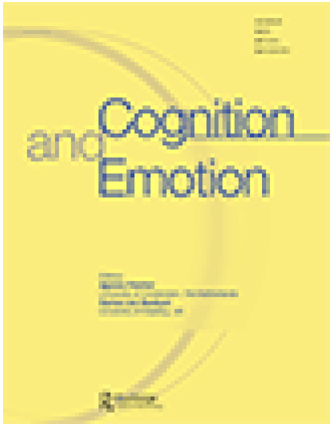

Cognition and Emotion
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pcem20

Training the removal of negative information from working memory: A preliminary investigation of a working memory bias modification task

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Published online: 11 Mar 2015.

COGNITION AND EMOTION, 2015
http://dx.doi.org/10.1080/02699931.2015.1014312

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BRIEF REPORT

Training the removal of negative information from working memory: A preliminary investigation of a working memory bias modification task

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(Received 30 June 2014; accepted 29 January 2015)

Rumination in depressed adults is associated with a bias toward retaining negative information in working memory. We developed a task designed to modify this cognitive bias by having subjects repeatedly practice removing negative words from working memory, thereby enabling them to retain positive and neutral words. To assess the efficacy of this task, we recruited 60 adults who reported elevated repetitive negative thought (RNT) and randomly assigned them to receive a single administration of either the working memory bias modification (WMBM) task or a control task. Subjects in the WMBM condition exhibited greater reduction in proactive interference for negative information than did those in the control condition. These results suggest that the WMBM task reduces biased retention of negative information in working memory and, thus, may be useful in investigating the possible causal role of this cognitive bias in RNT or depression.

Keywords: Cognitive bias modification; Working memory; Rumination; Proactive interference; Repetitive negative thought.

INTRODUCTION

Repetitive negative thought (RNT) is a style of thinking about one's problems, concerns or negative experiences (past, present or future) that is repetitive, intrusive and difficult to terminate (Ehring et al., 2011, p. 226). It is a hallmark of mood and anxiety disorders (Ehring & Wahl, 2008; Ehring & Watkins, 2008). Depressive rumination is a type of RNT characterised by "repetitive and passive thinking about one's symptoms of depression and the possible causes and consequences of these symptoms" (Nolen-Hoeksema, 2004, p. 107). It is a prominent feature of depression and is implicated in the disorder's aetiology. It worsens mood, predicts depression recurrence, and is associated with longer

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episode duration (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008).

Rumination may result from deficits in the ability to control the contents of working memory (Harvey et al., 2004; Joormann, 2010; Koster, De Lissnyder, Derakshan, & De Raedt, 2011), a limited capacity temporary storage system that enables the maintenance and manipulation of information (Baddeley, 2000). In particular, the inability to expel negative information from working memory may provide the cognitive basis for rumination and thereby figure in the aetiology of depression (Joormann, 2010). Consistent with this possibility, Joormann and Gotlib (2008) found that a deficit in the ability to expel negative words from working memory was associated with rumination in people with depression. However, the cross-sectional design of that study precluded any determination of causality. To determine whether working memory impairments cause elevated rumination, researchers must experimentally manipulate those impairments and evaluate their impact on rumination (Kraemer, Stice, Kazdin, Offord, & Kupfer, 2001).

Although general working memory training paradigms exist, their effects frequently fail to transfer to assessments of general or emotion-specific working memory performance (e.g., Onraedt & Koster, 2014). When near-transfer effects are observed, the effects are typically not long-lasting or generalisable (Melby-Lervåg & Hulme, 2013). Accordingly, training general working memory performance may not be a useful tool for researchers interested in modifying working memory bias with the aim of studying its potential link with rumination and depression.

The current study

In the current study, we took a different approach to training working memory. Rather than trying to improve overall working memory performance, we aimed to train subjects to remove negative material from working memory in favour of retaining positive or neutral information. In recent years, researchers have successfully modified cognitive biases by exposing subjects to task contingencies during the completion of simple tasks that instill a favourable, psychologically healthy, selective processing bias (Koster, Fox, & MacLeod, 2009). Inspired by this approach, we developed a working memory bias modification (WMBM) task in which optimal performance can be achieved by initially attending to both positive and negative words and, subsequently, removing negative words from working memory to facilitate the retention of neutral and positive words. We randomly assigned subjects to perform a single session of either the WMBM training task or a control working memory task in which there were no contingencies to facilitate performance and, thus, no instillation of a favourable processing bias. To assess change in subjects' ability to remove words from working memory, we administered a proactive interference (PI) task before and after administration of the WMBM and control tasks. We hypothesised that subjects who completed the WMBM training task would exhibit improvement in the ability to remove negative words from working memory as evidenced by reduced PI from negative words. We further hypothesised that the WMBM training task would produce greater improvement in the ability to remove negative words than would the control task.

