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BRIEF ARTICLE

Working memory capacity and spontaneous emotion regulation in generalised anxiety disorder

K. Lira Yoon[a], Joelle LeMoult[b], Atayeh Hamedani[c] and Randi McCabe[c,d]

[a]Department of Psychology, University of Notre Dame, Notre Dame, IN, USA; [b]Department of Psychology, University of British Columbia, Vancouver, BC, Canada; [c]Department of Psychiatry & Behavioural Neurosciences, McMaster University, Hamilton, ON, Canada; [d]St. Joseph's Healthcare Hamilton, Hamilton, ON, Canada

ABSTRACT

Researchers have postulated that deficits in cognitive control are associated with, and thus may underlie, the perseverative thinking that characterises generalised anxiety disorder (GAD). We examined associations between cognitive control and levels of spontaneous state rumination following a stressor in a sample of healthy control participants (CTL; $n = 27$) and participants with GAD ($n = 21$). We assessed cognitive control by measuring working memory capacity (WMC), defined as the ability to maintain task-relevant information by ignoring task-irrelevant information. To this end, we used an affective version of the reading span task with valenced (negative or neutral) distractors. Lower WMC in the presence of negative distractors was associated with greater state rumination in the GAD group, but not in the CTL group. These findings suggest that difficulty maintaining task-relevant information due to interference from negative distractors contributes to perseverative thinking in GAD.

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Considering that recurrent and unintentional negative thoughts and worries are the hallmark of generalised anxiety disorder (GAD; American Psychiatric Association, 2013), it is important to understand mechanisms underlying perseverative negative thinking. In this regard, recent evidence points to the role of inefficient working memory in perseverative negative thoughts (Koster, De Lissnyder, Derakshan, & De Raedt, 2011). For example, rumination (i.e. thinking perseveratively about one's feelings and problems; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008) is associated with impaired inhibition of irrelevant negative material (e.g. De Lissnyder, Koster, Derakshan, & De Raedt, 2010). Similarly, worry is associated with deficits in attentional control (Stefanopoulou, Hirsch, Hayes, Adlam, & Coker, 2014) and inefficient cognitive control (Owens, Derakshan, & Richards, 2015). Along this line, a recent cognitive model of GAD (Hirsch & Mathews, 2012) has proposed that pathological worry (i.e. repetitive, uncontrollable thoughts about possible negative life events) is largely attributed to cognitive control deficits, such as difficulty ignoring distracting information.

Individual differences in cognitive control is frequently indexed by working memory capacity (WMC), defined as the ability to maintain task-relevant information in working memory in the presence of distraction (see Conway et al., 2005, for an overview). Importantly, WMC does not simply reflect the number of items that can be stored in working memory; rather, it reflects the efficiency with which an individual filters out task-irrelevant information in order to maintain task-relevant information (e.g. Vogel, McCollough, & Machizawa, 2005). Thus, low WMC indicates greater interference from irrelevant material due to deficits in cognitive inhibition or attentional control. Not surprisingly, low WMC has been linked with various types of psychopathology (e.g. depression, obsessive-compulsive disorder, schizophrenia, etc.; see Joormann, Yoon, & Zetsche, 2007, for review), and with persistent negative thoughts, such as worry and rumination (e.g. De

CONTACT K. Lira Yoon lyoon@nd.edu

Lissnyder et al., 2010), in healthy controls. Thus, low WMC might also underlie perseverative thinking (i.e. worry and rumination) that characterises GAD (Kircanski, Thompson, Sorenson, Sherdell, & Gotlib, 2015). That is, low WMC might make it difficult for an individual with GAD to ignore negative internal or external stimuli resulting in negative repetitive thoughts in response to stress. Indeed, impairments in cognitive inhibition of irrelevant, non-emotional information were associated with high levels of general tendency to ruminate in college students (Whitmer & Banich, 2007).

