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Relationship between Trait Mindfulness and False Memory: A Bilingual Deese-Roediger-McDermott Paradigm

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Abstract Mindfulness-based interventions are known to increase false memory. However, high trait mindfulness is associated with an external encoding style and field independence, which in turn are associated with low false memory. The present study used a bilingual context to disentangle these contrasting findings. Sixty Chinese-English bilinguals completed a Deese-Roediger-McDermott (DRM) false recognition task and were evaluated using the Mindfulness Attention Awareness Scale (MAAS). Results showed negative and positive correlations between trait mindfulness and false recognition in Chinese-Chinese and Chinese-English conditions, respectively. The polar directions of the observed correlations suggest that trait mindfulness is associated with direct and analytical perception of objects and with cognitive flexibility in activating semantic information. The former improves source monitoring, whereas the latter increases the likelihood of generating false memories in the DRM paradigm.

Keywords Mindfulness, Bilingualism, False Memory, Fuzzy-Trace Theory, Memory Sensitivity

1. Introduction

1.1. Mindfulness and its Essential Components

The concept of mindfulness originates from the Buddhist tradition. The original Pali term for mindfulness is *sati*, which means "to recall" and "to bear in mind." In the Buddhist tradition, mindfulness is cultivated as a path to the cessation of mental suffering. From the 1980s, traditional mindfulness practices have been reformed for therapeutic use in medical settings [17, 36]. Although mindfulness is considered a mental state that can be achieved through practice, it is also recognized as a personal disposition that indicates the time span spent in a mindful state on a daily basis [4]. A recent study suggests that the continual practice of mindfulness can lead practitioners from state mindfulness (i.e., an immediate experience of being mindful) to long-term trait mindfulness (i.e., a general disposition of being mindful) [19].Several mindfulness-related scales, such as the Five Facts Meditation Questionnaire [2], the Kentucky Inventory of Mindfulness Skills [2], and MAAS [4], have been developed to assess the psychological constructs of mindfulness. Despite the constructs among these scales are not consistent, scholars generally agree that mindfulness has at least two essential components: (1) self-regulation of attention, which is characterized by observing and attending to internal and external experiences on a moment-to-moment basis and (2) an attitude of non-judgment and openness to the current experience [3].

1.2. Mindfulness and True Memory

The development of mindfulness is associated with an improvement in various cognitive abilities such as sustained attention [40], selective attention [14], and executive function [44]. However, few studies have demonstrated an overall positive effect of mindfulness training on memory performance. For instance, the practice of mindfulness improves long-term free recall [27], autobiographical memory specificity [11, 41] and episodic memory of visual images [4]. Although these studies have reported improved memory after mindfulness training, they have tested only true memory.

Although the aforementioned studies indicated that mindfulness is associated with an improvement of true memory, but no consensus exists on the relationship between mindfulness and false memory. Two recent studies have reported increased false memory in a DRM paradigm task after mindfulness training [42,35], whesreas others indicate otherwise [8, 10, 12, 25].

1.3. Effect of Mindfulness on False Memory

In a typical DRM paradigm [34], participants study several word lists and are subsequently required to retrieve them during a test. The words in each list are semantic associates of a non-presented critical lure. False memory is exhibited when critical lures are falsely recalled.

1.3.1. Mindfulness Induction Increases False Memory

Wilson et al. [42] were the first to examine the relationship between mindfulness and false memory. In their second experiment, participants were assigned to a mindfulness (15-min breathing meditation) or mind-wandering (freely think about whatever comes to mind) condition. The DRM false memory task was administered before and after the induction of the mindfulness or mind-wandering condition. Results showed that participants who were assigned to the mindfulness condition recalled significantly more critical lures after induction than before induction. By contrast, participants who were assigned to the mind-wandering condition recalled equivalent numbers of critical lures before and after induction. Accordingly, Wilson et al. concluded that the nonjudgmental aspect of mindfulness eliminates the memory trace related to the cognitive operation of internally generated information. Thus, participants who receive mindfulness-based interventions could be more vulnerable to false memory.

