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Impaired memory updating associated with impaired recall of negative words in dysphoric rumination—Evidence for a removal deficit

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ABSTRACT

We present evidence that dysphoric rumination involves a working memory (WM) updating deficit. Sixty-one undergraduates—pre-screened with rumination and depression scales—completed a novel task providing a specific measure of WM updating. This task involved the substitution of emotionally-valenced words, and provided an online measure of the time taken to remove outdated items from WM. Results showed that dysphoric ruminators spent less time removing outdated words from WM when the new to-be-remembered word was negative. This effect was (1) associated with impaired subsequent recall of negative words, arguably caused by interference from the insufficiently removed outdated words; and (2) correlated with participants' rumination scores. This is the first study to use the novel removal task to investigate the nature of WM-updating impairments in rumination. The findings are consistent with a negative attentional bias in rumination, and provide preliminary evidence that rumination is associated with a valence-generic removal deficit during WM updating. Reducing the attentional bias could thus be an intervention target in the treatment of dysphoric rumination.

Working memory (WM) is a limited-capacity system responsible for the temporary short-term storage and processing of information (Baddeley, 1992). Due to its limited capacity, the ability to update the contents of WM and keep them relevant is necessary for its efficient functioning (Oberauer, Lewandowsky, Farrell, Jarrold, & Greaves, 2012). In the depression literature, it has been argued that a relative inability to update WM content may be related to an inability to regulate negative emotion, thus contributing to the development and/or maintenance of depression (Joormann & Gotlib, 2008). In line with this notion, a hallmark of depression is rumination: the repetitive and persistent focus on negative thoughts, including thoughts about depressive symptoms, their causes, and consequences (Nolen-Hoeksema & Morrow, 1991).

There are two ways in which impaired WM updating could contribute to rumination. (1) There could be a *general* WM-updating impairment such that updating is impaired for any material that is in WM, thus leading to an attentional focus on contents already in WM. These contents may be mainly negative if a person finds themselves in an ongoing negative life situation, or in a chronic negative mood (given the salience of negative schemas associated with a negative mood state). The persistent focus on negative information will then invoke deeper processing and integration of the negative information in WM. Such a mechanism would promote the maintenance of depression (Whitmer & Gotlib, 2013). (2) There could be a *valence-specific* WM-updating impairment, such that updating is impaired only with negative information. In this case, negative information that happens to enter WM will be more difficult to update and may thus linger in WM, which in turn could lead to a persistent focus on negative information and its consequences, including the fostering of negative mood.

Consistent with (1), Meiran, Diamond, Toder, and Nemets (2011) suggested that depression is characterized by a general WM-updating impairment. This study used a variant of an operation-span task that involved updating. Participants encoded a set of digits and this was followed by a series of updating steps; at each step, a digit was replaced with the result of an arithmetic operation performed on the to-be-replaced digit. It was found that rumination in participants with depression correlated negatively with post-updating digit recall. As digits are valence-neutral, this is evidence for a relation between depressive rumination and a general

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WM-updating impairment.

In line with (2), it has been found that WM updating in depression is specifically impaired when it involves negatively-valenced materials (Joormann & Gotlib, 2008). Joormann and Gotlib used a modified Sternberg task; in this task, individuals memorized two lists of words—one negative and one positive—and were subsequently told to ignore one of the lists (i.e., the irrelevant list). This was followed by a recognition task, where participants had to reject words that were not from the relevant list. The effect of interest here was an intrusion effect: At test, when participants were presented with words from both the relevant to-be-remembered and the irrelevant to-be-ignored list, as well as new words, response times were longer for rejections of irrelevant words compared to new words of the same valence. For negative words, this intrusion effect was greater in individuals with depression than controls, and correlated positively with rumination scores. This valence-specific intrusion effect was interpreted as a WM-updating impairment for negative information in participants with depression. However, Yoon, LeMoult, and Joormann (2014) failed to replicate this finding and instead found that depression was associated with a WM-updating impairment for any emotionally-valenced material—that is, both negative and positive words. Furthermore, Levens and Gotlib (2009) suggested an alternative explanation for the valence-specific WM-updating impairment in depression, namely that depression is associated with an impaired selection of positive information (i.e., a positive insensitivity). In sum, there seems to be some evidence for impaired WM updating in rumination/depression but the nature of this impairment remains unclear.