METHOD

In the method description below, we describe our sample, the power afforded by our sample size, all study procedures, all measures and outcome variables, and all data exclusions and manipulations in this study.

Subjects

Subjects were students and community members fluent in English and between 18 and 40 years old. We used the upper age limit of 40 to avoid large age-related variability in working memory. To facilitate recruitment of individuals with difficulty removing negative information from working memory, we further limited recruitment to individuals who endorsed elevated RNT on a screening questionnaire (i.e., the Perseverative Thinking

Questionnaire, PTQ; Ehring et al., 2011). We set a cut-off score of 38 or higher (i.e., the upper quartile on the PTQ; T. Ehring, personal communication, May 7, 2013) to indicate elevated RNT. Among the 505 individuals who completed the screening PTQ, 122 exceeded the cut-off score and were invited to participate in a single two-hour visit.

Among eligible subjects, 89 scheduled a visit and 63 attended the visit. Three subjects did not complete the visit and were excluded from the final sample. The final sample included 60 subjects, with 30 subjects in each condition. This sample size provided sufficient power ($1\text{-}\beta = .86$) to detect large ($d = .80$) between-group differences when tests are two-tailed with $\alpha = .05$. Power was .48 and .12 for medium and small effects, respectively.

The majority of subjects were female (68.3%) and Caucasian (53.3%). The mean age was 26.3 years. Although we aimed to recruit subjects below the age of 40, we inadvertently recruited two subjects above this age limit (age 41 and 50). Because there was no evidence that these individuals deviated from the norm on measures of working memory, we included them in the final sample. Excluding these subjects from the analyses does not meaningfully change the results of the study (i.e., the pattern of significant findings remained intact).

Study tasks

Proactive interference task

To assess change in each subject's ability to inhibit previously relevant information, we administered a modified version of Tolan and Tehan's (1999) PI task on a desktop computer with OpenSesame software (Mathôt, Schreij, & Theeuwes, 2012). The PI task contained 60 trials. Each trial contained three phases: the learning phase, the distractor phase, and the recall phase. In the learning phase, subjects saw either one or two lists of four words (50% of trials, each). In both one-set and two-set trials, the first set contained either four negative words, four positive words or four neutral words (33% of trials, each). In two-set trials, the second set contained four neutral words. Words appeared sequentially in the middle of the screen for 1 second. Subjects were instructed to read the words aloud as the words appeared on the screen and to remember the four words from the most recent set they saw (i.e., the first set of words in one-set trials and the second set of words in two-set trials). Because subjects did not know whether they would see a second set, they first had to attend to the first set. The task instructed subjects that, when they see a second set of words, they should immediately forget the words from the first set and, instead, remember the words from the second set.

In the distractor phase, eight one- or two-digit numbers appeared sequentially in the middle of the screen for 1 second each. As each number appeared, subjects reported out loud if the number was bigger or smaller than 50. The distractor phase disrupted the ability to hold recently presented words in the phonological loop, thereby increasing PI (Tolan & Tehan, 1999).

Finally, in the recall phase, subjects saw a word fragment (e.g., _ _ _ t h) and had to type the word from the most recently presented set that fit the word fragment (e.g., *south*) within 8 seconds. In two-set trials, both the target word from the second set (e.g., *south*) and a lure word from the first set (e.g., *death*) fit the word fragment. Consequently, subjects who had failed to effectively remove the lure word from working memory experienced interference when attempting to recall the target word. The lure and target words appeared in the same position in the sequence of four words in their respective sets. For example, if the lure word appeared as the second word in the first set, then the target word would appear as the second word in the second set. The target and distractor word pairs differed between the pre- and post-versions of the PI task.

Stimuli. The PI task stimuli were words from the Affective Norms of English Words list (ANEW; Bradley & Lang, 1999). Negative words had valence ratings between 1.25 and 2.28 (M = 2.14, SD = 0.27). Neutral words had valence ratings between 4.00 and 6.46 (M = 5.38, SD = 0.69). Positive words had valence ratings between 7.55 and 8.72 (M = 7.91, SD = 0.29). There was no difference between the pre-PI and post-PI in target word frequency, $t(118) = -.31$, $p = .76$, age of acquisition, $t(118) = 1.26$, $p = .21$, length, $t(118) = .18$, $p = .86$, valence, $t(118) = -.28$, $p = .78$, or arousal, $t(118) = .96$, $p = .34$.

