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Jenna Holton April 10, 2024

Individual Differences in Bilinguals' False Memories: Investigating the Role of Language Proficiency, Executive Functioning, and Memory Monitoring

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Abstract

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Our memories are often considered accurate and reliable, but they are subject to reconstructive processes, sometimes resulting in the creation of false memories or memories of events that never occurred. Despite the growing interest in the malleability of memory research, the field is still in its early stages in terms of understanding the mechanisms and individual differences contributing to the formation of false memories. Recent research has analyzed the association between language background and false memory creation using the Deese-Roediger-McDermott (DRM) paradigm, which has shown that bilinguals are more susceptible to forming false memories in their dominant language than in their non-dominant language(s). However, few studies have examined the potential mechanisms that lead to individual differences in false memory susceptibility within a bilingual's dominant language. Therefore, the current study aimed to investigate three potential mechanisms—language proficiency, executive function, and memory monitoring—to understand individual differences in false memory expression, particularly among linguistically diverse individuals. Results from the present study did not show support for a relation between individual differences in these constructs and false memory susceptibility among bilinguals; however, the findings highlight the need for further investigation and modification of existing techniques to better understand individual differences influencing malleability of memory, in both those who are linguistically diverse and more broadly.

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Thank you to my friends and family whose care, encouragement, and support has been imperative to the success of my thesis. I do not have enough words to express my gratitude for my full support network throughout this process.

I would also be remiss if I didn't take this space to acknowledge the interdisciplinary ways we can approach the study of memory. I find beauty in the ways our memories are central to how we define and identify ourselves as we build connections through coauthored stories. Where science cannot always capture as creatively the beauty of our connective and reconstructive memories, poetry and the arts can:

"Memory Sack" by Joy Harjo

That first cry opens the earth door.

We join the ancestor road.

With our pack of memories

Slung slack on our backs

We venture into the circle

Of destruction,

Which is the circle

Of creation

And make more—

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Investigating the Role of Language Proficiency, Executive Functioning, and Memory Monitoring

While we often trust our memories for accuracy and reliability, our memories are malleable accounts subject to reconstructive processes (Bartlett, 1932; Roediger, 2001; Wagoner, 2013). We integrate our perceptions of events with information and details we have previously encountered or encounter following an event to build our own cohesive narratives (Bilman, 1996; Loftus & Palmer, 1974). For instance, our reconstructive memories may confuse the sources of information (e.g., misplacing where we have seen someone as an eyewitness; Loftus, 2018; Schacter, 1999), integrate information provided by others into our recollections (e.g., introducing new perceptions from leading questions or incorporating details from another person's account; Gabbert et al., 2004; Loftus & Palmer, 1974), or misremember past emotions and feelings experienced during an event (e.g., consistency bias; Levine et al., 2009). Such revisions of memory may be a facet of false information from exogenous sources (e.g., hearing misinformation from a trusted authority figure or from others' accounts of the same event) or endogenous sources (e.g., making inaccurate associations with one's own prior experience or knowledge; Kolodner, 1983; Schacter, 1999, 2022). Sometimes such forms of memory distortions can result in a false memory, or a memory for details or events that never occurred (Roediger & McDermott, 1995; Suarez & Beato, 2021). Although malleability of memory research has garnered interest in the last few decades, the field remains underdeveloped in its exploration of the mechanisms and individual differences that lead to false memories. The aim of the current study is to explore three potential mechanisms driving individual differences in susceptibility to false memories, particularly within the context of linguistically diverse (i.e., bilingual or multilingual) individuals.

Associative Memory Illusions in the DRM

The Deese-Roediger-McDermott (DRM) paradigm is one of the most cited examples of inducing spontaneous false memories by presenting participants with conceptually related words (e.g., bed, night, tired, pillow, etc.) that prompt them to incorrectly think of and report remembering the critical lure word associating those concepts (e.g., sleep; Coburn et al., 2021; Grant et al., 2023; Hume et al., 2009; Otgaar et al., 2016; Roediger & McDermott, 1995). False memories induced in the DRM paradigm have been proposed to be facilitated by spreading activation, an unconscious psycholinguistic phenomenon in which a concept activates a network of similar concepts within one's semantic memory (e.g., 'cat' activating 'dog'; Collins & Quillian, 1969; Collins & Loftus, 1975; Nozari & Novick, 2017). Within the DRM task, accessing multiple semantically related concepts leads to the automatic co-activation of other similarly related concepts. In co-activating related concepts in one's memory either when first encountering the word list during encoding or when trying to recollect the word list during recall, individuals experience heightened activation of non-presented, semantically linked items, which may be falsely recalled as part of the original list (Colombel et al., 2016; Meade et al., 2007).

Bilingualism and False Memories

Much of the early work using the DRM paradigm focused on establishing that people can remember words or events that never occurred while also seeking to explain how such spontaneous false memory creation occurs and the contexts within which false memory propensity varies (e.g., variations in associative strength: Brainerd and Wright, 2005; Arndt, 2012, 2015; Beato and Arndt, 2014, 2017; variations in presentation rate and modality: Boldini et al., 2013; Mao et al., 2010; Seamon et al., 1998; Smith & Kimball, 2012; Stadler et al., 2018; variations in cognitive load and attention: Pêrez-Mata et al., 2002; Otgaar et al., 2012; variations

in emotional valence: Bookbinder & Brainerd, 2016; Hellenthal et al., 2019; Chang et al., 2020). More recently, there has been a shift to understanding spreading activation as the primary mechanism facilitating the associative memory illusions demonstrated in the DRM (see Gallo, 2006, 2010 for review). The field has expanded to consider how individual differences within development (Howe et al., 2009; Otaar et al., 2016), aging (McCabe et al., 2009; Devitt & Schacter, 2016), clinical populations (Favre et al., 2020; Howe & Akhtar, 2020; Malone et al., 2019; Wojcik et al., 2018), and language background (see Suarez & Beato, 2021 for review) interact with spreading activation to make one individual more or less likely than another to have false memories.