To the extent that a WM-updating impairment contributes to a focus on negative information in WM, it may thereby also contribute to the well-established finding that individuals with depression tend to better remember negative information. For example, Matt, Vazquez, and Campbell (1992) found a valence-specific memory enhancement for negative materials in individuals with depression across studies using different tasks. However, a valence-specific memory enhancement could also result from a basic attentional bias towards negative information that results in stronger encoding of negative items into memory (cf. Joormann & Gotlib, 2007).

The empirical situation is further complicated by two methodological issues. First, in the literature, sample selection is typically based on depressive symptoms, despite the fact that rumination is considered a more stable trait than depression, and a stronger predictor of WM impairments (Koster, De Raedt, Leyman, & De Lissnyder, 2010). Second, there is considerable variability in the tasks employed, and the utilized tasks may not always measure precisely what they purport to measure. To illustrate, Gotlib et al. (2004) found that different measures of cognitive bias (e.g., emotional Stroop, dot probe, self-referential encoding) did not correlate in a sample of individuals with depression. This could indicate either that there are uncorrelated cognitive processes underlying performance on these tasks (Gotlib et al., 2004), such that the tasks all measure the same broad bias construct but different aspects of it (Dalgleish et al., 2003), or that some of the tasks do not actually measure cognitive bias.

Likewise, in the context of WM updating more specifically, it has been argued that tasks traditionally used to investigate WM updating measure primarily WM *capacity* (Ecker, Lewandowsky, Oberauer, & Chee, 2010; Schmiedek, Hildebrandt, Lövdén, Wilhelm, & Lindenberger, 2009), or do not even involve WM updating (Bunting, Cowan, & Saults, 2006). Ecker and colleagues (Ecker, Lewandowsky, & Oberauer, 2014; Ecker, Oberauer, & Lewandowsky, 2014) recently argued that an item-wise removal process lies at the core of WM updating, serving to actively remove no-longer relevant information from WM so it can be replaced with new information. They introduced a novel WM-updating task that specifically measures the efficiency of this core updating process of removal. In a nutshell, this task provides an online measure of the time taken for the removal of outdated information from WM.

1. The present study

The main aim of the present study was to investigate the nature of potential WM-updating impairments in dysphoric ruminators. To address the two methodological issues mentioned earlier, we selected participants based on a combination of rumination and depression indicators,[1] and we used the novel removal measure of WM updating as the main dependent variable.

Following previous findings of a more pronounced WM-updating impairment in depression with self-referential materials (Kuiper & Derry, 1982), we used positive/negative self-referential words as stimuli. Drawing on research that found an WM-updating impairment for negatively-valenced materials in depression (e.g., Joormann & Gotlib, 2008), we hypothesized that there would be a valence-specific impairment in WM updating in dysphoric ruminators such that they would be slower to update negative (compared to positive) words.

2. Method

2.1. Participants

A-priori power analysis suggested a minimum sample size of 62 participants to detect a medium-size effect of $f = 0.15$ at $\alpha = 0.05$, $1-\beta = 0.8$, and a moderate correlation between repeated measures of $r = 0.5$. Seventy-eight undergraduate students from the University of Western Australia participated in this study for partial course credit, after reading an ethically-approved information sheet and providing informed consent. Participants were recruited based on their responses on the Ruminative Response Scale (RRS)—a subscale of the Response Style Questionnaire (Nolen-Hoeksema & Morrow, 1991)—and the Depression scale of the short-form version of the Depression Anxiety Stress Scales (DASS-21; Lovibond & Lovibond, 1995) in a screening exercise ($N \approx 800$; participants were selected from the outer quintiles of the respective distributions). Given its temporal specificity, the DASS was re-administered on test day in its full form (DASS-42; Lovibond & Lovibond, 1995), and participants from the pre-screened sample were removed if the test-day depression score did not confirm

[1] Based on the notion that rumination is considered a stronger predictor of WM impairments than depression (Koster et al., 2010), we could have selected participants just based on rumination tendencies. Indeed, had we hypothesized that any potential updating deficit was generic, this would have been an obvious choice: In this scenario [see point (1) above], the updating deficit would contribute to rumination tendencies, and this could contribute to the onset of depression to the extent that a person finds themselves in an ongoing negative life situation or negative mood. In this case, rumination could be seen as a primary symptom. However, we also hypothesized [see point (2) above] that there might be a valence-specific updating deficit associated with dysphoria or depression, which could itself lead to rumination. In this case, rumination would be a secondary symptom, and discovering such a deficit would be possible only by screening on depression, and even more likely if screening on both depression and rumination concurrently. Moreover, the approach of previous memory updating studies of selecting participants based solely on depression scores has produced inconsistent findings, as reviewed earlier. For these reasons, we selected participants who scored high and low on both constructs simultaneously. While this approach prevents us from disentangling the relative contributions of rumination and depression directly, it can nevertheless provide hints regarding how these conditions may relate to potential generic or valence-specific memory updating deficits, which future research can explore.

classification based on the pre-screened score ($n = 10$).

