corrected False Recognition

The items *doctor*/*doctor* were excluded from the final recognition because of their identical spelling in both English and Spanish. As shown in Figure 2, the proportion of false alarms to critical lures from presented lists was significantly higher in the between-language condition (M = .517, SD = .317) than in the within-language condition (M = .431, SD = .320), $F(1, 94) = 10.337$, MSE = .068, p = .002 , η^2_p = .099. The proportion of false alarms to lures was significantly higher in the between-language condition than in the mixed-language condition (M = .422, SD = .334), $F(1, 94) = 14.630$, MSE = .059, p =.000 , η^2_p = .135. There was not significant difference between the false alarms to critical lures in the within-language and mixed-language conditions, $F(1, 94) = .156$, MSE = .054, p = .694 , η^2_p = .002. The main effect of test language was not significant, nor did it interact with the effects of the encoding language condition, ps > .1.

3.3.2 Corrected Veridical Recognition

As shown in Figure 2, hit rates for studied items from presented lists were significantly higher in the within-language condition (M = .599, SD =.186) than in the between-language condition (*M* = .535, *SD* =.182), $F(1, 94) = 12.856$, *MSE* = .030, *p* = .001 , $\eta^2_p = .120$. The proportion of hit rates for studied items was significantly higher in the mixed-language condition (*M* = .579, *SD* = .172) than in the between-language condition, $F(1, 94) = 6.004$, *MSE* = .030, *p* =.016 , $\eta^2_p = .060$. There was not a significant difference between the proportion of hit rates for studied items in the within-language and mixed-language conditions, $F(1, 94) = 1.341$, *MSE* = .029, *p* = .250 , $\eta^2_p = .014$. The main effect of test language was not significant, nor did it interact with the effects of the encoding language condition, *p*s > .1.

3.4 Association Between Language Proficiency and False Memory Effect

To address whether language proficiency was associated with the strength of the false memory effect, correlations were conducted for both recall and recognition. We examined correlations of language proficiency scores in the assigned test language with recall rates and corrected recognition rates for studied items (*veridical*) and critical lures (*false*) from the presented lists only in the within-language condition. The W scores for language proficiency were used for the correlational analyses because they are closer to being normally distributed than the age equivalency scores. Language proficiency was not significantly associated with recall rates either for studied items, $r(94) = .066$, $p = .525$ or critical lures, $r(94) = .031$, $p = .766$. Language proficiency also was not significantly correlated with corrected recognition rates for studied items, $r(94) = -.027$, $p = .796$ or critical lures, $r(94) = .004$, $p = .973$. We did not analyze the correlations between language proficiency and items in the between-language condition or mixed-language condition because of the uncertainty of whether the false memory effect is a result of the encoding language or test language.

As a secondary method to examine proficiency effects, independent samples t-tests were conducted to compare L1 and L2 performance on the memory measures in the within-language conditions. For false recall, there was not a significant difference in the proportion of false recall of the non-presented critical lures for the within-language conditions in the participants' L1 (M = .214, SD = .242) and L2 (M = .243, SD = .259), $t(94) = -.570$, $p = .570$. For veridical recall, there was not a significant difference in the proportion of presented items recalled for the within-language conditions in the participants' L1 (M = .563, SD = .151) and L2 (M = .529, SD = .105), $t(94) = 1.206$, $p = .231$. For the corrected false recognition, there was not a significant difference in the proportion of non-presented critical lures falsely recognized for the within-language conditions in the participants' L1 (M = .427, SD = .317) and L2 (M = .438, SD = .330), $t(94) = -.170$, $p = .865$ .For the corrected veridical recognition, there was not a significant difference in the proportion of presented items recognized for the within-language conditions in the participants' L1 (M = .583, SD = .198) and L2 (M = .623, SD = .166), $t(94) = -1.030$, $p = .306$.