Outcome variables. We calculated three indices of PI. *Accuracy interference cost* was the proportion of correctly recalled words on one-set trials minus the proportion of correctly recalled words on two-set trials. Higher accuracy interference cost scores indicate greater PI. *Response time interference cost* was the time to provide a correct response in two-set trials minus the time to provide a correct response in one-set trials. If subjects failed to provide a correct response, their response time was set to the maximum time subjects were given to recall the word (i.e., 8 seconds). Greater PI should lengthen the time taken to retrieve the target word on two-set trials. Accordingly, higher response time interference cost scores indicate greater PI. Finally, we examined the number of *intrusions*, defined as the number of instances in which the subject incorrectly recalled the lure word on two-set trials. More intrusions indicate greater PI. For each index, we calculated change scores as the PI-Post–PI-Pre, such that negative change scores indicate a reduction in PI.

Working memory training tasks

We administered the working memory training tasks on a desktop computer with OpenSesame software (Mathôt et al., 2012). Each trial of the tasks had two phases: the learning phase and the recall phase. In the learning phase, two columns of three words appeared centred on the screen. One column contained a set of three positive words and the other contained a set of three negative words. Each valence type appeared in the left and right columns 50% of the time in random order. These six words remained on the screen for 7.8 seconds (1.3 seconds per word; cf. Joormann & Gotlib, 2008) during which time subjects read each word aloud. In 12 of the 60 trials, the task proceeded directly to the recall phase. Thus, on these "two-set trials", subjects saw two sets of three words. The remaining 48 trials were "three-set trials". In these trials, the task proceeded to a second learning screen in which subjects saw a third set of words in a single column in the middle of the screen. The third set of words contained neutral words. These words remained on the screen for 3.9 seconds (1.3 seconds per word). Subjects again read each word aloud.

In the recall phase, subjects first saw a blank screen for 1.8 seconds to allow the representation of the neutral words in iconic memory to decay (Kane et al., 2004). Then, the task asked subjects to type three words from a specified set (i.e., positive, negative or neutral). After submitting their third response, or after 20 seconds, subjects saw a feedback screen that informed them of the correct responses.

Stimuli. The words for the working memory training tasks were from the ANEW list (Bradley & Lang, 1999). Negative words had valence ratings between 1.25 and 2.93 (M = 2.29, SD = 0.40), neutral words had valence ratings between 4.89 and 5.81 (M = 5.34, SD = 0.25), and positive words had valence ratings between 7.15 and 8.82 (M = 7.73, SD = 0.39).

WMBM task. Subjects completed either the WMBM task or a similar control working memory task with no contingency (WMNC). Two characteristics distinguished the WMBM task from the WMNC task: (1) the frequency with which subjects recalled the positive, negative and neutral word sets and (2) the instructions subjects received at the beginning of the task. Most importantly, in the 48 three-set trials in the WMBM task, the task never requested the recall of negative words. Because nine words (i.e., three sets of three words) should be difficult for most individuals to actively maintain in working memory (Miller, 1956), subjects were able to improve performance on the task by removing the negative words from working memory in favour of maintaining neutral and positive words (i.e., retaining two sets of three words rather than three) on three-set trials. To ensure that subjects in the WMBM condition attended to and then removed the negative words from working memory, rather than ignoring the negative words altogether, the task prompted them to recall negative words on 100% of the twelve two-set trials (20% of the total WMBM trials). To encourage the retention of positive words in working memory, the task prompted subjects to recall positive words on 67% of three-set trials (53% of the total WMBM trials). In the remaining 33% of three-set trials, the task prompted subjects to recall neutral words (27% of total WMBM trials).

The task instructions informed subjects that the task would never ask for recall of negative words during three-set trials, and the instructions provided subjects with an explicit strategy for improving task performance (i.e., initially attending to both positive and negative words and, if a third set appears, forgetting negative in favour of retaining neutral and positive words). To facilitate comprehension, we spread the task instructions over a sequence of 25 screens with visual aids and interactivity. At the conclusion of the instructions, the experimenter orally tested subjects' understanding of this strategy, and, if necessary, made clarifications until subjects showed clear understanding of the appropriate strategy.