The high-RRS group comprised individuals with RRS scores ≥ 41 (cf. Cook & Watkins, 2016; Onraedt & Koster, 2014; score range was 41–83; possible range is 22–88) and test-day DASS scores ≥ 10 (cf. Lovibond & Lovibond, 1995; score range: 10–42; possible range: 0–42). The low-RRS group comprised individuals with RRS scores ≤ 32 (range 22–32) and test-day DASS scores ≤ 9 (range 0–9). Three participants were removed due to outlying accuracy in the recall test of the memory updating task (see Results for details); another four participants were removed due to a program error. The final sample thus comprised $N = 61$ participants (25 in the high-RRS group, 36 in the low-RRS group; 20 males, 41 females) with a mean age of 19.4 years (age range 17–52 years; $SD = 5.13$). High- and low-RRS groups differed significantly in mean RRS scores, $t(59) = 19.27$, and DASS scores, $t(59) = 11.12$, $ps < 0.001$ (high-RRS: $M_{RRS} = 66.20$, $SD_{RRS} = 10.12$; $M_{DASS} = 21.28$, $SD_{DASS} = 8.49$; low-RRS: $M_{RRS} = 26.24$, $SD_{RRS} = 2.71$; $M_{DASS} = 2.11$, $SD_{DASS} = 1.79$). The mean RRS scores are comparable to the samples in Joormann and Gotlib (2008) and Watkins et al. (2007). The level of depression severity in the high-RRS group was above the clinical cut-off proposed by Ronk, Korman, Hooke, and Page (2013).

2.2. Stimuli

In the WM-updating task, we used nouns selected from the Affective Norms for English Words pool (ANEW; Bradley & Lang, 2010). From this list, nouns with three to eight letters and up to three syllables were selected; negative and positive word pools were created from words with valence ratings ≤ 4.37 and ≥ 6.02 (on 1–9 scale, with higher ratings reflecting positive valence), matched for word frequency, following Joormann and Gotlib (2008).

To obtain general self-referentiality (SR) ratings, the resulting list of 620 words (321 negative, 299 positive) was presented to a separate sample of $N = 85$ participants (45 males, 40 females; age range 18–69; $M = 35.56$, $SD = 11.95$) in an online pilot rating survey. Words were presented in random order, and participants were instructed to rate how easily they could relate each word to themselves (i.e., if they would use it to describe themselves or a concept they could easily relate to) on a 1–5 Likert scale, with higher ratings indicating greater SR.

Based on these SR ratings (i.e., selecting words with high SR), 150 negative and 150 positive words were selected, maximising the difference in valence while attempting to minimise differences on all other variables (SR, word frequency, word length, number of syllables, and arousal). This final list of 300 words was used for the WM-updating task in the main study; mean ANEW valence scores were $M = 3.06$ for the negative words and $M = 7.57$ for the positive words.[2]

2.3. Design and procedure

The WM-updating task was adapted from Ecker, Lewandowsky et al. (2014), and used words randomly drawn from the list of 150 negative and 150 positive self-referential words. The task consisted of 90 trials, presented in three blocks of 30. Each trial in this task comprised three stages: encoding, updating, and recall.