Additionally, Rosenstreich [35] published a study examining the effect of mindfulness-based interventions on false memory. He originally hypothesized that mindfulness-based interventions increase true memory and reduce false memory. However, both experiments—one using a 5-week mindfulness-based intervention and the other using a short mindfulness induction—showed increased false recognition after practicing mindfulness. Rosenstreich did not attribute the underlying mechanism of these findings to the nonjudgmental aspect of mindfulness but rather suspected that increased semantic activation might be responsible for the high false memory.

1.3.2. High Trait Mindfulness Associates with Low False Memory

Encoding style refers to an individual's tendency to perceive stimuli as they are or by using the individual's own interpretative schemata [23]. People with an internal encoding style develop perceptions based on their expectations. By contrast, people with an external encoding style rely more on perceptual features. Currently, two studies have shown that trait mindfulness is associated with the external encoding style, which in turn is associated with decreased source-monitoring errors [12, 10]. Herndon [12] reported that participants with high trait mindfulness, as measured by MAAS, were more likely to adopt the external encoding style. In addition, Dehon et al. [10] argued that participants with the external encoding style were less likely to recall critical lures because of successful source monitoring. The combined findings of Herndon [12] and Dehon et al. [10] suggest that high trait mindfulness leads to fewer source-monitoring errors in the DRM paradigm.

Field independence refers to an individual's cognitive ability to analytically perceive stimuli and ignore distractions. Similarly, a typical mindfulness-based intervention requires practitioners to be aware of the present moment and ignore distractions. Linden [25] investigated whether mindfulness-based interventions could improve trainees' field independence. In his study, children who performed a mindfulness-based intervention (i.e., breathing meditation) showed high field independence. In a more recent study, college students who were categorized as field independent demonstrated lower false recall and false recognition than did those who were categorized as field dependent [8]. Consequently, combined findings from these two studies suggest that mindfulness is associated with low false memory.

Accordingly, we can conclude that high trait mindfulness is associated with low false memory. However, this conclusion is contradicted by findings from studies on mindfulness-based interventions [42, 35]. We propose that being nonjudgmental should not reduce one's discriminability, because an essential component of the practice of mindfulness is increased attentiveness to sensory and perceptual stimuli and experiences. Additionally, greater awareness to perceptual stimuli might be beneficial for source monitoring because memories of actual experiences usually possess rich perceptual details [16, 26].Therefore, individuals who are more attentive to perceptual stimuli might be more likely to retrieve perceptual details for validating or invalidating their memories.

Moreover, these contradictory findings should not be attributed to the differences between trait mindfulness and mindfulness interventions because mindfulness interventions also result in high trait mindfulness [19]. Alternatively, two plausible reasons for these contradictory findings are as follows. First, the main underlying mechanism for the false memory phenomenon in the DRM paradigm is the increased activation of semantic information; thus, high false memory might reflect the improved ability to activate related semantic information after mindfulness induction [35]. Second, the free recall and old-new recognition tasks used in previous studies have a relatively low source-monitoring requirement, which may increase the likelihood of generating false memories because of semantic familiarity.

1.4. Increased Semantic Activation Boosts False Memories

One of the theoretical frameworks of false memory in the DRM paradigm is the fuzzy-trace theory (FTT) [33]. According to FTT, there are two types of memory traces: verbatim traces, which represent the perceptual details of an item, and gist traces, which represent the semantic information that is common between list items and critical lures. The verbatim and gist traces work together to generate true memory. With regard to false memory, the repeated

activation of gist information leads participants to accept critical lures as studied items, whereas the activation of verbatim information helps participants to exactly remember studied items and contexts and to reject critical lures.

Because increased activation of related semantic information is the primary cause of false memory, individuals who can activate more or stronger related semantic information may generate higher false memory. An 8-week mindfulness-based intervention improved participants' performance in a semantic fluency task [11]. Similarly, another study demonstrated that participants with memory loss showed improved semantic fluency after mindfulness-based interventions [31]. In a typical semantic fluency test, participants are given 1 min to name as many words as possible within the same semantic category (e.g., animal). Because mindfulness-based interventions can improve participants' ability to activate related semantic words, the high false memory reported by Wilson et al. [42] and Rosenstreich [35] may actually reflect an improved ability to activate related semantic information.