WMNC task. In contrast to the WMBM task, the WMNC task asked subjects to recall word valences in equal proportion on the two-set (50% positive and 50% negative) and three-set trials (33% positive, 33% negative, 33% neutral). Consequently, WMNC subjects were not able to improve task performance by preferentially removing negative words from working memory. The instructions did not suggest any strategy for performing the task. As with the WMBM task, the experimenter tested subjects' understanding of the task and clarified instructions as necessary.

Procedure

After providing written informed consent, subjects completed the first administration of the PI task (PI-Pre). We then randomly assigned subjects to complete either the WMBM task (n = 30) or the WMNC task (n = 30), after which they completed a second administration of the PI task (PI-Post). Each task took approximately 30 minutes. Next, subjects responded to questions about their experience completing the WMBM or WMNC task and filled out a self-report measure of depression (Depression Anxiety Stress Scales-Depression subscale, DASS-D; Lovibond & Lovibond, 1995; α = .93), attention control (Attention Control Scale, ACS; Derryberry & Reed, 2002; α = .86) and RNT (PTQ; Ehring et al., 2011; α = .95). The PTQ is strongly correlated with domain-specific measures of RNT (e.g., worry and rumination) and exhibits high internal consistency and test–retest reliability (Ehring et al., 2011). Finally, subjects completed a questionnaire on mental illness history and the depression module of the Mini-International Neuropsychiatric Interview (MINI; Sheehan et al., 1998). The second author administered the MINI. The first and last authors re-rated a randomly sampled 20% of these interviews. Inter-rater agreement was 100%. Subjects received $20 or course credit. The Committee on the Use of Human Subjects at Harvard University approved the protocol for this study.

RESULTS

Subject characteristics

There was no difference between the WMBM and WMNC groups in age, $t(58) = 0.09$, $p = .93$, gender, $\chi^2(2) = 0.75$, $p = .69$, ethnicity, $\chi^2(4) = 3.10$, $p = .54$, PTQ scores at screening, $t(58) = 0.48$, $p = .63$, PTQ during the lab visit, $t(58) = 1.02$, $p = .31$, DASS-D scores, $t(58) = 0.08$, $p = .93$, ACS scores, $t(58) = -0.47$, $p = .66$, endorsement of a mental disorder diagnosis, $\chi^2(1, n = 60) = 0.08$, $p = .78$, or MINI depression diagnosis, $\chi^2(1) = 0.30$, $p = .58$. The mean PTQ, DASS-D, and ACS scores for each group appear in Supplementary Table.

Working memory tasks

Subjects in the WMBM group showed a greater proportion of correct responses (M = .74, SD = .12) than did those in the WMNC group (M = .65, SD = .15) on three-set trials, $t(58)$ = 2.64, p = .01. In particular, they correctly recalled a significantly higher proportion of positive words (M = .67, SD = .17), than did the those in the WMNC condition (M = .53, SD = .24), $t(58)$ = 2.75, $p < .01$, suggesting that subjects in the WMBM condition used the task contingency to improve their performance. Importantly, there was no difference in accuracy between the groups on two-set trials, $t(58) = -.21$, p = .83, suggesting that this improved performance on three-set trials is not the result of a general tendency to ignore negative words but, rather, a result of removing negative material from working memory upon seeing a third set.

Proactive interference tasks

The results for the PI tasks for both the WMBM and WMNC groups appear in Table 1. The accuracy interference cost, response time interference cost and intrusions for positive, negative and neutral stimuli for the PI tasks appear in Figure 1. A 2 (group) × 2 (time) × 3 (valence) mixed-model analysis of variance (ANOVA) with accuracy interference cost as the dependent variable revealed no main effects of group, $F(1, 58)$ = 0.03, p = .86, $\eta_p^2 = .001$. The main effect of time, $F(1, 58)$ = 3.49, p = .07, $\eta_p^2 = .06$, and valence, $F(2, 57)$ = 2.51, p = .09, $\eta_p^2 = .08$, were marginally significant. The interaction effect of valence and group, $F(2, 57)$ = 0.22, p = .80, $\eta_p^2 = .01$, valence and time, $F(2, 57)$ = 0.72, p = .49, $\eta_p^2 = .02$ and time and group, $F(1, 58)$ = 0.77, p = .38, $\eta_p^2 = .01$ were each non-significant. There was a significant three-way interaction, $F(2, 57)$ = 3.41, p = .04, $\eta_p^2 = .11$ of group, time and valence. We next examined the change in accuracy interference cost for each valence in the WMBM and WMNC groups. In the WMBM group, there was a significant reduction from PI-Pre to PI-Post in accuracy interference cost for negative words, $t(29)$ = 2.28, p = .03, but not positive words, $t(29) < 0.01$, p = 1.00, or neutral words, $t(29)$ = 0.93, p = .36. There were no significant changes from PI-Pre to PI-Post in the WMNC condition for negative, positive or neutral words, $ts(29) \leq 1.69$, $ps \geq .10$. The reduction in accuracy interference cost for negative words was significantly greater in the WMBM group than in the WMAC group, $t(58) = -2.54$, p = .01.