Participants first encoded three words, presented simultaneously in individual frames for 3000 ms. This was followed by a series of updating steps, which was of unpredictable length (i.e., there was a constant stopping probability of $p = 0.15$, and a maximum number of 9 updating steps, resulting in a mean of approximately 5.12 updating steps per trial). At each updating step, one word was replaced by a new word. Before the new word was presented, a cue—one of the three frames turning bold and red—indicated which word was about to be updated. The duration of this cue (the cue-target interval, CTI) was either long (1500 ms) or short (200 ms); this varied randomly on a step-by-step basis and was thus a within-subjects manipulation. The reason for this variation in CTI is that a short CTI would only allow participants to move their focus of attention to the to-be-updated frame, without any opportunity to remove the currently held item; by contrast, the long CTI should allow active removal of the outdated item (Ecker, Lewandowsky et al., 2014). The task involved updating in four different valence-shift conditions: from a negative to a negative word (neg-neg), a negative to a positive (neg-pos), a positive to a negative (pos-neg), or a positive to a positive (pos-pos) word; again, this was a randomly varying within-subjects manipulation. The experiment thus had a 2 (RRS group) × 2 (CTI) × 4 (valence-shift condition) mixed-factorial design with approximately 49 updating steps per cell.

At each updating step, participants pressed the space bar to indicate completion of memory updating, with a response deadline of 5 s; this provided a measure of updating response time (RT), measured from onset of the new word. The dependent variable of main interest was a removal-time index, which was derived from the difference in updating RT between the long- and short-CTI conditions for each valence-shift condition, calculated as a proportional-gain score following Ecker, Lewandowsky et al. (2014) as follows:

$$\text{Removal-time Index} = (mean(short\ CTI) - mean(long\ CTI)) \times /mean(short\ CTI).$$

It can be assumed that the time taken for removal is a constituent component of updating RT in the short-CTI condition but not the long-CTI condition (Ecker, Lewandowsky et al., 2014); hence, the RT difference between conditions can be considered an estimate of the time taken for removal of an outdated item. Expressing this measure as a proportional score controls for overall differences in processing speed.

At the end of each trial, there was a cued-recall test of the last word that was presented in each of the frames, with words cued in a random order. Participants typed the first three letters of the word they remembered for a particular frame, and this provided a measure of recall accuracy (following Fenton & Ecker, 2015).[3] An example of a trial sequence is shown in Fig. 1.

3. Results

3.1. Recall accuracy analyses

Word recall was scored as correct when at least two of the first

[2] There were statistically significant but numerically negligible differences in the number of syllables and ANEW arousal ratings between negative and positive words; all descriptive statistics and the full set of words are presented in Table OS1 and Table OS2, respectively, in the Online Supplement. Also, in an additional manipulation-check experiment, we obtained SR ratings from $N = 61$ high- and low-RRS participants (48 of whom also participated in the main study). We found that SR ratings of positive words were slightly higher than those of negative words, and not unexpectedly, this difference was larger for the low-RRS group; further details are given in Table OS1.

[3] This was done to minimize inter-trial interval variance across trials and participants, and to reduce participant workload and overall testing time. In the vast majority of cases, the first three letters were unique; of the 300 words, only 21 pairs and 3 triplets shared the first three letters, and so it would only happen on less than 1% of all trials that two words sharing the first three letters would appear.