Chapter 4: Discussion

The present study implemented a bilingual DRM paradigm to address three goals. Our first goal was to investigate the between-language false memory effect and its greater strength compared to the within-language effect. We predicted that we would observe a stronger false memory effect for between-language conditions in comparison to within-language conditions. Our findings followed a consistent pattern for both the recall and recognition data, in which the false memory effect was stronger for between-language conditions compared to within-language conditions.

The second goal was to investigate whether there would be an effect when mixing languages within a list, and whether the novel mixed-language condition would change the false memory effect compared to within-language or between-language conditions in comparison to within-language conditions. We predicted that the false memory effect for the mixed-language condition would be between the within-language and between-language conditions. The false-memory effect was found in mixed-language conditions. A novel finding of the present study was the false memory effect for mixed-language conditions was in between the between-language conditions and within-language conditions for recall, whereas the false memory effect for the mixed-language conditions did not significantly differ from the within-language conditions for recognition.

The third goal was to investigate whether and to what degree language proficiency has an influence on the false memory effect. We predicted that the production of false memories would be greater in the more proficient language (L1) or with higher proficiency, more generally. We did not find an association between language proficiency and the false memory effect, and the false memory effect did not differ for L1 and L2. However, we offer explanations as to why we did not find an influence of language proficiency on false memory in our study.

These findings can be interpreted according to logic from the fuzzy trace theory (Brainerd & Reyna, 2002). Firstly, the finding that there was a stronger false memory effect for the between-language conditions for recall suggests that because participants were instructed to recall the presented items in a different language from encoding, any verbatim traces that may have been encoded were not helpful to reject critical lures if they came to mind at recall. Instead, the findings suggest that participants relied on the encoded language-general gist traces when asked to generate the presented items at recall. For recognition, the same explanation applies. Because the items on the recognition test were presented in a different language during the study-recall portion, the verbatim traces that were encoded and available were not useful in rejecting the non-presented critical lures, thus a reliance on the gist traces. Furthermore, the finding that there was a stronger false memory effect for the between-language conditions compared to the within-language for recall and recognition is consistent with findings from an earlier study investigating the bilingual false memory effect (Marmolejo et al, 2009).

Secondly, to our knowledge, the present study is the first to investigate whether mixing languages in associative lists would elicit a false memory effect or change the magnitude of the effect relative to lists that were language pure. The finding that the false memory effect was observed for the mixed-language condition in both recall and recognition is important evidence that participants integrated information across languages to form gist representations. In recall specifically, there was a significantly stronger false memory effect in the mixed-language condition than in the within-language condition. Although participants had the encoded verbatim traces for half of the presented items, there was still a reliance on the gist trace when recalling the items during the study-recall portion. In recognition, we observed a mixed-language false memory effect that did not significantly differ from the false memory for the within-language condition. One explanation is that because participants encoded verbatim traces for half of the presented items in the same language at test, these verbatim traces were available to participants to correctly reject the critical lures, similar to the within-language condition. Furthermore, recall is a more conceptually driven task than recognition (Durgunoglu & Roediger, 1987), which may explain why there was a false memory effect observed for the mixed-language condition in recall that was not observed in recognition. Specifically, recall may rely on gist traces to a greater extent than recognition.

Lastly, we predicted that higher proficiency in a language would result in a higher rate of false recall and recognition of non-presented critical lures in the dominant language due to stronger gist traces being encoded for items presented in the dominant language. We did not find a significant association between the language proficiency and the magnitude of the false memory effect for either recall or recognition. Our null findings were inconsistent with previous studies investigating the DRM paradigm in bilinguals (Kawasaki-Miyaji et al., 2003; Sahlin et al., 2005; Howe et al., 2008; Marmolejo et al., 2009; Arndt & Beato, 2017). These previous studies found that the rate of false recall and/or false recognition was higher in their participants' dominant language compared to the non-dominant language. However, in all these studies, participants were only asked to self-report their language dominance, whereas in the present study, we administered standardized language assessments (WMLS; Woodcock et al., 2005).