1.5. Low Source-Monitoring Requirement Increases False Memories

Another factor that may account for high false memory is the memory task. In two studies [42, 35], participants were either required to demonstrate free recall in a one-source condition or to make an old-new judgment on test words. Free recall was associated with higher false memory in the one-source condition than in the two-source condition, suggesting that a low source-monitoring requirement increases false memories [13]. Furthermore, the old-new judgment measure has a lower differentiation requirement than does a source-specific monitoring measure [16]. For example, a major research question in the field of bilingual memory is the extent to which false memories can occur when the study and test languages are different. Although some studies have shown that the recognition of critical lures is decreased when the study and test languages are different [6, 18, 37, 28], other studies have shown the opposite [15, 30]. After carefully examining their task procedures, Mao, Wang, and Kang [29] identified that studies reporting high false memory in the cross-language condition had adopted the old-new recognition measure (e.g., respond "old" to a test word regardless of which language it appears in), whereas studies reporting low false memory in the cross-language condition adopted a language-specific recognition measure (e.g., respond "old" to a test word only when it appears in the same language). The aforementioned findings suggest that source-specific monitoring measures could make participants more attentive to the encoding context and therefore reduce false memories.

1.6. Main Hypotheses of the Present Study

The present study investigated the relationship between trait mindfulness and false memory. According to the abovementioned literature review, we hypothesized that trait mindfulness might be associated with high or low false memory due to distinctive underlying processes. Trait mindfulness is associated with individuals' abilities to perceive stimuli completely and analytically; simultaneously, trait mindfulness is associated with individuals' abilities to activate related semantic information. The former process decreases and the latter one increases false memory. To disentangle these two processes, the present study was conducted in a bilingual context in which the study and test languages were either the same or different. Studies have shown that bilinguals have separate lexical representations for each language and share the same semantic representations [20].Therefore, conducting a study in a bilingual context allowed us to separate the effects of verbatim and gist information. We hypothesized that when the study and test languages are the same, list items share both verbatim and gist information, whereas critical lures share only the gist information between the study and test conditions. Thus, participants can use verbatim information to compete with gist information for decreasing source-monitoring errors. Moreover, as people with high trait mindfulness are more attentive to perpetual features, they are even more capable of utilizing verbatim information to reduce false memory. Conversely, when the study and test languages are different, neither list items nor critical lures share verbatim information between the study and test conditions. Thus, participants can only rely on gist information to make a recognition decision. Accordingly, because mindfulness is related to the increased activation of semantic commonalities, people with high trait mindfulness are prone to increased false memories.

2. Research Method

2.1. Participants

Table 1. Participants' language background

Language	Chinese	English
Average Age of Acquisition (year)	3.1	7.6
Average Self-Report Proficiency[1]		
Reading	5.6	5.2
Writing	5.3	4.7
Speaking	5.7	4.7
Listening	5.7	5.1

[1]. On a scale of 1-7

A total of 73 Chinese-English bilingual students majoring

in English from a university in Taiwan were recruited. All participants completed a language history questionnaire (LHQ) [24]. To ensure that participants had a homogenous language-learning experience, foreign and domestic students who had lived in English-speaking countries for longer than a year were excluded. Thus, data of 60 participants were included in the statistical analyses. Table 1 provides a summary of the participants' language background. Paired comparisons showed that participants learned Chinese earlier ($t(59) = -13.3$, $p < .01$) and were more proficient in Chinese, as measured by the aggregated rating for the four language skills ($t(59) = 2.0$, $p = .05$).

2.2. Materials

2.2.1. DRM Word Recognition Task: List Items in the Study Phase

In total, 24 English wordlists were extracted from Stadler, Roediger, and McDermott [38], and their Chinese equivalents were extracted from Lee et al. [22]. These word lists were selected because they had false recognition rates higher than 59% for each language [22]. Each word list consisted of 15 items. To ensure that our participants knew all the English words, another group of 40 Chinese-English bilinguals were first asked to translate all the items in each list. From each word list, only the first 10 correctly translated English words were chosen for the experiment. The average correct translation percentage was 94%. The 24 word lists were divided into 2 sets. The first set was presented in Chinese to half the participants and in English to the other half. Participants who were first presented the Chinese set were then presented the English set and vice versa.