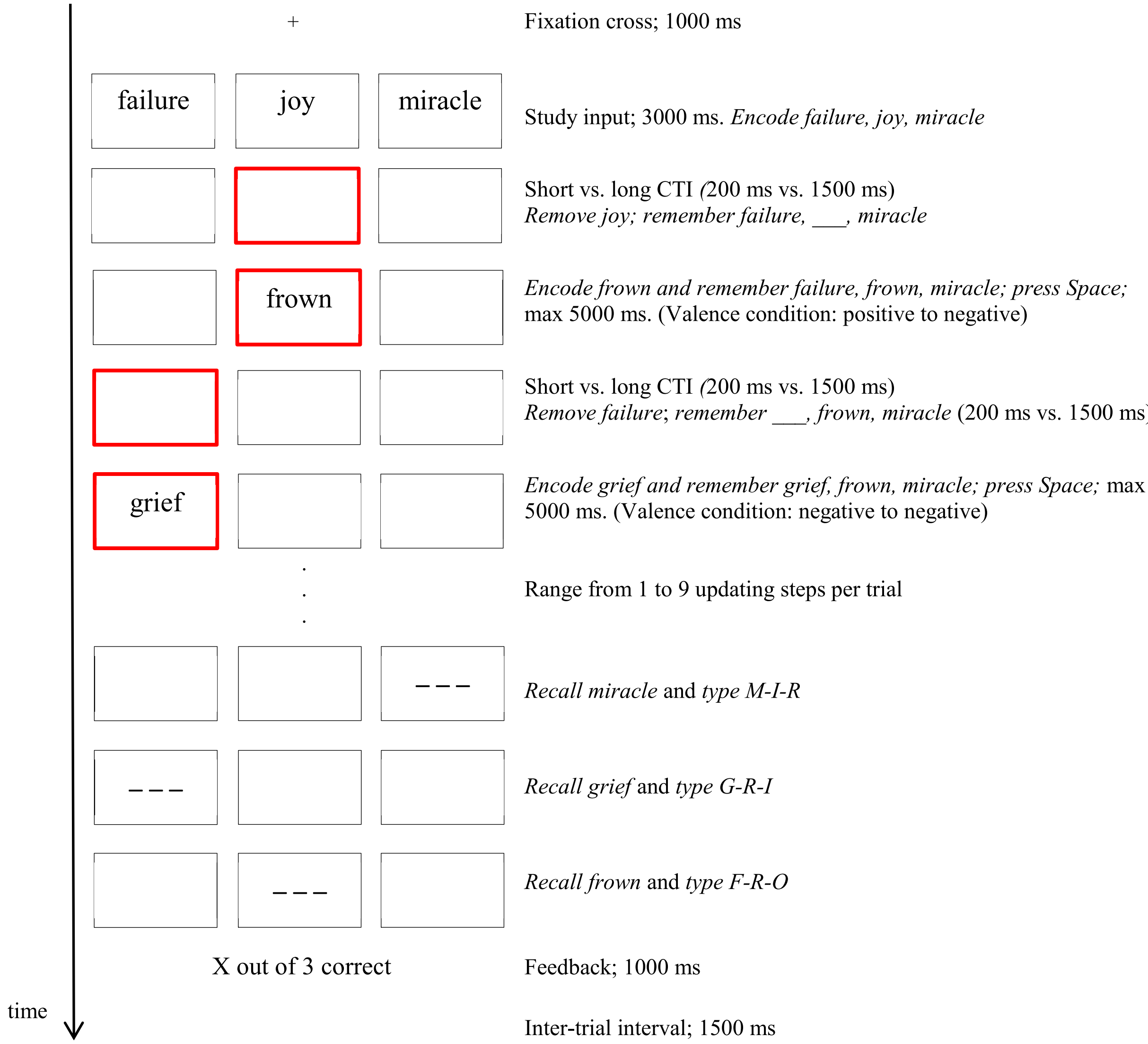

Fig. 1. A trial sequence of the removal task. The example trial features 2 updating steps. Adapted from Ecker, Lewandowsky, et al. (2014).

three letters were correctly entered.[4] To ensure adequate encoding and updating, three participants with recall accuracy more than 3 *SD*s from the grand mean were discarded for the RT analyses, as mentioned earlier. As expected, overall recall accuracy was high at 92% correct; mean recall accuracies by group and word valence are shown in Fig. 2. A 2 (RRS group: high vs. low) × 2 (word valence: negative vs. positive) repeated measures ANOVA revealed a significant interaction between RRS group and word valence in mean recall accuracy, $F(1,59) = 4.02$, $p = 0.05$, $\eta_p^2 = 0.06$. Contrary to expectations, recall accuracy in the high-RRS group was lower for negative words than positive words, $F(1,59) = 4.70$, $MSE = 0.004$, $p = 0.03$.[5]

3.2. Updating response time analyses

Mean updating RTs excluded RTs below 300 ms and above the time limit of 5 s. The overall mean RT was $M = 1096$ ms ($SD = 375$ ms). Removal-time indices derived from the updating RTs across conditions are presented in Fig. 3. A 2 (RRS group: high vs. low) × 4 (valence-shift: neg-neg vs. neg-pos vs. pos-neg vs. pos-pos) mixed-design ANOVA on the removal-time index data revealed an RRS group × valence-shift interaction, $F(3,177) = 3.51$, $p = 0.02$, $\eta_p^2 = 0.06$. Participants in the low-RRS group showed prolonged removal time when updating from a negative to another negative word, while otherwise showing relatively uniform removal times [i.e., the neg-neg condition differed from the other three pooled conditions, $F(1,59) = 19.70$, $MSE = 0.003$, $p < 0.001$].