The absence of a proficiency association seems unlikely to be due to restriction of range, because participants in the present study had a wide range of language proficiency for English and Spanish (*Note*: standard deviations for the language proficiency age equivalency scores are provided in the participant characteristics table). The null effect also does not appear to be an artifact of the choice of materials. Prior to conducting the experiment, we normed the English and Spanish associative lists utilized in our study, which were borrowed from earlier studies (Anastasi et al., 2005; Marmolejo et al., 2009). Both sets of associative lists had been adapted from the original English DRM paradigm associative lists and had successfully replicated the false memory effect in Spanish-speaking and Spanish-English bilingual populations. They also produced the false memory effect in norming with bilinguals from the same population as the participants in the current study. Another possible explanation as to why we did not find an association between false memory and language proficiency is the nature of the language exposure that our bilingual participants have. Although the participants primarily speak one language at home (e.g., Spanish), they are exposed to both English and Spanish in other contexts (e.g., school, stores, entertainment) at similar levels, thus the bilingual participants in the present study may have more experience in their less proficient language compared to the bilingual participants in the other studies.

4.1 Explanations from Activation-Monitoring Theory & Global-Matching Models

Though the predictions made for the present study were based on the fuzzy trace theory, other false memory theories can accommodate the pattern of results observed. The *activation-monitoring theory* explains that critical lures are falsely remembered because they are activated due to their semantic relatedness to the presented items and the failure of source monitoring. By fitting our data to the activation-monitoring theory, the stronger false memory effect for the between-language condition would be the result of the reliance on semantic activation. The presented items receive both semantic and lexical activation, whereas the critical lures only have semantic activation that is elicited from the semantic activation of the presented items. Because the critical lures in the between-language condition only have semantic activation and not lexical, participants are not able to monitor the source of activation. In contrast, lexical activation of the presented items facilitates the rejection of the critical lures for the within-language condition.

In recall, the finding that the false memory effect was stronger for mixed-language conditions than for within-language conditions, as explained by activation monitoring theory, would be the result of the shared semantic network in the bilingual mental lexicon. Although only half of the presented items are lexically activated, their semantic activation spreads to the critical lures, therefore the reliance of semantic activation when participants are generating the items at recall, similar to between-language conditions. We did not find a significant difference between mixed-language and within-language false memory effects for recognition which, according to activation monitoring theory, suggests that the lexical activation for half of the presented items helps participants to reject the critical lures that do not have lexical activation. *Activation-monitoring theory* suggests that the critical lures would be activated more strongly at encoding when the words are more strongly associated with their conceptual representations. Critical lures in the more proficient language were expected to be falsely recalled and recognized at higher rates compared to lures in the less proficient language. However, we did not observe an association between language proficiency and the production of false memories.

Global-matching models focus on recognition; therefore, we will provide explanations only for our findings for the recognition data. The global-matching model explains that when critical lures are presented at test, they are falsely remembered as studied due to their “similarity” to studied items, which leads to a high activation value. The match in semantic similarity between the studied items and critical lures can lead to the false recognition of the critical lures, but in within-language conditions, a mismatch in perceptual or contextual similarity sometimes allows the lure to be rejected. The stronger between-language false memory effect can be explained according to the global-matching model. In between-language conditions, neither the studied items nor the lures on the recognition test match the study phase with respect to perceptual features. The encoded semantic information from the presented items leads to the critical lures becoming activated, and the semantic activation for the critical lures does not differ compared to the presented items, so they are classified as being studied. This suggests that participants mostly rely on the semantic information to determine whether the studied items and critical lures were studied or not, therefore the stronger between-language false memory effect.

We observed a false memory effect for the mixed-language conditions similar to the within-language condition effect, which suggests that the contextual information from half of the encoded presented items was available at retrieval to correctly reject the critical lures due to their lack of encoded contextual details. We did not find a significant association between language proficiency and false memory, although global-matching models would suggest that the stronger match in semantic similarity between critical lures and presented items based on the stronger activation of the presented items would result in higher rates of recognition for the non-presented critical lures in the more proficient language.