2.2.2. DRM Word Recognition Task: List Items in the Test Phase

The items in the test phase consisted of 144 words divided into 3 categories: studied items, critical lures, and new items. A total of 72 studied items were obtained by extracting the first, eighth, and tenth items from each of the 24 lists. Among these items, 36 were in English, with 18 each from lists studied in English and Chinese. The other 36 studied items were in Chinese, with 18 each from lists studied in English and Chinese. A total of 24 critical lures that were semantically associated with each list were included. Of these lures, 12 were in English: 6 each from lists studied in English and Chinese; the other 12 critical lures were in Chinese: 6 each from lists studied in English and Chinese. A total of 48 new items were unrelated new words: 24 each in English and Chinese.

2.2.3. Chinese Mindful Attention Awareness Scale (CMAAS)

The MAAS is a 15-item unidimensional scale used to measure individuals' natural tendency to be attentive to or aware of present-moment experiences in daily life [4]. In the present study, we used the CMAAS to examine participants' trait mindfulness. According to Chang, Lin, and Huang [7], the CMASS has high internal consistency ($\alpha = .88$) and 8-week test-retest reliability ($r = .75$). The reason of using MASS is twofold. Firstly, the present moment attention or awareness is highly relevant to the quality of encoding which is crucial for the correct retrieval. Secondly, MAAS was used in Herndon [12] and Brown & Ryan [5] respectively. Therefore, in order to make our study more comparable with previous studies, the same questionnaire was selected.

2.3. Procedure

The DRM word recognition task was programmed using E-prime 2 [32]. Participants were tested individually. The words were presented visually in the study and test phases. At the beginning of each list, participants saw the instruction "get ready for list X" on the computer screen, where X corresponded to the list number (1-24). Each word appeared on the screen for 1500 ms. Immediately after the study phase, participants entered the test phase. For each item, participants had to press 1 (studied) or 2 (unstudied) to indicate whether or not they had seen that exact same word, in the same language, in the study phase. Participants were instructed to respond as spontaneously and accurately as possible. After completing the DRM word recognition task, participants completed the CMAAS and LHQ. The entire experiment was completed in approximately 60 min.

3. Results

3.1. Adjusted Recognition Rate and Trait Mindfulness

Table 2 shows participants' recognition rates in all conditions. To account for baseline differences in recognition (i.e., the spontaneous false recognition of new items), an adjusted recognition score was calculated by subtracting the recognition of list items and critical lures from the recognition of new items. In the within-language condition, a 2 (item type) × 2 (study-test language) repeated measures analysis of variance (ANOVA) was performed. This analysis yielded significant main effects for item type ($F(1,59) = 129.23$, $p < .01$, partial $\eta^2 = .69$) and study-test language ($F(1,59) = 6.5$, $p < .05$, partial $\eta^2 = .1$). The main effects for item type and test language were also qualified by an interaction ($F(1,59) = 80$, $p < .01$, partial $\eta^2 = .55$).Simple effect analysis indicated that participants demonstrated a higher recognition of list items in the English-English condition than in the Chinese-Chinese condition [70 vs..60, $p < .01$, 95% confidence interval (CI)for difference = [.06, .15]). Participants also showed a higher recognition of critical lures in the Chinese-Chinese condition than in the English-English condition (.44 vs .21, $p < .01$, 95% CI for difference = [.15, .31]).

Moreover, in the cross-language condition, a similar 2 (item type) × 2 (study-test language) repeated measures ANOVA was performed. This analysis yielded significant main effects for item type ($F(1,59) = 43.5$, $p < .01$, partial

η^2= .43) and study-test language (F(1,59) = 17.8, p < .01, partial η^2= .23). Additionally, these two main effects were qualified by an interaction (F(1,59) = 21.3, p < .01, partial η^2= .27). Simple effect analysis showed that participants were more likely to recognize list items as "old" in the English-Chinese condition than in the Chinese- English condition (.43 vs. .24, p < .01, 95% CI for difference = [.14, .26]). However, the recognition of critical lures did not significantly differ between the English-Chinese and Chinese-English conditions. The aforementioned results suggest that the list items in one language activated related semantic representations, which in turn increased the probability that bilinguals would falsely recognize their translation equivalents and associated critical lures in the other language.