We next conducted the same 2 × 2 × 3 mixed-model ANOVA with response time interference cost as the dependent variable. The ANOVA revealed a main effect of valence, $F(2, 57)$ = 3.15, p = .05, $\eta_p^2 = .10$ and a marginally significant main effect of time, $F(1, 58)$ = 5.12, p = .03, η_p^2 = .08. There was no main effect of group, $F(1, 58)$ = .09, p = .76, $\eta_p^2 < .01$. There was no significant interaction effect of valence and group, $F(2, 57)$ = 0.17, p = .85, $\eta_p^2 = .01$, valence and time, $F(2, 57)$ = 1.55, p = .22, $\eta_p^2 = .05$, or time and group, $F(1, 58)$ = 0.78, p = .38, $\eta_p^2 = .01$. There was also no significant three-way interaction effect, $F(2, 57)$ = 2.04, p = .14, $\eta_p^2 = .07$. We next examined the change in response time interference cost for each valence in the WMBM and WMNC groups. In the WMBM group, there was a significant reduction from PI-Pre to PI-Post in response time interference cost for negative words, $t(29)$ = 2.85, p = .01, but not positive words, $t(29) = -.05$, p = .96, or neutral words, $t(29)$ = .99, p = .33. There were no significant changes from PI-Pre to PI-Post in the WMNC group for negative, positive or neutral words, $ts(29) \leq 1.22$, $ps \geq .23$. The difference between the WMBM and WMAC groups in response time interference cost change scores was marginally significant, $t(58)$ = 1.99, p = .05.

Finally, we conducted the same 2 × 2 × 3 mixed-model ANOVA with the number of intrusions as the dependent variable. The ANOVA revealed a main effect of time, $F(1, 58)$ = 4.91, p = .03, $\eta_p^2 = .08$, and valence, $F(2, 57)$ = 17.20, $p < .01$, $\eta_p^2 = .38$, but not group, $F(1, 58)$ = 0.13, p = .72, $\eta_p^2 = .002$. There was no significant interaction effect of valence and group, $F(2, 57)$ = 0.56, p = .57, $\eta_p^2 = .02$, valence and time, $F(2, 57)$ = 0.77, p = .47, $\eta_p^2 = .03$, or time and group, $F(1, 58)$ = 0.15, p = .70, $\eta_p^2 < .01$. There was no significant