There are at least two issues that have not been addressed by previous research on WMC and GAD. First, although mounting evidence demonstrates that GAD is characterised by biased processing of *emotional* information (see Hirsch & Mathews, 2012, for review), the majority of research on WMC in trait anxiety and GAD has focused on interference from non-emotional distractors (e.g. Stefanopoulou et al., 2014). Emerging evidence demonstrates that reduced WMC in the presence of negative distractors is related to intrusive, ruminative thoughts (e.g. De Lissnyder et al., 2010) and trait worry (Stout, Shackman, Johnson, & Larson, 2015) in non-clinical populations. These findings suggest that valence-specific WMC impairment might underlie elaboration of negative content in perseverative thinking (e.g. Daches & Mor, 2014). Thus, it is critical to use emotional material when assessing WMC in GAD.

Second, most research in GAD has focused on worry, a central feature of GAD. For example, non-clinical participants who were instructed to worry exhibited lower levels of WMC than participants in the control condition (e.g. Hayes, Hirsch, & Mathews, 2008). That is, high levels of state-worry resulted in lower WMC. There is, however, a pressing need to examine rumination in GAD given that rumination is emerging as important and common perseverative thinking style in GAD (Kircanski et al., 2015). In addition, it is important to examine the association between WMC and the amount of in-vivo rumination in response to an acute stressor, which we will refer to as *state* rumination hereafter. Levels of trait rumination may not reflect the actual level of rumination at any given moment, which is affected by context and fluctuates over time (Moberly & Watkins, 2008). Thus, it would be important to examine state rumination in response to an acute stressor to better understand mechanisms underlying perseverative thinking in GAD.

To address these two issues, the current study examined whether individual differences in WMC, especially in the presence of negative distractors, moderate the association between GAD and levels of state rumination in response to an acute stressor. We expected lower WMC in the presence of negative distractors to be associated with more rumination following the stressor, particularly in the GAD group versus control (CTL) group. That is, participants with GAD were expected to ruminate more following a stressor, especially if they exhibited lower WMC in the presence of negative distractors.

Method

Participants

Participants were recruited from the greater Toronto area through Internet-based advertisements, community board postings, and referrals to a specialised anxiety disorders outpatient clinic in a large academic hospital. Participants completed a telephone interview, which provided initial selection information. Based on the telephone interview, we excluded individuals if they reported severe head trauma or learning disabilities, psychotic symptoms, a manic or hypomanic episode, or alcohol or substance abuse within the past six months. Participants were also excluded if they were younger than 18 years old, older than 60 years of age, or not fluent in English.

Trained interviewers administered the Structured Clinical Interview for the DSM-IV – Clinical version (SCID-IV; First, Spitzer, Gibbon, & Williams, 1996) to invited individuals. All interviewers had extensive training in the use of the SCID. Inter-rater reliability in the current study was high, $\kappa = .813$. Individuals were included in the GAD group if they met the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; American Psychiatric Association, 2000) criteria for GAD. The CTL group ($n = 27$) consisted of individuals with no current psychiatric diagnosis and no history of any Axis I disorder. Participants in the GAD group ($n = 21$) were allowed to have comorbid conditions as long as GAD was their primary diagnosis. A total of 18 participants in the GAD group had at least one additional diagnosis: 10 with Major Depressive Disorder (MDD; including three in partial remission), 8 with Panic Disorder with Agoraphobia, 1 with Panic Disorder without Agoraphobia, 7 with Social Anxiety Disorder, 5 with Obsessive-Compulsive Disorder, 2 with Specific Phobia, 2 with Eating Disorder

NOS, 1 with Bulimia Nervosa, 1 with Body Dysmorphic Disorder, and 1 with Impulse-Control Disorder NOS.

Tasks

Affective reading span task (RSpan)

We used an affective version (LeMoult, Carver, Johnson, & Joormann, 2015) of the RSpan (Engle, Tuholski, Laughlin, & Conway, 1999) to assess WMC in the presence of negative versus neutral distractors. On each trial, letters were presented one at a time, and participants were asked to memorise these letters in the order that they appeared. After the presentation of each letter, a sentence appeared. Participants' task was to indicate whether the sentence was logical by pressing the appropriate key. The affective version of the RSpan task differed from the original version in that half of the 30 trials presented sentences with negative content (e.g. "When I saw the man get shot I felt terrified and helpless."). The other half of the trials (i.e. 15 trials) presented neutral sentences (e.g. "We like to eat eggs and bacon for breakfast in the morning."). All sentences within a trial were of the same valence. Cumulative sentence accuracy was recorded and displayed to the participants. Following Conway et al. (2005), participants were informed that their average sentence accuracy must be above 85% for the data to be valid. At the end of each trial, 12 letters appeared in a 4×3 matrix on the screen, and participants indicated which of those letters they had been show in the trial in the order that they had been shown. The set length ranged from three to seven letter-sentence sets that were equally distributed across two valence conditions. Half of the sentences in each set size and valence conditions were logical.