Table 2. Mean recognition rates for list items, critical lures, and new items

	Study-test language condition	
Within-language	Chinese-Chinese	English-English
List items	.69	.82
Critical lures	.53	.33
Cross-language	English-Chinese	Chinese-English
List items	.52	.36
Critical lures	.24	.27
	-Chinese	-English
New items	.12	.09

Table 3. Correlations between CMAAS scores and adjusted recognition rates in study-test language conditions

	Study-test language conditions	
Within-language	Chinese-Chinese	English-English
List items	.14	.33***
Critical lures	-.21*	-.09
Cross-language	Chinese-English	English-Chinese
List items	-.11	.08
Critical lures	.26**	.14

*p < .10, **p < .05, ***p < .01

To examine whether trait mindfulness was related to participants' recognition performance, we calculated Pearson correlations between the CMAAS scores [mean=59, standard deviation (SD) =9.8] and recognition rates in all study-test language conditions (Table 3). Overall, the results showed a significant positive correlation between trait mindfulness and the recognition of list items when the study and test languages were both English (r = .33, p < .05). Most importantly, trait mindfulness was positively correlated and marginally negatively correlated with the recognition of critical lures in Chinese-English (r = .26, p < .05) and Chinese-Chinese (r = −.21, p < .10) conditions, respectively. The abovementioned results support our hypothesis that trait mindfulness is related to source monitoring. Participants with higher trait mindfulness also generated more correct recognition of English list items in the within-language condition. More critically, the relationship between trait mindfulness and false recognition is dependent on the language context in the study and test phases.

3.2. Memory Sensitivity, Response Bias, and Trait Mindfulness

The memory sensitivity index (d') was used to examine how easily participants could differentiate a target stimulus (i.e., list item) from background noises (i.e., critical lures). The d's in within- and cross-language conditions conveyed different meanings. In the within-language condition, the recognition of list items measured a combination of semantic and surface information, whereas the recognition of critical lures measured only semantic information. Therefore, d' measured the likelihood of participants applying surface information to differentiate internally generated representations from externally presented items. Conversely, in the cross-language condition, both the recognition of list items and critical lures measured semantic information; therefore, the d' measured the extent to which participants were likely to be fooled by list items than by critical lures because of the higher association between translation equivalents. Response bias (C) was used to examine the extent to which one type of response was preferable (i.e., "studied" versus "unstudied"). C is independent of memory sensitivity. An unbiased C-score is zero. Positive C-scores represent the preference for responding "unstudied," and negative C-scores represent the preference for responding "studied."

Table 4 shows the signal detection analyses of d' and C in different study-test language conditions. In the separate examination of within- and cross-language conditions, participants showed higher d' when the study language was English than when it was Chinese (within-language: 1.8 vs. .38, t(59) = 7.9, p < .01; cross-language: 1.0 vs. .48, t(59) = 2.8, p < .01). These result indicated that participants were capable of differentiating list items from critical lures when English items were presented at the study. C was examined by a 2 (study language) × 2 (test language) repeated ANOVA. This analysis yielded a significant interaction between the study and test languages(F(1,59) = 7.7, p < .01, partial η^2= .12). Simple effect analysis indicated that when the study language was Chinese, participants showed higher C-scores if the test language was English (.72 vs. −.36, p <.01, 95% CI for difference = [.85, 1.30]). Similarly, when the study

language was English, they showed higher C-scores if the test language was Chinese (.53 vs. −.21, p<.01, 95% CI for difference = [.51, .99]). These results indicated that participants preferred to respond "unstudied" to list items and critical lures in the cross-language condition compared to those in the within-language condition. This result is expected because "unstudied" is the correct response for both list items and critical lures in the cross-language condition.