Table 1. *Means and standard errors for proactive interference indices*

			WMBM group			*WMNC group*		
			Pre	*Post*	*Change*	*Pre*	*Post*	*Change*
Accuracy (proportion correct)	Negative	One-set	.81 (.16)	.67 (.17)		.75 (.18)	.69 (.18)	
		Two-set	.56 (.22)	.54 (.24)		.58 (.21)	.47 (.24)	
		Cost	.25 (.24)	.13 (.24)	−.12 (.29)	.17(.18)	.21 (.19)	.04 (.20)
	Positive	One-set	.81 (.15)	.78 (.15)		.75 (.22)	.74 (.16)	
		Two-set	.64 (.21)	.61 (.19)		.58 (.22)	.59 (.22)	
		Cost	.17 (.20)	.17 (.21)	.00 (.24)	.17(.18)	.15(.17)	−.02 (.22)
	Neutral	One-set	.75 (.17)	.67 (.16)		.76 (.18)	.64 (.16)	
		Two-set	.60 (.19)	.57 (.19)		.58 (.25)	.54 (.22)	
		Cost	.15 (.22)	.10 (.19)	−.05 (.28)	.19 (.23)	.10 (.19)	−.08 (.27)
Response time (*ms*)	Negative	One-set	4417.25 (1010.22)	5138.79 (1042.44)		4525.76 (1432.53)	4960.66 (1091.64)	
		Two-set	5560.95 (1237.25)	5504.59 (1346.12)		5383.80 (1355.05)	5737.11 (1348.54)	
		Cost	1143.70 (1207.19)	365.79 (1063.71)	−777.90 (1496.39)	858.04 (1040.00)	776.45 (904.65)	−81.59 (1202.06)
	Positive	One-set	4467.91 (1088.19)	4393.85 (1031.86)		4487.01 (1389.76)	4613.33 (1113.41)	
		Two-set	5214.64 (1214.92)	5152.86 (1138.03)		5248.76 (1283.61)	5311.12 (1349.07)	
		Cost	746.73 (981.89)	759.01 (938.61)	12.28 (1298.05)	761.75 (727.40)	697.79 (844.55)	−63.96 (972.71)
	Neutral	One-set	4623.34 (1141.79)	4931.17 (1031.10)		4445.06 (1377.11)	4985.46 (1133.15)	
		Two-set	5243.62 (1117.50)	5306.24 (1093.29)		5184.14 (1453.33)	5425.61 (1393.14)	
		Cost	620.27 (928.78)	375.07 (903.81)	−245.20 (1353.10)	739.09 (1121.60)	440.15 (936.44)	−298.94 (1337.85)
Intrusions	Negative	Two-set	2.20 (1.69)	2.40 (1.75)	.20 (2.33)	1.97 (1.47)	2.87 (1.68)	.90 (1.82)
	Positive	Two-set	1.40 (1.30)	1.70 (1.12)	.30 (1.47)	1.23 (0.97)	1.47 (1.11)	.23 (1.19)
	Neutral	Two-set	1.60 (1.43)	1.90 (1.47)	.30 (2.15)	1.60 (1.10)	1.60 (1.07)	.00 (1.26)

Note: WMBM, working memory bias modification; WMNC, Working Memory No Contingency.