Within the domain of language background, prior work has suggested that bilinguals have higher false memory rates when recalling lists in their dominant language than in their non-dominant language(s) (Beato et al., 2023; Cabeza et al., 2005; Sahlin et al., 2005; Suarez & Beato, 2021; Suarez et al., 2021). Both language dominance and language proficiency vary according to usage and context, but language dominance refers to the language an individual engages with and uses most at a given time, while language proficiency refers to one's ability to use a language in terms of comprehension, speaking, reading, and writing (Beatty-Martinez et al., 2020; Dolgoarshinnaia & Martin-Luengo, 2021; Heredia, 1997; Pérea et al., 2008; Suarez & Beato, 2021). Language proficiency within a dominant language may moderate false memory expression because of language proficiency's role in developing semantic networks. Language proficiency facilitates vocabulary acquisition, understanding of semantic relations, and expression of thoughts and ideas, which allows for the development and reinforcement of connections and categorizations between concepts within and across semantic networks (Collins & Loftus, 1975; Dóczi, 2019; Pérea et al., 2008). Furthermore, prior work has suggested the

conceptual links, or associations, between individual words and their concepts may be stronger in one's dominant language than one's non-dominant language(s) because of increased language proficiency (Gollan et al., 2008; Kroll & Tokowicz, 2001; Pérea et al., 2008; Suarez & Beato, 2021). Increased language proficiency supports increased lexical access and concept development to facilitate spreading activation within semantic networks (Arndt & Beato, 2017; Cabeza & Lennartson, 2005; Issa et al., 2022; Kroll & Stewart, 1994; Liang & Chen, 2019; Sahlin et al., 2005). Therefore, language proficiency is directly related to the robustness of semantic networks and, thus, the automaticity of spreading activation that facilitates and primes broader associations in semantic memory.

Beyond the role of language proficiency, two additional potential mechanisms driving the false memory effect in bilinguals have been proposed. Specifically, Circi et al. (2021) and Grant et al. (2023) suggest that using a less dominant language encourages increased executive functioning and memory monitoring, respectively, and one can extend these findings to suggest this leads to fewer false memories in that less dominant language (or, conversely, relatively more false memories in one's more dominant language). Thus, the present study aims to directly assess the interrelations between language proficiency, executive functioning, and memory monitoring and one's proportion of false memories in their dominant language.

Possible Factors Related to False Memory Susceptibility Among Bilinguals

Language Proficiency

Individuals likely exhibit higher language proficiency in their dominant language, which suggests they will have a larger lexical knowledge base with denser associative networks to draw upon as they engage with new concepts. With stronger conceptual links within a semantic network, more proficient individuals will experience greater availability and automaticity of

spreading activation between associated concepts. Therefore, the richness of these associative networks may be related to an increased likelihood of false memory susceptibility. If an individual has fewer representations of related concepts available in semantic memory to activate due to lower language proficiency, then they are less likely to be susceptible to associative memory illusions. While at a conceptual level, higher proficiency would relate to more robust semantic networks and it has been previously demonstrated that bilinguals have more false memories in their dominant (and likely more proficient) language (Arndt & Beato, 2017; Beato & Ardnt, 2021; for a review, see Suarez & Beato, 2021), no studies to date have directly tested this association. Thus, the present study aims to explicitly test the hypothesis that language proficiency is a driving factor contributing to individual differences in false memory reporting in bilinguals' dominant language.

Executive Function

Studies of bilingual language use have suggested that both languages remain activated, regardless of the language in use. To respond in or to recall the correct language, bilinguals must then inhibit the irrelevant language (Green, 1998; Hilchey & Klein, 2011; Linck et al., 2008). Yamasaki & Prat (2021) describe how individual differences in conflict management, a subcomponent of executive function, are associated with one's ability to manage and reduce disruptive cross-linguistic interactions when reading. Thus, individuals who have stronger executive function skills may be better at managing interference associated with the activation of irrelevant language representations. While these findings do not specifically relate to bilinguals' engagement with and suppression of false memories, the evidence concerning individual differences among bilinguals in their ability to suppress irrelevant or interfering cross-linguistic

interactions could relate to individual differences among bilinguals in their ability to inhibit distorting information that could impact whether one reports or creates a false memory.

Few studies have specifically investigated the predictive links between individual differences in executive function and the propensity for false memories in bilinguals. However, the relation between inhibitory control (one subcomponent process under the umbrella of executive functioning) and false memories has been investigated in studies exploring impairment- and age-related false memory susceptibility (Butler et al., 2004; Colombel et al., 2016; Gronchi et al., 2023). For instance, prior work has examined individuals with impairments to the prefrontal cortex and executive function deficits to suggest decreased inhibitory control results in more frequent associative false memories on tasks like the DRM (Butler et al., 2004; Colombel et al., 2016; LaVoie et al., 2005). With greater executive functioning skills, participants may inhibit the activated critical lure when encoding or retrieving DRM word lists to preserve their accuracy for memories of the presented words. Therefore, the current study will test the hypothesis that individual differences in inhibitory control among bilinguals may relate to differential abilities to inhibit associative memory illusions that lead to false memories.

Memory Monitoring

Memory monitoring refers to a metacognitive practice in which individuals actively evaluate the accuracy and reliability of one's own memories. In experimental settings, memory monitoring is often assessed by having participants rate their confidence in the accuracy of their memories at the time of retrieving that information (Bryce et al., 2023; Gallo & Lampinen, 2015; for a review, refer to Fleming, 2024).

Grant et al. (2023) is one of the first studies to put forth a memory monitoring hypothesis to explain why bilinguals report fewer false memories in their less dominant language. Their

work draws upon the decision-making and foreign language effect literature to suggest using a less dominant language encourages more effortful over intuitive processes. To assess their memory monitoring hypothesis, Grant et al. (2023) tested Mandarin-English bilinguals in both languages in two language blocks on the DRM task and specifically asked participants to write down all the words that came to mind in two columns: (1) words they remembered from the list and (2) words that came to mind but were not in the original list. Participants reported the critical lure less often in the less dominant language, English, but also correctly monitored the critical lure more often in their less dominant language (Grant et al., 2023).

Building from Grant et al.'s (2023) memory monitoring hypothesis, the present study investigates memory monitoring from a metacognitive framework and tests the hypothesis that one's more explicit engagement with their confidence in the accuracy of their recollections may lead to decreased susceptibility to false memories.

Current Study

To date, there has been little work investigating the mechanisms driving the greater proportion of false memories in bilinguals' dominant language. Thus, the aim of the current work is to explore the relations between three proposed, but understudied, constructs (i.e., language proficiency, executive function, and memory monitoring) and rates of false memories among English-dominant bilinguals to provide support for a mechanistic model of memory intrusions in bilinguals.

It is hypothesized that participants with lower English language proficiency, higher executive functioning skills, and higher memory monitoring skills will have fewer false memories in English (their dominant language).