Table 4. Signal detection analyses of d' and C in different study-test language conditions

Within-language				Cross-language			
Chinese-Chinese		English-English		Chinese-English		English-Chinese	
d'	C	d'	C	d'	C	d'	C
.38	-.36	1.8	-.21	.48	.72	1.0	.53

Table 5 shows the correlations between CMAAS scores (mean = 59, SD =9.8), d', and C in all study-test language conditions. Overall, the results showed a significant positive correlation between trait mindfulness and memory sensitivity when the study and test languages were both Chinese. However, when the study language was Chinese and the test language was English, trait mindfulness and memory sensitivity were negatively correlated. Moreover, participants' trait mindfulness was not associated with C in any study-test language conditions.

Table 5. Correlations between CMAAS scores, English semantic fluency, and d' and C in study-test language conditions

	Within-language				Cross-language			
	Chinese-Chinese		English-English		Chinese-English		English-Chinese	
	d'	C	d'	C	d'	C	d'	C
CMAAS	.26**	.09	.17	-.01	-.35***	-.04	-.05	-.09

*p<.10, **p<.05, ***p<.01

4. Discussion

The present study investigated the relationship between trait mindfulness and false memory, so the following discussion will address this topic first and then discuss bilingual false memory in general. We identified negative and positive correlations between trait mindfulness and the recognition of critical lures in the Chinese-Chinese and Chinese-English conditions, respectively. Such correlation patterns support our hypothesis that mindfulness could be related to false memory through distinctive processes. Trait mindfulness is associated with participants' ability to perceive objects directly and analytically. Therefore, participants with high trait mindfulness remember more verbatim information because of increased source monitoring. By contrast, trait mindfulness is associated with participants' ability to activate related semantic information. Thus, participants with high trait mindfulness activate more gist information, which may contribute to true and false memory. These arguments can be applied to the results of our current bilingual DRM task as follows. When the study and test languages were the same, both verbatim and gist information was available. Thus, participants with higher trait mindfulness were more likely to use verbatim information to compete with the highly activated gist information for decreasing the recognition of critical lures. However, when the study and test languages differed, verbatim information acquired during encoding was no longer effective, and only the gist information was available. Therefore, participants with high trait mindfulness used the highly activated gist information to increase the erroneous recognition of critical lures.

However, the pattern of polar correlations between trait mindfulness and the recognition of critical lures was only observed in conditions where Chinese was the study language. Inconsistent results were identified in conditions where English was the study language. Additionally, trait mindfulness was positively correlated with the true recognition of list items when English was used in both study and test. We propose that such a lack of correlations between trait mindfulness and false recognition (when the study language was English) and the positive correlation between trait mindfulness and true recognition (when English was used in both the study and test) could be explained using the revised hierarchical model (RHM) [20]. In the RHM, the processing of unbalanced bilinguals' first language and second language are asymmetric in the sense that only the first language can directly access semantic representations, whereas the second language primarily accesses semantic representations through word associations with the first language at the lexical level. Therefore, the lack of association between trait mindfulness and false recognition in both the English-English and English-Chinese conditions might be because only a small amount of semantic representations was activated during the study phase. Accordingly, the effect of trait mindfulness would be less salient. By contrast, because processing of the second language for unbalanced bilinguals is primarily at the lexical level, participants with high trait mindfulness are better at using surface information to increase their true recognition of list items.

The results on memory sensitivity confirmed our findings on recognition rates. Participants with high trait mindfulness demonstrated high memory sensitivity when the encoding and retrieval contexts were both in Chinese. However, they showed decreased memory sensitivity when the encoding and retrieval contexts were shifted from Chinese to English. Moreover, trait mindfulness did not affect memory sensitivity when the encoding and retrieval contexts were both in English. The finding of mindfulness and memory sensitivity is in line with the other study in which state

mindfulness was positively related with memory sensitivity (A') of *remember* judgment and people who received short mindfulness induction also demonstrated higher memory sensitivity of *remember* judgment than people from the control group did [4]. In term of the underline mechanism, they have found that mindfulness is related with intrinsic motivation to engage in the present activities which may in turn increase encoding quality.