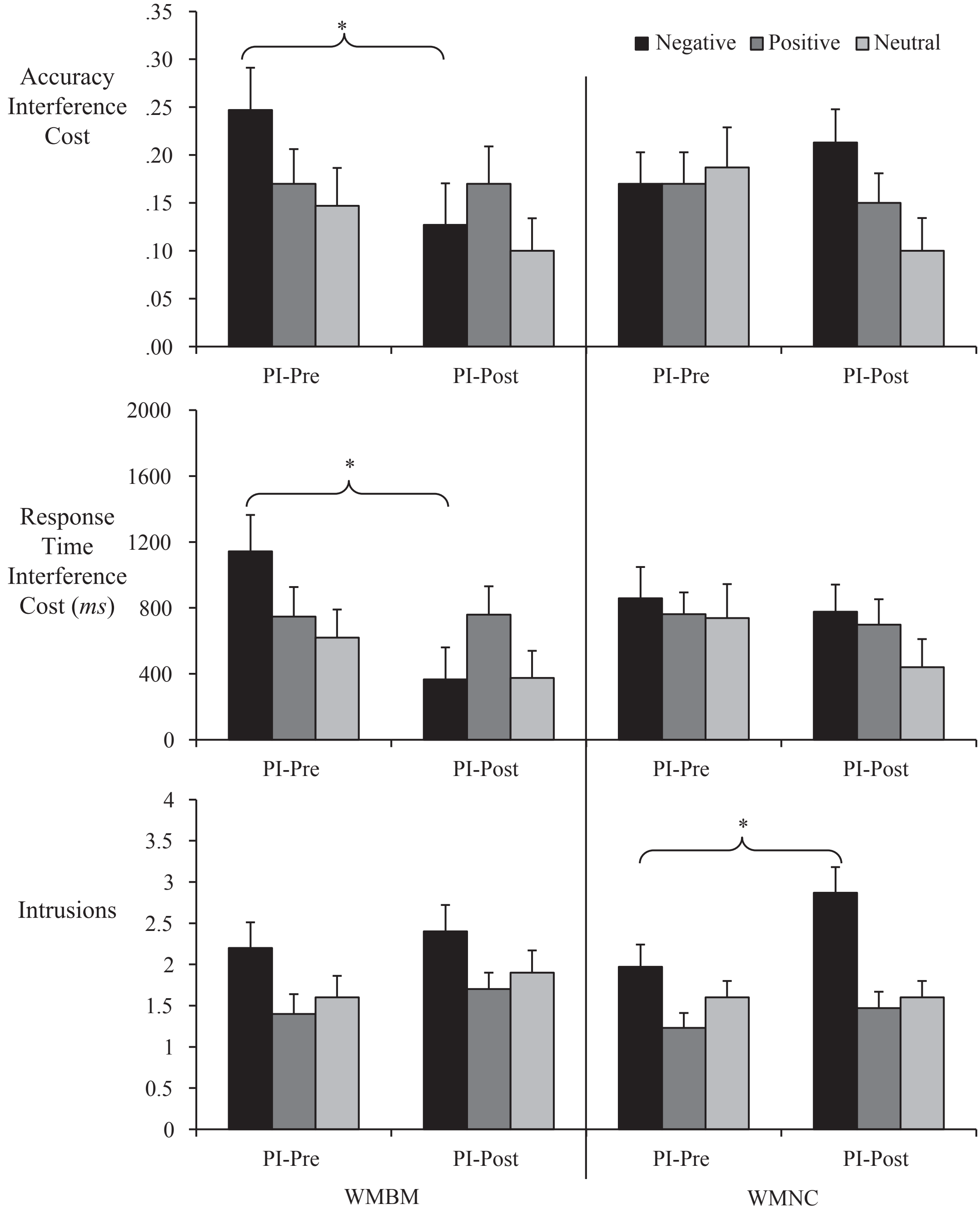

Figure 1. *Means and standard errors for accuracy interference cost, response time interference cost and intrusions for negative, positive and neutral words on the pre- and post-proactive interference task (PI-Pre and PI-Post). Higher values reflect greater interference cost. There was a significant reduction in accuracy and response time interference cost in the working memory bias modification condition but not in the working memory-no contingency condition.* $^{*}p < .05$.

three-way interaction effect, $F(2, 57) = 1.26$, $p = .29$, $\eta_p^2 = .04$. Follow-up tests on the main effect of valence revealed higher intrusion for negative words relative to neutral words and positive words, $ts(59) \geq 4.8$, $ps < .01$. Follow-up tests on the main effect of time revealed higher intrusions at PI-Post ($M = 6.0$, $SD = 3.2$) relative to PI-Pre ($M = 5.0$, $SD = 2.8$), $t(59) = 2.2$, $p = .03$. There were no significant changes in intrusions from PI-Pre to PI-Post in the WMBM group for negative, positive or neutral words, $ts(29) \leq 1.22$, $ps \geq .23$. In the WMNC group, there was a significant increase in intrusions from PI-Pre to PI-Post in intrusions for negative words, $t(29) = -2.70$, $p = .01$, but not positive words, $t(29) = -1.07$, $p = .29$, or neutral words, $t(29) = .00$, $p = 1.00$. The difference in intrusion change scores for negative words between the WMBM group and the WMAC group was not significant, $t(58) = 1.30$, $p = .20$.

Exploratory analyses

We conducted exploratory analyses to examine (1) whether individual differences in attention control, RNT or depression symptom severity were associated with changes in PI task performance and (2) whether those individual difference variables moderated the effect of training. After collapsing across groups, we found that greater attention control was associated with reductions in accuracy interference cost, $r(58) = -.41$, $p < .01$, and response time interference cost, $r(58) = -.30$, $p = .02$, but not number of intrusions, $r(58) = -.20$, $p = .12$. Conversely, higher depression severity scores were associated with increased accuracy interference cost, $r(58) = .36$, $p < .01$, and increased response time interference cost, $r(58) = .35$, $p = .01$. Similarly, higher RNT scores were associated with increased accuracy interference cost, $r(58) = .37$, $p < .01$, response time interference cost, $r(58) = .44$, $p < .01$, and number of intrusions, $r(58) = .32$, $p = .01$. We next used linear regression to examine whether these individual difference variables moderated the effect of training condition. The interaction terms in these regression analyses were not significant for attention control, RNT or depression symptom severity when predicting changes in overall accuracy interference, $\beta s \leq |-.91|$, $p \geq .16$, response time interference, $\beta s \leq |-.75|$, $p \geq .27$, or intrusions, $\beta s \leq 1.53$, $p \geq .11$, nor were they significant when examining changes in accuracy interference, $\beta s \leq |-.34|$, $p \geq .62$, response time interference, $\beta s \leq .40$, $p \geq .56$, and intrusions, $\beta s \leq .97$, $p \geq .32$, for negative trials. These findings suggest that the effect of the training condition did not differ depending on attention control, RNT or depression symptom severity.