Methods

Participants

In the current study, undergraduate students (N = 23; aged 18 to 27 years; N_{female} = 14; N_{male} = 9) attending a mid-size, private university in the southeast United States were recruited for a 1.5-hour, in-person behavioral testing session. All participants self-identified as bilingual and reported English as one of their known languages. Only data from self-identified English-dominant participants (i.e., participants who—at the time of the study—self-reported either (1) English as their most dominant language, (2) engaging in English language use more frequently than any other known language, and/or (3) English as the language they would most likely choose to speak in) were included in the final analyses; this resulted in the exclusion of 5 participants. No restrictions were placed on participants' non-English language, so any individual expressing English dominance with any other non-English secondary language reported was included in this study. This approach allows for greater heterogeneity of the bilingual language profiles represented; however, it is also important to acknowledge that this an Anglocentric approach with a focus on interactions within English and a limited capacity to consider the unique cross-linguistic interactions appearing from the diverse language profiles represented. Results from the 18 English-dominant participants (M_{age} = 20.4; N_{female} = 11; N_{male} = 7) included in this study are outlined. The racial and ethnic demographics of the participants were Asian (N = 13), Hispanic (N = 6), and White (N = 3). Of the non-English languages spoken, Mandarin Chinese (N = 6), Spanish (N = 6), Korean (N = 4), Hindi (N = 2), and Cantonese (N = 1) were reported as primary or secondary languages used. Additional characteristics of the bilingual profiles represented can be found in Table 1. Participants provided informed consent

prior to participation and received course credit for participating. All study procedures were approved by an Institutional Review Board.

Table 1.
Language Characteristics of Participants (N = 18)

	English (Dominant Language) M (SD)	Non-English (Non-Dominant Language) M (SD)
Average Age of Acquisition	3.65 (1.62)	1.59 (2.67)
Average Percentage of Exposure	66.83% (16.79)	28.82% (16.77)
Average Percentage of Usage (Speaking)	57.18% (25.14)	39.53% (24.92)
Average Speaking Proficiency (0-10)	9.00 (.87)	8.59 (1.73)
Average Understanding Proficiency (0-10)	9.18 (.88)	8.76 (1.48)
Average Proficiency (0-10)	9.09 (0.88)	8.68 (1.56)

*Note: Across both the English (Dominant Language) and Non-English (Non-Dominant Language), the average percentages of exposure and usage may not add up to 100% across the two reported languages because some participants were multilingual speakers.

Materials

False Memories

Deese-Roediger-McDermott (DRM) Task. The DRM paradigm (Deese, 1958; Roediger & McDermott, 1995; Stadler et al., 1999) is one of the most cited examples of inducing spontaneous false memories. In the version used in the current study, participants were presented with six word lists consisting of 15 semantically-related words (e.g., bed, rest, awake, tired,

dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, and drowsy) that have been previously shown to reliably prompt individuals to think of the unpresented word (critical lure) that semantically links the entire word list (e.g., sleep; Roediger & McDermott, 1995; Coburn et al., 2021; Grant et al., 2023; Hume et al., 2009; Otgaar et al., 2016). Across the six word lists, the presented words (and the critical lures) did not differ in average word length or average word frequency (Length: *p*s > .05; Frequency: *p*s > .05; Balota et al., 2007). The semantic association (i.e., backwards associative strength) between the critical lure and the presented words also did not significantly differ across word lists (*p*s > .05; Roediger & McDermott, 1995). The word lists used in the current study were pulled from Stadler et al. (1999) and can be found in the Appendix.

Participants completed two blocks of the DRM task, each with three 15-word lists presented. For each word list, individual words were visually presented on the screen for two seconds, and participants were instructed to silently read and remember each word. After this encoding phase, participants completed simple addition math problems (e.g., 2 + 4, 6 + 3, etc.) using single-digit keypress responses as part of a one-minute buffer task to disrupt phonological rehearsal. After the distraction task, participants free recalled aloud the words they could remember from the previous list. Before completing the actual task, participants completed a brief practice of the task elements. Across the two blocks, the total proportion of lists in which participants incorrectly reported the critical lure was used to index the "False Memory Rate."

Language Proficiency

Language Experience Proficiency Questionnaire (LEAP-Q). The LEAP-Q (Marian et al., 2007; find the survey here https://bilingualism.northwestern.edu/leapq/) is a standardized language history survey that assesses an individual's language dominance, patterns of language

usage, and language proficiency. Responses on the LEAP-Q were used to index self-reported language dominance (used to ensure all included participants spoke English as a dominant language) and language proficiency (evaluated on a 0-10 point scale for speaking, understanding, and reading) in each of a participant's languages. Average self-reported language proficiency (taking the combined average scores of their self-reported English speaking and understanding proficiency) was used in study analyses.

Executive Function

Flanker Task. In the Flanker task (Eriksen & Eriksen, 1974), participants were presented with a series of five fish and were asked to press a key corresponding to the direction the center fish was facing. Congruent trials consisted of five fish all oriented in the same direction (e.g., > > > > >), whereas incongruent trials consisted of one centrally located fish oriented in the opposite direction of the flanking fish (e.g., > > < > >). On incongruent trials, participants must inhibit the competing response (e.g., selecting the key in alignment with most of the fish) to produce the correct response (e.g., selecting the key in alignment with *only* the central fish).

Before the test trials, participants completed two practice rounds. Of the 80 test trials, 75% were congruent and 25% were incongruent. Participants' reaction time on each trial was used to calculate the Flanker Effect, defined as an individual's average incongruent reaction time (IRT) minus their average congruent reaction time (CRT) on correct trials only (i.e., Flanker Effect = IRT – CRT). Prior to calculating the Flanker Effect, outlier trials in which a participant's reaction time was less than 250ms or greater than 3 standard deviations above their overall average reaction time on correct trials (collapsed across both conditions) were removed.

Memory Monitoring

Memory Confidence (MC) Task. In the MC task participants were presented with three word lists consisting of 15 words sharing no semantic overlap. Across the three word lists, the words did not differ in average word length or average word frequency (Length: *p*s > .05; Frequency: *p*s > .05; Balota et al., 2007).