Of main interest, however, participants in the high-RRS group spent significantly less time removing words when updating towards a negative word (i.e., valence-shift conditions neg-neg and pos-neg) compared to updating towards a positive word (neg-pos and pos-pos), $F(1,59) = 4.05$, $MSE = 0.004$, $p = 0.05$. Moreover, this measure—the time taken for removal when updating towards a negative word—correlated significantly with high-RRS participants' rumination scores ($r = -0.41$, $p = 0.04$). The mean updating

[4] Lenient scoring was applied to accommodate for certain types of occasionally occurring errors resulting from typos and non-registered key presses; thus, if the correct response was *abc*, responses *abx*, *axc*, *xbc*, and also *acx* were scored as correct. The following analyses were also run with strict correct-in-position scoring. This reduced the accuracy rate to 87%, but analysis outcomes were identical unless indicated otherwise.

[5] Applying strict recall-accuracy scoring, the interaction between RRS group and word valence was no longer statistically significant, $p = 0.38$; however, the valence effect in the high-RRS group remained significant, $p = 0.04$.

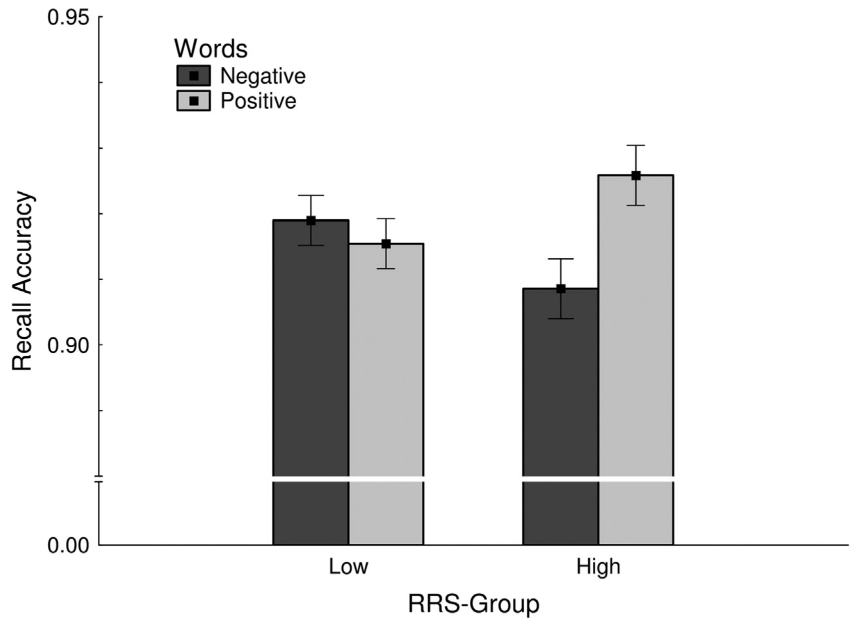

Fig. 2. Mean recall accuracy in updating task for negative and positive words by RRS group. Error bars indicate within-subject standard errors of the mean. *Note*. RRS = Ruminative Response Scale.

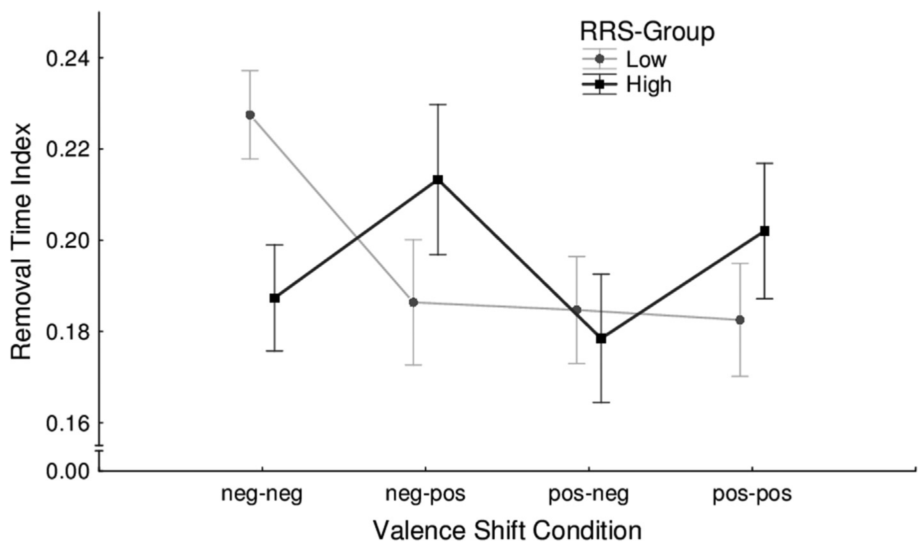

Fig. 3. Removal-time index in updating task across valence-shift conditions by RRS group. Error bars indicate within-subject standard errors of the mean. *Note*. RRS = Ruminative Response Scale.