4.2 Veridical Recall and Recognition

While it was not the focus of our study, we also analyzed veridical (true) recall and recognition. We found that the rate of veridical recall was significantly higher for the within-language condition, consistent with the bilingual false memory literature (Marmolejo et al., 2009). The rate of veridical recognition was also higher for the within-language condition than for the between-language condition, also consistent with previous literature (Marmolejo et al., 2009), but did not significantly differ from the mixed-language condition.

We did not observe a significant association between language proficiency and veridical recall and recognition, which was consistent with an earlier study by Sahlin et al. 2005. Similarly, recall and recognition performance did not differ for L1 and L2. However, our null findings were inconsistent with other earlier studies (Howe et al., 2008; Marmolejo et al., 2009; see Arndt & Beato, 2017) which found higher rates of recall and recognition for items in their participants' more dominant language.

4.3 Caveats

Some caution is warranted in the interpretation of the recognition test results. Because the recognition task occurred after the study-recall cycles were completed, performing the recall tests may have affected performance during the recognition test. However, it should be noted that having a final recognition test immediately after recall is a common method in the literature (e.g., Howe et al., 2008; Marmolejo et al., 2009), but some studies only focused on recognition (Kawasaki-Miyaji et al., 2003; Cabeza & Lennartson, 2005; Sahlin et al., 2005).

4.4 Future Directions

The present study's novel and intriguing finding of the mixed-language false memory effect opens the door for future research. One potential future direction would be to study false memory in a more realistic setting, such as the misinformation effect paradigm. This future research would begin to address how bilinguals encode an event and later retrieve details of the event. Specifically, research can investigate whether encoding and retrieval processes differ for contexts where more than one language is involved.

4.5 Conclusion

In conclusion, the present study incorporated two novel methodological features to address the goals of the study. First, we included a mixed-language condition, and secondly, we measured participants' language proficiency using standardized language assessments and treated language proficiency continuously rather than categorically. The current work is the first to investigate and find evidence that mixed-language conditions are capable of eliciting false memory effects similar to between-language conditions in recall and similar to within-language conditions in recognition. The results of the present study suggest that language proficiency is not associated with the susceptibility of producing false memories.

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Table 1

Participant Characteristics

Measures	*Mean*	*SD*
Age	21.5	4.35
Age of Acquisition		
English	6.67	3.89
Spanish	1.85	1.73
Age Equivalency		
English	13.6	5.36
Spanish	13.9	4.80
W		
English	510	12.5
Spanish	512	11.6

Note. Age Equivalency and W scores are composite scores of oral language proficiency from the Woodcock-Munoz Language Survey Revised (Woodcock et al., 2005) standardized language assessments.

Table 2

Mean Proportions of Items Recalled

Type of Item	Test Language			
Encoding Language	English		Spanish	
Critical Lure	*Mean*	*SD*	*Mean*	*SD*
Within	.246	.255	.205	.242
Between	.379	.241	.375	.237
Mixed	.300	.271	.293	.229
Presented Item				
Within	.564	.136	.535	.134
Between	.414	.100	.401	.125
Mixed	.477	.141	.456	.117

Table 3

Mean Proportions of Items Recognized

Type of Item Encoding Language	Proportion of Yes Responses English		 Spanish		Corrected Recognition English		 Spanish	
Critical Lure	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Within	.753	.238	.737	.208	.449	.305	.414	.337
Between	.831	.187	.829	.205	.527	.298	.506	.337
Mixed	.704	.216	.767	.236	.400	.302	.444	.366
Non-Presented	.304	.249	.323	.288	---	---	---	---
Presented Item								
Within	.748	.153	.773	.151	.601	.167	.596	.206
Between	.684	.160	.711	.135	.538	.170	.533	.195
Mixed	.754	.146	.728	.122	.607	.138	.550	.198
Non-Presented	.148	.103	.178	.159	---	---	---	---

Note. Corrected recognition scores were obtained by subtracting the proportion of the non-studied items condition from each of the presented items conditions.