The sum of correctly recalled letters on negative sentence trials and neutral-sentence trials as proportions of the total letters presented served as indices of WMC in the presence of negative (*RSpan-Negative*) and neutral (*RSpan-Neutral*) distractors, respectively (see guidelines by Conway et al., 2005). Lower RSpan scores reflected lower WMC when performing in the presence of distractors, indicating greater interference from irrelevant material when attempting to maintain task-relevant information.

Trier social stress test (TSST)

The TSST (Kirschbaum, Pirke, & Hellhammer, 1993) is a well-validated task designed to induce stress in participants. We followed the protocol described by Kirschbaum and colleagues, which consisted of anticipatory speech preparation, speech performance, and verbal arithmetic performance. More specifically, participants were instructed to imagine themselves as applicants interviewing for a job and asked to prepare a 5-min speech about why they were the best candidate for the position. Participants were given 3-min to prepare the speech. Participants then gave a 5-min speech and completed an unexpected 5-min mental arithmetic task during which they were instructed to count aloud backwards from 2083 to zero in 13-step sequences. Whenever participants made an error, they had to start over.

Measures

Affect ratings

Participants completed several ratings over the course of the study. At each time point, participants rated their current anxiety on 10-point Likert scales ranging from *not at all* (0) to *extremely* (9). In the current study, we focused on anxiety ratings made immediately before and after the TSST as a check of the effectiveness of the stressor.

Questionnaires

We used the Beck-Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996) to assess the severity of depressive symptoms, and the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) to assess the severity of worry. To assess the extent to which participants typically engage in rumination, participants completed the 10-item version of the Ruminative Responses Scale (RRS) of the Response Styles Questionnaire (Nolen-Hoeksema & Morrow, 1991), which excludes items that overlap with measures of depression (Treynor, Gonzalez, & Nolen-Hoeksema, 2003). In the current study, Cronbach's α was .93 for rumination (RRS), .96 for depression (BDI), and .86 for the PSWQ. In addition, we administered a state version of the RRS, in which we revised the instructions to assess the degree to which participants engaged in rumination during the recovery phase following exposure to the stressor (i.e. state rumination). State rumination demonstrated high internal consistency ($\alpha = .95$).

Procedure

Eligible individuals returned to the laboratory for the main study session within two weeks of completing

the SCID. During the main study session, participants provided written informed consent and completed the RSpan task. Participants then completed other tasks unrelated to the focus of the current study. Next, participants completed the TSST (Kirschbaum et al., 1993) followed by a recovery phase during which participants watched a calming nature video. Participants then completed the state version of the RRS to indicate the extent to which they had engaged in rumination while watching the nature video. Lastly, they completed the other questionnaires listed above. All procedures were approved by the Institutional Review Board.

Results

Participant characteristics

Demographic and clinical characteristics of the participants are presented in Table 1. Not everyone responded to all items, which is reflected by different dfs associated with different analyses. The CTL and the GAD groups did not differ significantly in sex composition, χ^2 ($N = 44$) = 0.54, $p = .53$, or in age, $t(43) = 0.77$, $p = .44$. As expected, the two groups significantly differed in their BDI scores, PSWQ scores, levels of trait rumination, $|ts| > 6.37$, $ps < .001$, and levels of state rumination, $t(46) = 3.28$, $p = .002$. As expected, the BDI scores were highly correlated with levels of both trait, $r(47) = .80$, $p < .001$, and state, $r(47) = .71$, $p < .001$, rumination. BDI scores were also highly correlated with PSWQ scores, $r(47) = .69$, $p < .001$, which were also significantly related to the levels of both trait, $r(47) = .71$, $p < .001$, and state, $r(47) = .52$, $p < .001$, rumination.