The correlations between mindfulness and C were not significant in all four study-test language conditions, suggesting that participants with high trait mindfulness did not adopt a more liberal C. This finding is different from the results of Wilson et al. [42] and Rosentreich [35], who reported that participants showed a higher preference for responding "studied" after the mindfulness-based intervention. This may be because of the higher differentiation requirement (i.e., language-specific monitoring) used in the current study so that the relationship between trait mindfulness and C would not be salient.

Although this study mainly dealt with the relationship between trait mindfulness and false memory, our research findings also shed some light on bilinguals' false memory in general. Our research results corroborated the findings of previous bilingual false memory studies [6, 37, 28]. Although the bilinguals generated false recognition in all four study-test language conditions, they showed more false memories in the within-language condition than in the cross-language condition. This result was expected because participants were required to perform language-specific source monitoring in the test phase. Moreover, in the within-language condition, participants showed increased true recognition in English and increased false memories in Chinese, possibly because our participants are English majors and are thus intensively trained to memorize English words. However, the higher recognition of critical lures in Chinese still indicated that it was the Chinese items that could initiate more semantic activation. Regarding memory performance in the cross-language condition, participants were more likely to recognize list items in the English-Chinese condition than vice versa, suggesting a strong word association from the second to the first language. In other words, participants might have automatically associated English list items with their Chinese equivalents during the study phase. Therefore, they were more likely to incorrectly recognize the non-appeared Chinese list items.

4.1. Conclusion, Limitations and Future Directions

To the best of our knowledge, this is the first study to demonstrate that trait mindfulness could either facilitate or inhibit false memory depending on whether the encoding and retrieval language contexts are the same or different. We found that trait mindfulness may influence false memory through the examination of the resemblances of lexical information between encoding and retrieval. Therefore, when the lexical contexts between encoding and retrieval are the same, trait mindfulness reduces false recognition. However, when the lexical contexts differ, trait mindfulness is unable to facilitate significant differentiation. Moreover, because mindfulness is associated with the increased activation of related semantic information, it actually even increases false recognition in the DRM paradigm.

There are several limitations to the current study. First, this is only a correlational study, so a causal relationship between mindfulness and false memory cannot be drawn. Because no mindfulness-base intervention or induction was inserted, we cannot falsify the thesis of Wilson [42] that nonjudgmental attitude is responsible for the increased false memory. Nevertheless, critical correlational findings suggest the need for further investigation of the relationship between mindfulness and false memory. Our lab is currently undergoing a study in which participants' false memory of words with different fonts will be tested before and after a short mindfulness induction.

Second, in the present study, trait mindfulness was only measured by MAAS which consists of questions on ones' moment-to-moment receptive attention in daily life. However, trait mindfulness is also considered a multi-dimensional construct; therefore, we will utilize multidimensional measures (e.g. Five Facet Mindfulness Questionnaire) [43] to examine whether other dimensions (e.g. act with awareness and non-reacting) might also influence one's false memory in future studies. Third, although we believe that highly activated semantic information is responsible for increased false memory rates and for the positive correlation between trait mindfulness and false recognition, we did not directly measure participants' levels of semantic activation. However, given that the DRM paradigm and its mechanisms have been intensively studied, we believe that our inference is plausible and logical.

Forth, the current correlations between trait mindfulness and false memory are solely based on the DRM paradigm. Therefore, the same relationship may not be exhibited in other types of false memory paradigms such as misleading information. Future research might be conducted to investigate this issue. Another direction of future research may be related to the dual processes of recognition memory [44]. Recollection is usually referred to as a consciously controlled process, whereas familiarity is an automatic process. Because mindfulness is related to increasing one's awareness, it may only influence the recollection process but not the familiarity process.

The findings of this research also have implications for task performances that rely on the capacities of recalling or recognize stimuli encoded in the past. For example, future study will address the effect of mindfulness intervention on reducing cognitive failures in daily life. According Martin [45], "An everyday cognitive failure is a cognitively based error that occurs during the performance of a task that a person is normally successful in executing", for instances, dropping a pen, losing wallets or not noticing a road sign. While some cognitive failures may just bring inconveniences in life, some could be deadly (e.g. not noticing a road sign). Because cognitive failures are related with poor encoding

and retrieval [46], increasing one's level of mindfulness should reduce this kind of cognitive errors.

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