Table 4

Associations of Task Language Proficiency with Memory Measures in Within-Language Conditions

Memory Measures	Correlations	L1 (n = 58)		L2 (n = 38)	
	r(94)	*M*	*SD*	*M*	*SD*
Recall					
Lure	.031	.214	.242	.243	.259
Veridical	.066	.563	.151	.529	.105
Recognition					
Lure	.004	.427	.317	.438	.330
Veridical	-.027	.583	.198	.623	.166

Note. L1 = dominant language, L2 = nondominant language

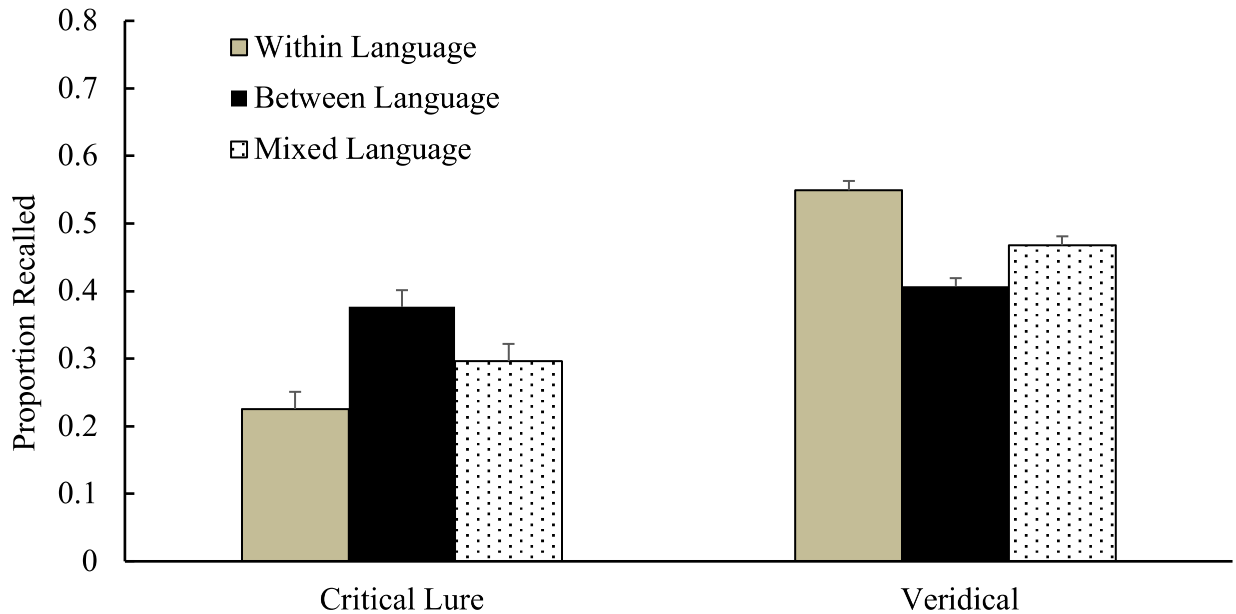

Figure 1: Proportion of Items Recalled as a Function of Item Type and Encoding Language