RTs by RRS group, CTI conditions, and valence-shift conditions are presented in Table 1.

As less time removing an outdated item when updating towards a to-be-remembered item might negatively impact on memory for the to-be-remembered item, particularly in the short-CTI condition (where removal and encoding are not artificially segregated as in the long-CTI condition), we applied a linear-regression analysis to predict recall accuracy for words last updated with a short CTI from the removal-time indices. Specifically, the regression analysis concurrently predicted recall accuracy for all four valence-shift conditions separately; that is, the removal-time index associated with each valence-shift condition was used to predict recall of words last updated in that given condition. This regression analysis revealed that removal time was a significant predictor of recall accuracy in the short-CTI condition, particularly in the high-RRS group [$R^2 = 0.04$, $F(1,98) = 4.95$, $p = 0.03$; low-RRS group, $R^2 = 0.01$, $F(1,142) = 2.97$, $p = 0.09$]. We also note that the encoding times of negative words cannot account for the lower recall accuracy of negative words in the high-RRS group, as in fact high-RRS participants took slightly longer to encode negative relative to positive words, as reflected in the long-CTI updating RTs, $F(1,59) = 6.15$, $MSE = 0.02$, $p = 0.02$.

4. Discussion

The main aim of the present study was to investigate the nature of potential WM-updating impairments in dysphoric ruminators, specifically with regards to the removal subprocess of WM updating (Ecker, Lewandowsky et al., 2014; Ecker, Oberauer, et al., 2014). WM updating has real-world relevance as there is a constant need

Table 1
Updating response times, in seconds, by RRS groups, CTI conditions, and valence-shift conditions.

	High-RRS group $N = 25$	Low-RRS group $N = 36$
	M (*SD*)	*M* (*SD*)
Long CTI		
Negative-Negative	1.047 (0.43)	0.918 (0.32)
Negative-Positive	1.018 (0.42)	0.948 (0.32)
Positive-Negative	1.038 (0.39)	0.948 (0.32)
Positive-Positive	1.014 (0.40)	0.960 (0.33)
Short CTI		
Negative-Negative	1.265 (0.43)	1.190 (0.38)
Negative-Positive	1.278 (0.44)	1.169 (0.38)
Positive-Negative	1.262 (0.45)	1.170 (0.38)
Positive-Positive	1.257 (0.42)	1.181 (0.39)

Note. RRS = Ruminative Response Scale; CTI = cue-target interval.

to attend to new information in the environment and disengage from irrelevant or outdated WM contents. We hypothesized that there would be a valence-specific impairment in WM updating in the high-RRS group, with slower removal of negative words from WM compared to positive words, in line with the notion of ruminators potentially "clinging" onto negative information in WM. This hypothesis was derived from previous studies that investigated WM updating in depression and rumination, which found that irrelevant negative material created substantial interference in WM (Joormann & Gotlib, 2008).

However, contrary to expectations, the removal deficit found in the high-RRS group depended on the valence of the *new* words—not the valence of the *to-be-removed* words. Of main interest, participants in the high-RRS group spent less time on outdated-item removal when updating towards a negative word. This exploratory finding can be interpreted as the result of an attentional bias towards negative information (Joormann & Gotlib, 2007), such that cognitive resources are prematurely directed towards the encoding of a new negative word at the expense of the removal process. This arguably resulted in incomplete or inadequate removal of outdated words, regardless of their valence, in the presence of new negative words in high-RRS individuals.

We speculate that this diminished-removal effect had a direct effect on recall of to-be-remembered negative words. Overall, the high recall accuracy across groups demonstrated that both groups engaged in active WM updating and maintenance processing to a comparable degree. However, high-RRS individuals exhibited worse recall for negative words compared to positive words. This is contrary to the often reported enhanced recall performance for negative information in depression (i.e., the so-called negative memory bias; e.g., Matt et al., 1992; but see Koster et al., 2010). However, in the context of an updating task, failure to adequately remove outdated words will subsequently create interference with memory for the new to-be-remembered words (e.g., Oberauer & Lewandowsky, 2008). Given the reduced removal time in the high-RRS group when updating towards negative information, this account can explain the poorer recall accuracy of negative words in high-RRS individuals: Incompletely removed outdated words may have selectively interfered with memory for the negative words. This notion is substantiated by the fact that in the high-RRS group, the removal-time index was a significant predictor of recall accuracy for words updated in the short-CTI condition (where removal and encoding are not artificially segregated and thus potentially compete for resources).