Like the DRM task, for each word list, participants were visually presented with words one at a time each for two seconds and asked to silently read and remember each word. After this encoding phase, participants completed simple addition math problems (e.g., 2 + 4, 6 + 3, etc.) as a buffer task to disrupt phonological rehearsal. After the distraction task, participants were given a forced choice recognition task, in which they viewed 30 words (15 of which were presented in the encoding phase and 15 of which were novel words) one at a time and rated their confidence on whether each presented word was old or new. Participants had four options corresponding to a keypress response to rate their confidence in recognizing each word during the testing phase, including "Confident Old," "Confident New," "Unsure Old," and "Unsure New" (see Figure 1**)**. The side of the screen the "Old" and "New" responses appeared on was randomized between task versions (i.e., A or B) to better account for individual differences related to handedness. The proportion of correctly confident responses (regardless of whether the word was old or new) was used to index "Memory Monitoring."

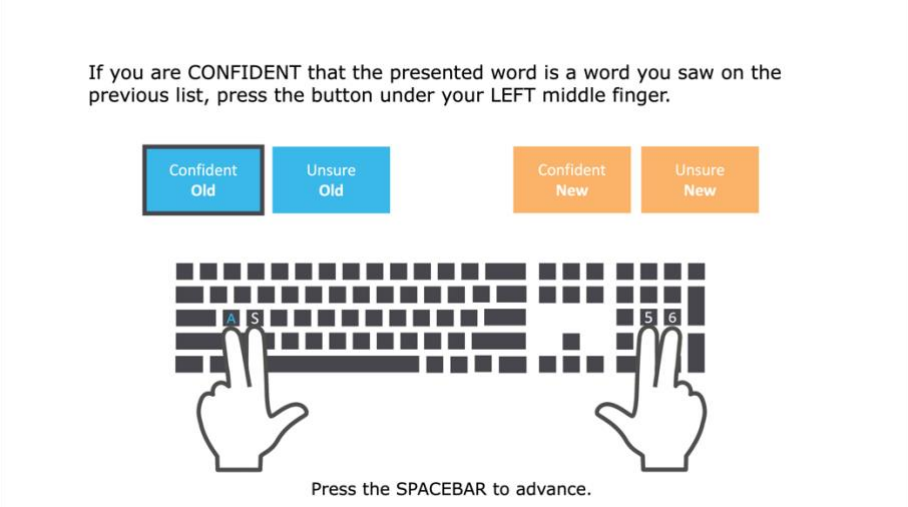

Figure 1. *Example instructions from the Memory Confidence (MC) task, illustrating the four potential response options.*

Analysis Plan

Four outcome variables were created: (1) False Memory Rate, (2) Executive Functioning, (3) Memory Monitoring, and (4) Language Proficiency. Correlational analyses, conducted in SPSS, were used to examine the relations between language proficiency, memory monitoring, and executive functioning with susceptibility to false memories in one's dominant language (English).

Results

Descriptive Statistics

False Memories. On average, across the six 15-word lists presented, participants recalled about half of the words correctly (mean = 0.51, standard deviation = 0.10) and reported the critical lure on about 25% of the DRM word lists (see Table 2).

Table 2.
Average Proportions of List Words Recalled (Hit Rate), Critical False Memories, and Noncritical False Memories (including noncritical words) (N = 18)

	Proportion Across all Lists	Proportion of Lists
Hit Rate	0.51	--
Critical False Memories	--	0.25
Noncritical False Memories (including noncritical intrusions*)	--	0.28

**Note: Noncritical False Memories including noncritical intrusions represent trials in which a participant reported either the critical lure and/or a word other than the critical lure that was not included in the original word list.*

Correlational Analysis

No significant relations were found between false memories and Language Proficiency,

Executive Functioning, or Memory Monitoring (see Table 3).

Table 3.
Correlations between False Memory Proportion with Average English Language Proficiency Flanker Effect, and Correctly Confident Responses,

	Language Proficiency: Average English Language Proficiency (N = 18)	Executive Function: Flanker Effect (N = 17)	Memory Monitoring: Proportion of Correctly Confident Responses (N = 18)
Critical False Memory Proportion	.26	- .08	- .18
Noncritical False Memory Proportion	.35	- .15	.03

*Note: Values are Pearson's r coefficients. * Significant at p < .05*

Language Proficiency and False Memories

It was predicted that individual differences in language proficiency would be positively correlated with false memories, such that those with higher language proficiency (as reflected by higher average self-reported English Speaking and Understanding scores) would show more false memories on the DRM task. The correlational analysis revealed no significant relation between language proficiency and false memories [*Critical False Memories:* $r(16) = .26$., $p = .297$; *Noncritical False Memories*: $r(16) = .35$, $p = .161$; see Figure 2].