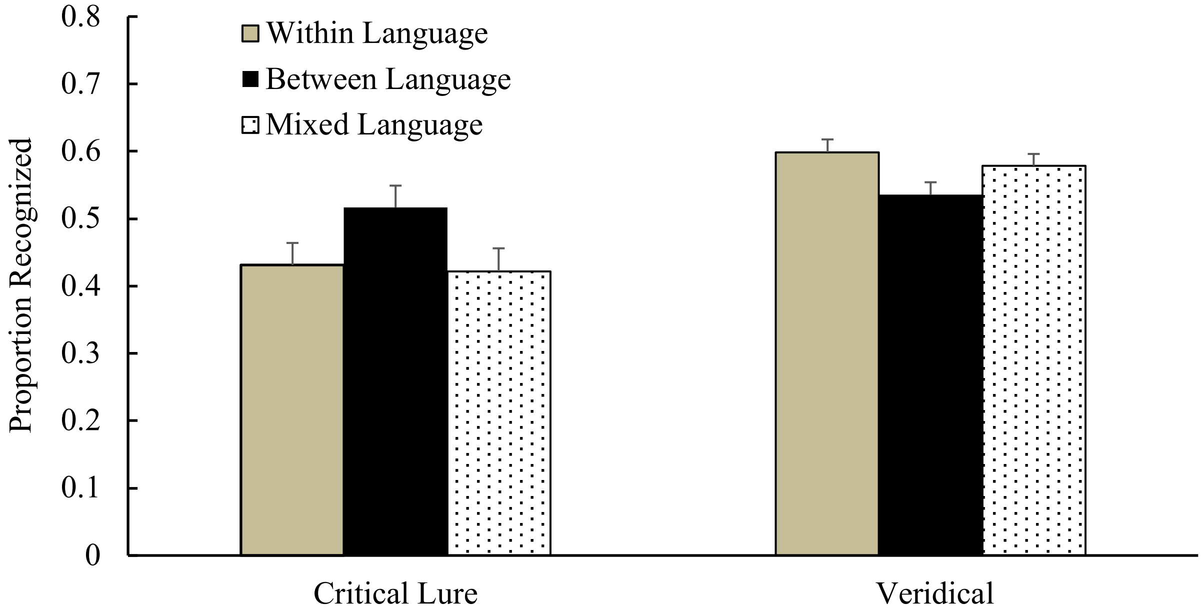

Figure 2: Proportion of Items Recognized as a Function of Item Type and Encoding Language

Appendix

Appendix A. Word Lists

ANGER[a]	ENOJO[a]	CITY[a]	CIUDAD[a]	DANCE[a]	BAILE (BAILAR)[a]
mad	furioso	town	pueblo	party	fiesta
fear	miedo	state	estado	fun	diversión
hate	odio	streets	calles	joy	alegría
rage	rabia	country	país	waltz	vals
temper	genio	New York	Nueva York	discoteque	discoteca
fury	furia	village	aldea	movement	movimiento
wrath	cólera	big	grande	sing*	cantar*
happy	contento	suburb	afueras	step	paso
fight	pelea	county	municipio	partner	pareja
mean	malo	people	gente	jump	saltar
calm	calmado	building	edificio	song	canción
enrage	enfurecerse	noise	ruido	costume	disfraz

NEEDLE[a]	AGUJA[a]	SLOW[a]	DESPACIO[a]	BREAD[a]	PAN[a]
thread	hilo	fast	rápido	butter	mantequilla
pin	alfiler	stop	detener	food	alimento
sewing	costura	apathy*	apatia*	eat	comer
sharp	punzante	snail	caracol	rye	centeno
point	punta	cautious	cauteloso	milk	leche
prick	pinchazo	delay	retraso	flour	harina
thimble	dedal	turtle	tortuga	jelly	mermelada
thorn	espina	hesitant	indeciso	dough	masa
hurt	lastimar	speed	velocidad	crust	corteza
syringe	jeringa	wait	esperar	slice	rebanada
cloth	tela	move	moverse	wine	vino
knitting	tejido	lazy	perezoso	yeast*	levadura*

COLD[a]	FRIO[a]	LOVE[a]	AMOR (AMAR)[a]	RIVER[a]	RIO[a]
hot	caliente	affection	afecto	water	agua
snow	nieve	kiss	beso	stream	corriente
warm	tibio	pain	dolor	lake	lago
winter	invierno	life	vida	boat	bote
ice	hielo	friendship	amistad	tide	marea
wet	húmedo	everything	todo	swim	nadar*
heat	calor	happiness	felicidad	run	correr
weather	clima	feeling	sentimiento	creek	arroyo*
freeze	congelar	heart	corazón	fish	pez
shiver	tiritar	tenderness	ternura	bridge	puente
frost	escarcha	pleasure	placer	winding	tortuoso
dark	obscuro	desire	deseo	deep	profundo