Manipulation check

To examine whether the stressor increased participants' anxiety, a 2 (time: baseline, stressor) × 2 (group: GAD, CTL) analysis of variance (ANOVA) with participants' self-reported levels of anxiety as the dependent variable was conducted. Main effects of group, $F(1, 46) = 20.01$, $p < .001$, $\eta_p^2 = .30$, 90% CI [.13, .45], and time were significant, $F(1, 46) = 12.45$, $p = .001$, $\eta_p^2 = .21$, 90% CI [.06, .37]. The interaction between time and group approached significance, $F(1, 46) = 3.79$, $p = .058$, $\eta_p^2 = .08$, 90% CI [.00,.21]. Both groups' anxiety increased significantly following the stressor, $ts > 2.49$, $ps < .02$, and the GAD group exhibited significantly higher anxiety levels than did the CTL group at both time points, $ts > 3.08$, $ps < .003$ (see Table 1).

Table 1. Participant characteristics.

	CTL (n = 27)	GAD (n = 21)
Female/Male	16/10	13/5
Age	28.48 (8.19)	30.56 (9.68)
Comorbidity	0	18
BDI	4.07 (6.7)	24.16 (11.4)
Rumination	14.11(3.94)	24.10 (6.83)
PSWQ	35.15 (8.21)	57.1 (7.55)
State rumination	12.56 (3.73)	18.81 (9.00)
Anxiety - Baseline	1.07 (.27)	2.1 (1.7)
Anxiety - Stressor	1.56 (.70)	3.76 (2.91)
RSpan-Negative	.80 (.15)	.72 (.13)
RSpan-Neutral	.78 (.15)	.73 (.16)

Performance on the RSpan

To examine group differences in their performance on the RSpan, a group (GAD, CTL) × valence (negative, neutral) ANOVA with participants' RSpan scores was conducted. The main effect of group was not significant, $F(1, 46) = 2.48$, $p = .12$, $\eta_p^2 = .05$. In addition, neither the main effect of valence nor the interaction between group and valence were significant, both $Fs < 1$.

WMC and in-session rumination

Our main hypothesis was that WMC in the presence of negative distractors would be associated with levels of state rumination particularly in the GAD (vs. CTL) group. Estimates of WMC in the presence of negative (RSpan-Negative) and neutral (RSpan-Neutral) distractors were highly correlated: $r(47) = .72$, $p < .001$ in the entire sample, $r(20) = .55$, $p = .01$ in the GAD group, and $r(26) = .83$, $p < .001$ in the CTL group. Given multicollinearity concerns, RSpan-Negative and RSpan-Neutral were examined separately by conducting two hierarchical multiple regression analyses predicting state rumination. For both analyses, group and RSpan scores were entered in Block 1, and the Group × Rspan interaction was entered in Block 2. Continuous variables were centred and the dichotomous variable was dummy coded. For RSpan-Negative, Block 1 was significant, $F(2, 45) = 5.83$, $p = .006$, $R^2 = .21$, 95%CI [.02–.40], and the interaction term significantly improved the prediction of state rumination, $\Delta F(1, 41) = 10.98$, $\Delta R^2 = .10$, $p = .002$. Follow-up simple slope analyses indicated that the association between lower RSpan-Negative scores and greater state rumination approached significance in the GAD group, $t(19) = -3.7$, $\beta = -.40$, $p = .07$, but not in the

CTL group, $t(25) = 1.17$, $\beta = .23$, $p = .25$. For RSpan-Neutral, Block 1 was significant, $F(2,45) = 5.57$, $p \leq .007$, $R^2 = .20$, 95%CI [.01–.39], and adding the interaction term improved the prediction of state rumination, $\Delta R^2 = .06$, $\Delta F(1, 44) = 3.23$, $p = .08$. However, simple slope analyses yielded non-significant results for both the GAD, $t(19) = -1.34$, $\beta = -.29$, $p = .20$, and the CTL, $t(25) = 1.14$, $\beta = .22$, $p = .26$, groups.