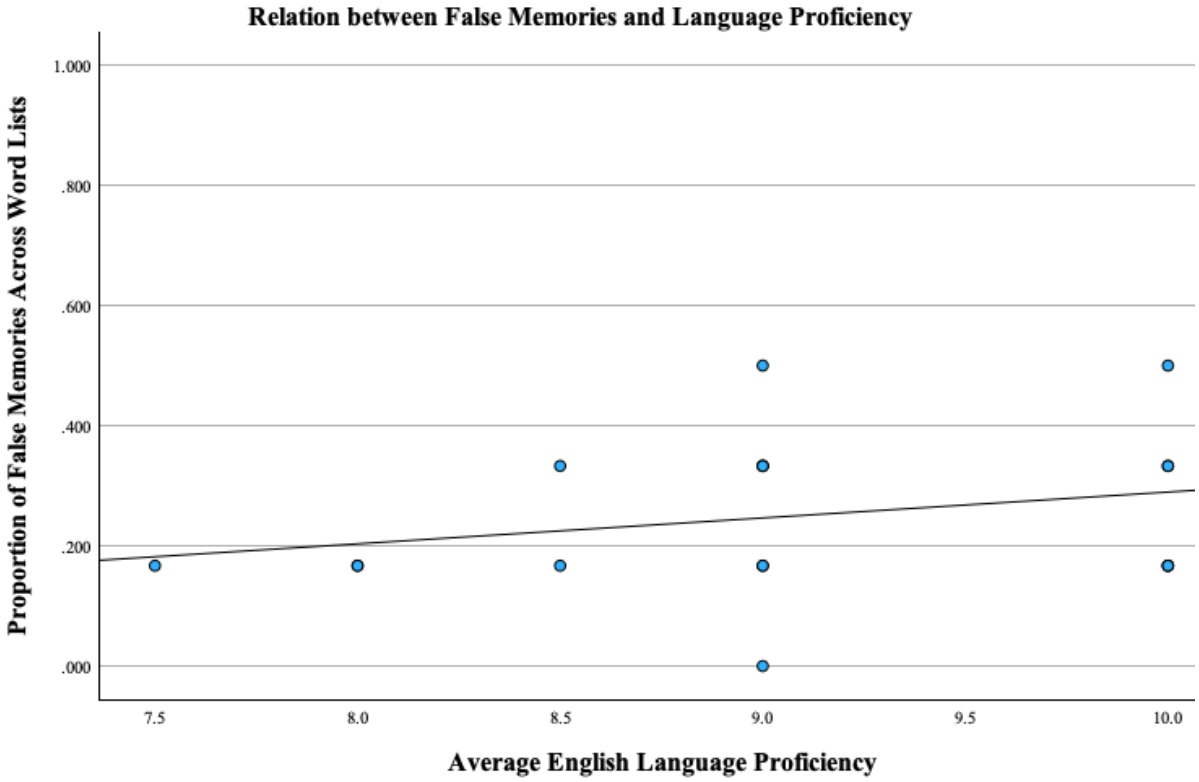

Figure 2. *Scatterplot of proportion of false memories and English language proficiency (as indexed by average of each participant's self-reported proficiency in understanding and speaking English on the LEAP-Q).*

Executive Function and False Memories

It was predicted that individual differences in the Flanker Effect would be positively correlated with false memories, such that those with higher executive functioning skills (as

reflected by smaller Flanker Effects) would show less false memories on the DRM task. For this analysis, data from one participant was excluded for having a Flanker effect more than three standard deviations from the mean Flanker Effect at the group-level. The correlational analysis revealed no significant relation between inhibitory control and false memories [*Critical False Memories:* $r(15) = -.08$, $p = .755$; *Noncritical False Memories*: $r(15) = -.15$, $p = .570$; see Figure 3].

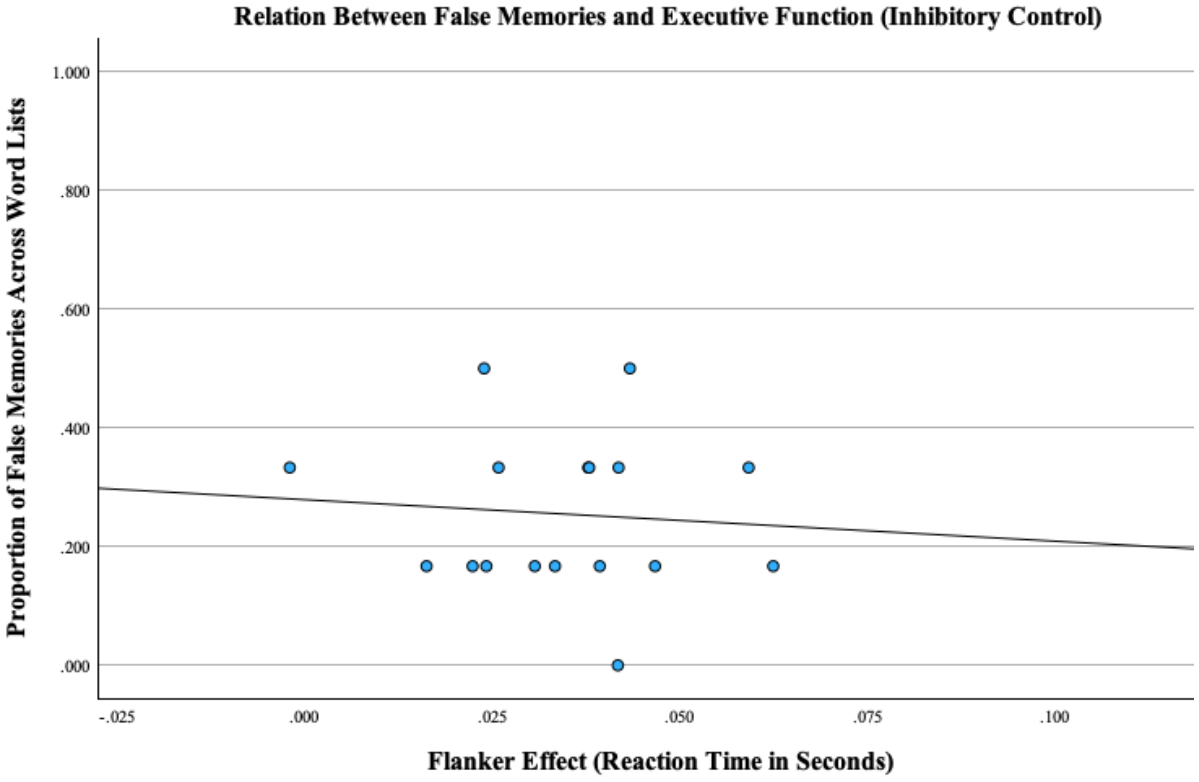

Figure 3. *Scatterplot of proportion of false memories and Flanker Effects (as indexed by the difference in reaction times on incongruent and congruent trials; e.g., IRT – CRT).*

Memory Monitoring and False Memories

It was predicted that individual differences in memory monitoring would be negatively correlated with false memories, such that those with higher memory monitoring skills (as reflected by more correctly confident responses) would show less false memories on the DRM

task. The correlational analysis found no significant relation between memory monitoring and false memories [*Critical False Memories: r*(16) = -.18, *p* = .468; *Noncritical False Memories*: *r*(16) = .02, *p* = .934; see Figure 4].