DISCUSSION

Individuals who completed the WMBM task exhibited reductions in interference from previously relevant negative information. Moreover, the reductions observed in the WMBM condition were greater than those observed in the WMNC condition. These findings provide preliminary support for the efficacy of this task in training the removal of negative information from working memory.

There are at least two conceptual frameworks for interpreting our results. Koster and colleagues (2011) and Joormann (2010) posited that rumination may result from a deficit in the *ability* to remove negative information from working memory. From this perspective, the WMBM task can be seen as strengthening an otherwise diminished ability by incentivising subjects to repeatedly inhibit previously relevant negative information, analogous to the strengthening of a muscle through repeated use. This interpretation implies that the WMBM task operates on a model similar to other working memory training programs (cf. Melby-Lervåg & Hulme, 2013, p. 272). It is distinguished from those other programs only in that it specifically targets the ability to remove negative information from working memory rather than more broadly targeting general working memory performance. Interestingly, this framework suggests that ongoing use of the WMBM may be necessary for sustained improvement in the ability to remove negative information from working memory, analogous to the necessity of ongoing exercise to sustain muscle strength.

In contrast, Whitmer and Gotlib (2013) proposed an attentional scope model of rumination. These researchers propose that negative mood induces both a narrowed attentional scope and a processing bias for negative information. From this perspective, the WMBM task works by shifting the processing bias away from negative information. That is, by repeatedly inhibiting previously relevant negative information, individuals who complete the WMBM task may experience a reduction in the tendency to retain negative information in working memory, with the scope of attentional capacity unaffected. It remains for future research to determine which of these conceptualisations is most appropriate when examining the effects of WMBM.

Limitations

Two of our findings suggest interpretive caution is warranted. First, the hypothesised reduction in interference from negative words in the WMBM group was not observed in one of our three interference indices: the number of intrusions. We suspect that individuals frequently experienced interference from lure words but did not report the lure words because they recognised that they came from the first set and, therefore, were incorrect responses. This pattern of responses would reduce accuracy and increase response time but would not increase intrusions. Consequently, although high intrusion scores provide strong evidence of interference, low intrusion scores do not necessarily signify an absence of interference. In other words, intrusion scores have high positive predictive value but low negative predictive value. Accordingly, we do not consider the absence of a finding for this outcome variable to be strong evidence against the conclusion that individuals in the WMBM condition were trained to remove negative information from working memory.

Second, although the hypothesised reduction in interference cost for negative words was observed, this reduction appeared to be due, in part, to a reduction in accuracy on one-set trials from pre- to post-PI rather than an increase in accuracy on the two-set trials. The reduction in accuracy on one-set trials was part of a broader trend toward decreased accuracy from pre- to post-PI for both one-set and two-set trials in both the WMBM and WMNC groups. Of particular interest, the WMNC group exhibited a substantial decline in accuracy for negative words in two-set trials. In contrast, the WMBM group did not exhibit this substantial decline for negative words in two-set trials. Persson, Welsh, Jonides, and Reuter-Lorenz (2007) suggest that challenging tasks can cause mental fatigue, leading to decreased performance on tasks that require similar cognitive resources. The absence of this fatigue effect for negative words in two-set trials in subjects who completed the WMBM task suggests that the training effect from the WMBM task may have counteracted that fatigue effect. Accordingly, we believe these data still support the conclusion that the WMBM task facilitated the removal of negative information from working memory.

Conclusions

Our results provide preliminary support for a task designed to train the removal of negative information from working memory. However, we only examined the near-transfer effects of a relatively brief administration of this task. In future studies, researchers should examine the short- and long-term, near- and far-transfer effects of larger doses of the WMBM task (e.g., daily WMBM completed over two or more weeks). In doing so, researchers will be better able to evaluate the effect of WMBM task on working memory bias and, in turn, its utility as a tool for assessing the causal role of working memory bias in the development of RNT and in the aetiology of mental disorders.

In addition, if subsequent research on the WMBM supports a causal role of working memory bias in the aetiology of mental disorders, this task may be a cost-effective and easily disseminable means of intervening directly on a cognitive vulnerability that contributes to RNT.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by a Sackler Scholarship in Psychobiology awarded to the first author and a grant awarded to the second author by the Harvard College Research Program.

Supplementary material

Supplementary Table is available via the 'Supplementary' tab on the article's online page (http://dx.doi.org/10.1080/02699931.2015.1014312).

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