There is an alternative explanation for the present findings: Participants in the high-RRS group may not be quicker to remove outdated items when updating towards a negative item, they instead may be generally slower to update towards a positive item; in other words, they may show positive insensitivity (Levens & Gotlib, 2009). Negative bias and positive insensitivity are not mutually exclusive, and thus both may contribute to the observed effects to some extent. Because of the absence of neutral words, the present study was not designed to differentiate between the two. However, seemingly speaking against the notion of positive insensitivity as the main explanans, RTs in the long-CTI condition, which reflect mainly encoding time, were lower for positive than negative items in high-RRS participants, suggesting *quicker* encoding of positive compared to negative items. While this quicker encoding could be attributable to less elaborative processing at encoding due to positive words not capturing the attention of high-RRS participants as effectively (in line with positive insensitivity), this seems inconsistent with the notion of slower updating towards positive items and the higher recall accuracy for positive compared to negative words in high-RRS participants. The overall pattern of findings would thus seem to favour an explanation in terms of negative attentional bias rather than positive insensitivity.

Furthermore, the significant correlation between RRS scores and the removal-time index when updating towards a negative word, in the high-RRS group, may point to a cognitive explanation of rumination tendencies: If people with a strong attentional bias towards negative information neglect the removal of outdated information in the presence of new negative information, this could lead to outdated (and if a person is in a chronic negative mood, typically also negative) information lingering in WM. This explanation is admittedly speculative but compatible with significant correlations found between an intrusion index (reflecting interference from irrelevant material) and rumination in studies by Joormann and Gotlib (2008) as well as Yoon et al. (2014) in participants with depression. This is because irrelevant distractor information also needs to be actively removed to avoid interference in WM (cf. Oberauer et al., 2012). Specifically, our finding of a general removal deficit for both negative and positive words in the presence of new negative information is most consistent with the Yoon et al. finding that depression is associated with impairments updating both positively- and negatively-valenced materials in WM.

Taken together, the pattern of results in the present study provides support for the coherence between attentional and memory biases for negative words in dysphoria (cf. Koster et al., 2010). However, the nature of the coherence in the present study differs from that found in Koster et al.: the present study found a *negative* association between attentional and memory biases for negative words in dysphoric ruminators, due to interference from the incomplete removal of outdated words.

Finally, regarding the selective delay in negative-to-negative removal time in low-RRS participants, we can only speculate that the effect could reflect reluctance to go from one negative to another negative item in participants with low dysphoria/rumination scores, or in other words, a desire to not deal with sustained negative information. Indeed, it has been suggested that a habit or desire to not dwell on negative thoughts—so-called anti-rumination tendencies—may protect against depression (Mak, Hu, Zhang, Xiao, & Lee, 2009). Moreover, impaired WM updating of negative self-referential information in an unselected sample has been linked to fewer resources devoted to the processing of negative self-referential information (Sedikides & Green, 2000); this is in line with the "self-enhancement principle", a motivational bias towards the processing of positive instead of negative information with reference to the self (Baumeister, 1998).

To conclude, this is the first study to use a specific, on-line measure of WM-updating efficiency (Ecker, Lewandowsky et al., 2014; Ecker, Oberauer et al., 2014; Fenton & Ecker, 2015) to investigate the nature of WM-updating impairments in rumination and dysphoria. The findings provide preliminary evidence that dysphoric rumination is associated with a valence-generic deficit in the removal of outdated items in the presence of attention-attracting negative information. This reduced rate of removal in dysphoric ruminators predicted post-updating recall performance, presumably because it led to enhanced interference in WM. Future research should aim to use more specific participant selection criteria to disentangle the relative contributions of rumination and depression to the observed generic updating deficit. From a clinical perspective, a reduction of attentional bias (e.g., through attentional-bias modification; cf. LeMoult, Joormann, Kircanski, & Gotlib, 2016) may achieve an indirect reduction of dysphoric rumination by increasing the resources available for removal.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.brat.2017.03.008.

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