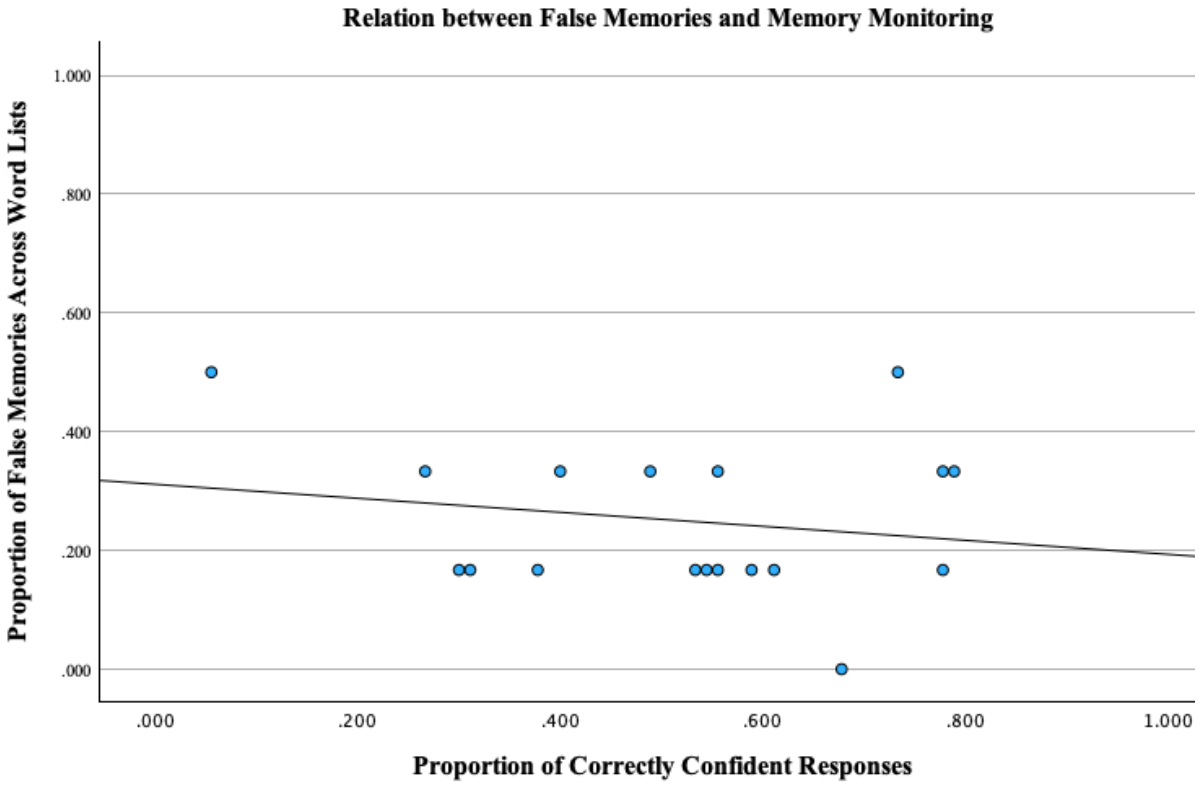

Figure 4. *Scatterplot of proportion of false memories and correctly confident memory judgments (as indexed by the proportion of correctly confident responses on the recognition task within the Memory Confidence task).*

Exploratory Analyses

All participants were recruited from an English-speaking university context, so it could be argued that for most of their day, participants are in an English-dominant environment. Therefore, the correlational analyses were repeated with all participants included (see Table 4).

Language Proficiency. It was predicted that individual differences in language proficiency would be positively correlated with false memories, such that those with higher language proficiency (as reflected by higher average self-reported English Speaking and

Understanding scores) would show more false memories on the DRM task. The correlational analysis revealed no significant relation between language proficiency and false memories [*Critical False Memories: r*(21) = .23., *p* = .286.; *Noncritical False Memories*: *r*(21) = .24, *p* = .268].

Executive Function. It was predicted that individual differences in the Flanker Effect would be positively correlated with false memories, such that those with higher executive functioning skills (as reflected by smaller Flanker Effects) would show less false memories on the DRM task. For this analysis, data from one participant was excluded for having a Flanker effect more than three standard deviations from the mean Flanker Effect at the group-level. The correlational analysis revealed no significant relation between inhibitory control and false memories [*Critical False Memories: r*(20) = -.09, *p* = .692; *Noncritical False Memories*: *r*(20) = -.21, *p* = .349].

Memory Monitoring. It was predicted that individual differences in memory monitoring would be negatively correlated with false memories, such that those with higher memory monitoring skills (as reflected by more correctly confident responses) would show less false memories on the DRM task. The correlational analysis found no significant relation between memory monitoring and false memories [*Critical False Memories r*(21) = -.29, *p* = .173; *Noncritical False Memories*: *r*(21) = -.08, *p* = .700].

Table 4.
Correlations between False Memory Proportion with Flanker Effect, Correctly Confident Responses, and Average English Language Proficiency for whole sample

	Language Proficiency: Average English Language Proficiency (*N* = 23)	Executive Function: Flanker Effect (Reaction Time in seconds) (*N* = 22)	Memory Monitoring: Proportion of Correctly Confident Responses (*N* = 23)
Critical False Memory Proportion	.23	- .09	- .29
Noncritical False Memory Proportion	.24	- .21	- .08

*Note: Values are Pearson's r coefficients. * Significant at p < .05*

Discussion

It was hypothesized that lower English language proficiency, higher executive functioning skills, and greater memory monitoring skills would be associated with fewer false memories in bilinguals' dominant language. Though none of the initial hypotheses were supported by the correlational analyses, the use of the DRM task to induce false memories was replicated from prior work, with participants in this study showing false memories on about 25% of the DRM word lists.

The findings presented here in no way invalidate the potential influence of language proficiency, executive function, or memory monitoring on susceptibility to false memories but instead suggest a need for further investigation and modification of techniques to assess the underlying relations mediating the increased susceptibility to false memories in bilinguals' dominant language. Redefining how we index and consider language proficiency, inhibitory control, and memory monitoring through more robust measures and a larger, more representative sample could demonstrate more clearly whether false memories may be related to any or all of

these mechanisms. The sections below outline methodological considerations for future studies aiming to further evaluate these (and other) potential mechanisms.

Heterogeneity of bilingual sample. While prior work investigating false memories among bilinguals has typically engaged cross-language comparisons to assess false memories within and across bilinguals' dominant and nondominant languages (e.g., Suarez & Beato, 2021), the present study only evaluated false memories within bilinguals' dominant language, English. By limiting the investigation to English-only, this study included a more diverse group of bilinguals as compared to previous work. However, one limitation of this approach is that confounding variables related to the unique nature of cross-linguistic interactions between each of the represented language systems may have influenced patterns of false memories observed in English (Angelis et al., 2017). By allowing any combination of English-dominant bilinguals to participate in the study, we provide a model for developing a more generalized approach to understanding nuances of false memories in bilinguals; however, in future work, this approach will need to be refined with more adequate balancing of the language groups represented to better address unique characteristics arising from diverse bilingual language profiles.