SOFT[a]	BLANDO[a]	CHAIR[a]	SILLA[a]	CUP[a]	TAZA[a]
hard	duro	table	mesa	mug	tarro
light	ligero	sit	sentarse	saucer	plato
pillow	almohada	legs	patas	measuring	medir
smooth*	suave*	seat	asiento	coaster	posavasos
cotton	algodón	desk	escritorio	lid	tapa
touch	tocar	wood	madera	handle	asa
fluffy*	pelusa	cushion	cojin	coffee	café
furry	peludo	swivel	girar	goblet	copa
kitten	gatito	stool	banquito	soup	sopa
skin	piel	rocker	mecedora	stain	mancha
tender	tierno	bench	banca	drink	bebida
silk	seda	relax	relajarse	sip	sorbo

MOUNTAIN[a]	MONTAÑA[a]	SLEEP[a]	DORMIR[a]	TIME[a]	TIEMPO[a]
hill	loma	bed	cama	hour	hora
climb	escalar	rest	descansar	clock	reloj
top	cima	awake	despierto	years	años
peak	pico	tired	cansado	past	pasado
plain	plano	dream	soñar	short	corto
goat	chivo	wake	despertar	age	edad
bike	bicicleta	snore	roncar*	space	espacio
climber	alpinista	nap	siesta	eternal	eterno
range	cordillera	peace	paz	epoque	época
ski	esquiar	yawn	bostezar	eternity	eternidad
cave	cueva	drowsy	soñoliento	century	siglo
rock	piedra	night	noche	second	segundo

HIGH[b]	ALTO[b]	FOOT[b]	PIE[b]	MAN[b]	HOMBRE[b]
thin	delgado	shoe	zapato	father	padre
stature	estatura	sock	calcetín	woman	mujer
ladder*	escalera*	toe	dedo	husband	esposo
skyscraper*	rascacielos*	nails*	uñas	handsome	guapo
sky	cielo	walk	caminar	sir	señor
short	chaparro	ankle	tobillo	male	macho
cloud	nube	hands	manos	strong	fuerte
star	estrella	smelly	apestoso	brother	hermano
above	arriba	stockings	medias	uncle	tío
giant	gigante	sandals	sandalias	grandfather	abuelo
length	largo	heel	talón	mature	maduro
reach	alcanzar	slippers*	pantuflas*	adult	adulto

DOCTOR[b]	DOCTOR[b]	FRUIT[b]	FRUTA[b]
medicine	medicamentos	apple	manzana

sick	enfermo	orange	naranja
disease	enfermadad	banana	plátano
hospital	hospital	pineapple	piña
relief	alivio	mango	mango
help	ayuda	grapes	uvas
blood	sangre	freshness	frescura
cure	curar	strawberries	fresas
patient	paciente	vegetable	vegetal
nurse	enfermera	juice	jugo
health	salud	watermelon	sandía
clinic*	clinicá*	tree	árbol

Note. Words in bold are non-presented critical lures.
[a] Lists borrowed from Marmolejo et al. (2009).
[b] Lists borrowed from Anastasi et al. (2005).
* Lists were modified to account for local usage in the El Paso-Ciudad Juárez community.

Vita

Bianca Gurrola earned a B.S. in Psychology from the University of Texas at El Paso in 2016. She began working in the Bilingual Cognition Lab as an undergraduate student in the fall of 2015. Bianca then began graduate work at UTEP in the fall of 2017 and is currently a PhD student in the Bilingualism, Language and Cognition program. During her time in graduate school, Bianca has worked as a graduate research assistant under her mentor Dr. Wendy Francis. Bianca has also served as a teaching assistant for a number of courses such as Cognitive Psychology, Lab for General Experimental Psychology, Learning & Memory and Categorical Data Analyses. Currently, Bianca has co-authored two publications published in the following journals: *Journal of Experimental Psychology: Learning, Memory, and Cognition* and *Memory & Cognition*. Bianca continues her education while she works on obtaining her PhD. After she receives her PhD, Bianca plans to continue with research by applying for a postdoctoral fellowship, and afterward work closely with the court system or government.

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