Characterizing language proficiency. By only using self-reported proficiency on the LEAP-Q to assess language proficiency, as in the current study, there are inherent limitations in the ability to represent true proficiency in a language. Within the survey itself, there are limited definitions of key terms (e.g., fluency, dominance, proficiency, etc.), and participants are instructed to give their best estimate, which may render more subjective responses from each participant's own experience that may not be equivalent to another participant's interpretation. Likewise, given language proficiency and language dominance are highly correlated, there may be insufficient variation in language proficiency with one's dominant language (e.g., in the

current study proficiency rating only ranged from 7.5 to 10 on a 0-10 point scale, see Table 1) to find a significant influence of individual differences within language proficiency on false memory propensity. Furthermore, while LEAP-Q responses have been correlated with behavioral measures of language proficiency (Marian et al., 2007), the strength of these correlations varies according to language dominance. Self-reported proficiency on the LEAP-Q has been found to be moderately-to-strongly correlated with behavioral measures of proficiency in one's second language (in the present study this may represent one's non-dominant, non-English language); however, these relations have been found to be weak-to-moderate for one's first language (in the present study this may represent one's dominant language, English; Kaushanskaya et al. 2019). Thus, the LEAP-Q may not be the best representation of language proficiency in one's native and/or dominant language, which was a key variable in the current study. Such limitations ground the need for adapting future approaches to indexing language proficiency to account for a more comprehensive assessment that may include both behavioral measures and self-report measures.

Indexing executive function as a construct. Executive functioning represents an umbrella term encompassing multiple sub-components related to higher-level cognitive functions that support goal-directed behavior, including working memory, inhibitory control, and task switching skills. As in the current study, measures of executive functioning often only represent one (or a few) domain-specific subcomponents of executive function (Cirino, 2023; Juardo & Rosselli, 2007). Assessing more subcomponents of executive function could have led to a more robust representation of executive functioning on which to investigate possible relations between false memory susceptibility and individual differences in these abilities.

Within studies finding decreased inhibitory control capacity being predictive of more false memories, researchers have typically used Stroop Tasks to index individual differences in executive functioning (Butler et al., 2004; Colombel et al., 2016; LaVoie et al., 2005; Yeung et al., 2020). While both the Stroop task and Flanker task (as was used in this study) are thought to index the same inhibitory control subcomponent, the former involves verbal interference and the latter involves spatial interference (Yeung et al., 2020). Given the DRM task and the Stroop task both involve linguistic cues, it is possible overcoming verbal interference in the Stroop task is more closely related to the linguistic associative memory illusions in the DRM task than overcoming spatial interference in the Flanker task is related to semantic false memories. As an alternative to more comprehensively assessing variability in executive functioning skills, future work could consider more specific tasks that have stronger overlap with the processes leading to false memories on the DRM task.

Operationalizing memory monitoring. Memory monitoring as a construct remains underdeveloped and inconsistently defined within the literature, which causes increased difficulty to replicate and generalize across studies. In addition, even within the memory monitoring task used in the current study, there were methodological limitations. For example, participants had only 1.5 seconds to respond to each recognition item; it is possible this fast pace caused participants to engage in more automatic, intuitive guesses rather than in deliberative, slower processing in line with our operational understanding of memory monitoring (Bryce et al., 2023; Gallo & Lampien, 2015; Goldsmith, 2015). Grant et al.'s (2023) study design eased this concern by incorporating a participant-paced, free recall modification to the DRM to more directly assess participants' ability to monitor out possible intrusions by having participants sort all words that came to mind into two lists: "On the list" and "Not on the list." Within studies

examining bilingualism and false memories, Grant et al. (2023) presents the first study to operationalize and find support for a memory monitoring hypothesis, in which participants were more successful in monitoring out false memories in their non-dominant relative to the dominant language. This finding is promising in terms of providing support for a potential mechanism driving the bilingual false memory effect. However, given the limited work in this space and the vast variation seen in the operationalization of memory monitoring, it is important to continue creatively thinking about how memory monitoring can be indexed, and, in particular, indexed independent of the DRM paradigm. Perhaps future iterations could feature the Metacognitive Awareness Inventory (Schraw et al., 2002) to gauge how participants think about their learning strategies, study habits, and language background generally. While introducing the Metacognitive Awareness Inventory (MAI) could introduce more self-report bias, taken together with a memory confidence judgment task, including the MAI in a future study may provide a more representative memory monitoring outcome variable that accounts for general monitoring practices beyond the study context.

Considering ecological validity. In considering the broader implications of this work, it is important to note that the DRM task does not readily map onto real-world cases where memory distortion may be present or influenced by additional factors like social influence and social contagion (Numbers, 2014; Patihis et al., 2018; Reysen, 2007). Starting with these laboratory-based false memory investigations is a first step towards understanding how language proficiency, executive function, memory monitoring, or other mechanisms may relate to false memories in bilinguals' dominant language, but more work is needed to understand how these mechanisms may contribute to false memories in more naturalistic environments.

Future work could incorporate more ecologically valid paradigms, such as the Misinformation Effect Paradigm (Calvillo & Parong, 2016; Loftus & Hoffman, 1989; see Chrobak & Zaragoza, 2012 for review), which involves a participant witnessing an event (typically through an audio recording or video), receiving misleading post-event information, and completing a memory assessment to see whether the individual's representation of the event incorporated false details. To date, few studies have investigated the nuances of bilingual malleability of memory within naturalistic contexts that feature more explicit misinformation to distort memory representations over time (Grant et al., 2023). By designing more studies that assess the extent to which misinformation becomes incorporated into an initial memory trace of a witnessed event, we may better understand mechanisms driving more everyday experiences of memory distortion among bilinguals.

Alternatively, additional approaches within the DRM task could also better index susceptibility to false memories. The present study does not account for false memories that may have been activated and rejected by the participant before and during the recall phase, as only critical lures participants reported aloud to the experimenter conducting the session were reported and considered in the present analyses. The DRM task can induce false memories both while the participant first encodes the list and while the participant recollects the word list, but the traditional design cannot differentiate the extent to which false memories arise from activation and monitoring during encoding or retrieval (Gallo, 2010). Perhaps incorporating a lexical decision task rather than a recall task could more implicitly assess the co-activation of critical lures during the encoding phase specifically. A lexical decision task would have participants decide as quickly as possible whether a string of letters is a real word or a non-word; by including the DRM critical lures on a task like this, one may be able to implicitly assess

spreading activation and co-activation effects by observing faster reaction times for those critical lure words (Perea & Rosa, 2002).

Broader Implications and Consideration

Examining Individual Difference Among Bilinguals to Diversify Psychology Research

With an increasing global population of people routinely using at least two or more languages, it is important to ground our understanding of individual differences in how bilinguals reconstruct their reality in memory (Ardila, 2007). While it is beyond the scope of this study to precisely define bilingualism, the present study is intentional in addressing individual differences among bilinguals as a means of better contextualizing a population whose intersectional identities have often been left underacknowledged and underdeveloped in research spaces (Cole, 2009; Suarez & Beato, 2021). However, by only assessing English-dominant bilinguals, the present study cannot be generalized to better understand the experiences of non-English speakers, which contributes to a historical overvaluing and overrepresentation of the English language in research. We recognize assessing only English-dominant bilinguals as a serious limitation that involves this study in the historical elevation of English language research over more linguistically diverse investigations. Future research studies could better address the role of individual differences related to false memory creation across more diverse linguistic profiles to avoid perpetuating an Anglocentric research model.

Though the current exploration of the role of language proficiency, executive function, and memory monitoring among bilinguals did not provide support that individual differences within these constructs relate to the varied expression of false memories, the work does decenter monolingualism to consider the dynamic and diversified interactions at play within bilingualism, itself. Historically, research investigating bilingualism has adopted monolingual hegemonic

lenses that position bilinguals relative to monolinguals, who have been considered the standard or norm through these comparisons (López et al., 2023; Ortega, 2018; Vaid & Meuter, 2016, 2017). Therefore, the current study intentionally sought to engage bilinguals as a diverse population with unique individual differences contributing to dynamic and varied lived experiences that can be investigated without a formal comparison or binary interpretation related to monolingualism.

While this study is limited in its exploration of those with intersectional identities who may additionally identify as bilingual (e.g., only featuring participants who identify as cisgender female and male, having only three racial and ethnic groups represented, only featuring English-dominant bilinguals, etc.), future efforts to enumerate individual differences should adopt more intersectional frameworks to guide recruitment strategies and research practices to ensure research reflects the dynamic and diverse lived experiences of people from traditionally underrepresented identities for better understanding and generalizability (Backer & Bortfeld, 2021). The current study joins the broader call to action for more considerations for psychological research approaches that elevate the inclusion and centering of intersectional identities in developing research questions, recruiting research participants, and analyzing study generalizability. Within the current study's particular context addressing false memories as they vary among bilinguals, we hope future research efforts will continue to examine the unique characteristics different bilingual people have to develop a more robust understanding of how cognitive functions vary among bilinguals to influence the expression of their malleable memories.

Domain General Mechanisms Driving False Memory Creation

While the current study finds value in assessing individual differences in false memories within bilinguals' dominant language on the DRM task, prior works have investigated differences among monolinguals and bilinguals to suggest the mechanisms underlying false memory creation may be domain-general but influenced by unique linguistic characteristics. Bialystok et al. (2020) found bilinguals (speaking English and one of five other languages: Cantonese, French, German, Mandarin, and Spanish) tended to report the same correct recognition of studied items, fewer semantic false memories, and more phonological false memories relative to monolinguals. Their study highlights the unique individual differences that mediate false memory expression, particularly highlighting how enhanced differences in language processing (i.e., more phonological activation of words with similar sounds among bilinguals, perhaps enhanced ability to select from activated lexical representation among bilinguals, etc.) relate to different false memory rates. In particular, Bialystok (2020) suggests bilinguals experience a coactivation of all languages known in everyday life where they must suppress competing language cues to respond in the most appropriate language for a given context (Green, 1998; Hilchey & Klein, 2011; Linck et al., 2008). Thus, bilingual individuals may have a heightened ability to allocate cognitive control functions to suppress interfering ideas and cues to promote the individual's goals in each moment, which may explain why some studies have found bilinguals have fewer semantic false memories on the DRM task than monolinguals. Future work could continue investigating individual differences in false memory expression among bilinguals to develop a generalized understanding of the nuances influencing bilingual memory distortions or memory distortions in general.

An Adaptive Perspective of False Memory

The aim of this study was to explore individual differences in susceptibility to false memories, and while the term 'false memory' may appear negative on its surface, it is important to note how the process underlying false memory creation can serve as an adaptive feature of memory. This adaptive feature allows one to extract overall meaning or gist, facilitating connections to prior knowledge and personal elaboration when encoding new information (Schacter, 2012, 2022). Such ability to extract meaning from presented information reflects a crucial step in the process of generalizing and abstracting information for ongoing retention and application in new contexts (Brainerd & Reyna, 2005; McClelland, 1995; Schacter, 1999, 2012, 2022) and is related to better memory for relevant information in the long term and for more flexibly in applying these memories as we learn and engage with new information (Goldsmith, 2015; Schacter et al., 2011; Schacter & Slotnick, 2004). Dewhurst et al. (2011) found that performance on tasks measuring convergent thinking is associated with the proportion of false memories reported on the DRM task, which suggests the associative mechanisms responsible for the false memories produced on the DRM task may relate to an individual's ability to creatively engage with and generate broad associations in an adaptive manner. While the links between DRM performance and adaptive constructions of associative memory have not been studied substantially, these findings further the discourse that an "imperfect" memory that allows for flexibility and personal elaboration may be an adaptive feature of our reconstructive memories rather than a flaw.

Conclusion

Though the present study is limited in its ability to discuss mechanisms related to memory intrusions in bilinguals' dominant language, further work continuing to investigate

individual differences in executive function, memory monitoring, and language proficiency may contribute to a more nuanced understanding of individual differences in false memories among bilinguals. The present study is among the first to evaluate the potential role of individual differences in language proficiency, executive function, and memory monitoring on false memories, all within the same study. Despite the lack of significant findings, the results of this study still further our understanding and serve as a foundation for fostering new ideas to address individual differences affecting false memory creation within bilinguals' dominant language. Future studies should better leverage and address diverse, heterogeneous bilingual language profiles outside of an English-centric framework to ground more generalizable understandings of bilinguals' malleable memories. As the malleability of our memories applies to broader lived experiences, the flexibility of our memories to generalize and abstract information in personally relevant ways enhances our ability to remember details and associations that construct and reconstruct our lived experience and identity. Therefore, further research on the mechanisms underlying memory reconstruction is necessary to broaden our understanding of our associative, malleable memories.

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Appendix

The Six 15-Word Lists and Their Associated Critical Lures

Critical Lure	Word
Bread	butter food eat sandwich rye jam milk flour jelly dough crust slice wine loaf toast
Car	truck bus train automobile vehicle drive jeep Ford Race keys garage highway sedan van taxi
Cold	hot snow warm winter ice wet frigid chilly heat weather freeze

	air shiver Arctic frost
Music	note sound piano sing radio band melody horn concert instrument symphony jazz orchestra art rhythm
Smell	nose breathe sniff aroma hear see nostril whiff scent reek stench fragrance perfume salts rose
Window	door glass pane shade ledge sill house open curtain frame view breeze

	sash screen shutter