Almost half of the participants in the GAD group had comorbid past or present MDD. Considering that depression is associated with both rumination and deficits in inhibiting negative distractors (see Koster et al., 2011, for review), we controlled for the levels of depressive symptoms. That is, to ensure that the significant group × RSpan-Negative interaction cannot be fully accounted for by high levels of depression in the GAD group, the BDI scores were entered in Block 1 along with group and the RSpan-Negative scores. Block 1 was significant, $F(3,42) = 17.16$, $p < .001$, $R^2 = .55$, 95% CI [.38–.72], and the interaction term significantly improved the prediction of state rumination, $\Delta F(1, 41) = 10.98$, $\Delta R^2 = .10$, $p = .002$. Consistent with our hypothesis, follow-up simple slope analyses indicated that lower RSpan-Negative scores were associated with significantly greater state rumination in the GAD group, $t(16) = -2.55$, $\beta = -.42$, $p = .021$, but not in the CTL group, $t(24) = .83$, $\beta = .14$, $p = .42$[1] (see Figure 1).

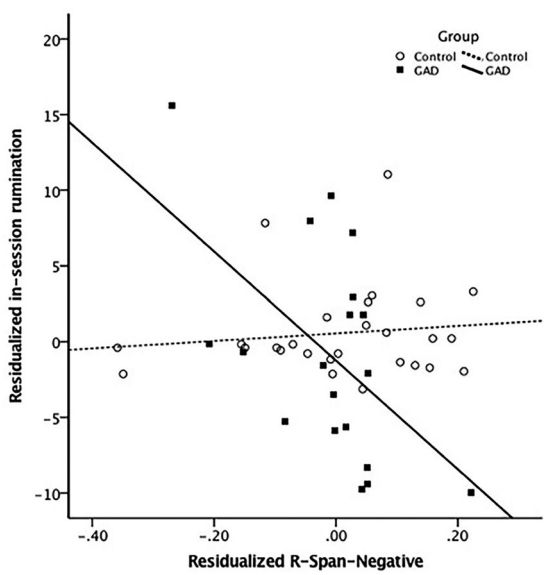

Figure 1. Scatterplot depicting the relation between RSpan-Negative scores and the level of in-session rumination in the GAD and the CTL groups when controlling for depressive symptoms.[2]

Discussion

The current study examined the association between WMC in the presence of negative versus neutral distractors and the spontaneous use of rumination following stress. We focused on rumination because individuals with GAD frequently ruminate (Kircanski et al., 2015). Although rumination is emerging as important and common perseverative thinking style in GAD, it remains largely unexamined in the context of this disorder (Kircanski et al., 2015). Consistent with our hypothesis, lower WMC in the presence of negative distractors was associated with higher levels of state rumination in participants with GAD following an exposure to stress. Importantly, this is the first study to examine the association between WMC for emotional material and rumination in GAD.

The current findings are in line with the growing body of literature demonstrating an association between impairments in cognitive control and rumination (Koster et al., 2011). Most previous research focused on individuals' general tendencies to engage in rumination, whereas the current study assessed the relation between WMC and levels of actual rumination following a lab stressor. Although individuals with GAD typically ruminate more than their non-anxious counterparts, levels of rumination naturally fluctuate depending on the context (Moberly & Watkins, 2008). Given that the level of rumination is not static even within an individual, state rumination could provide a better index of the degree of rumination at any given time. The current study extends previous findings by demonstrating that lower WMC in the presence of negative distractors is associated with higher levels of *state* rumination following stress in GAD. That is, individuals with GAD who were better at ignoring negative distractors while maintaining task-relevant information in working memory were less likely to ruminate in response to stress than individuals with GAD who experienced greater difficulties ignoring negative distractors. It is of note that depressive symptoms in the GAD group cannot fully explain our findings given that the effect was present while controlling for levels of depressive symptoms.

The current findings support the suggestion that lower WMC in the presence of negative, but not neutral, distractors contributes to perseverative thinking in GAD (Koster et al., 2011). Low WMC may hamper cognitive control over irrelevant thought content and make it difficult for an individual with GAD to

disengage from negative stimuli, thereby increasing intrusive, perseverative thinking (Koster et al., 2011). A recent longitudinal study bolsters this argument by demonstrating that impaired cognitive control moderated the association between stress and increased brooding in a non-clinical sample (De Lissnyder et al., 2012). Anxious individuals with low WMC may be particularly vulnerable to the deleterious effects of worry and rumination. Perseverative thoughts could further deplete resources (Hayes et al., 2008), resulting in greater difficulties disengaging from negative thoughts once a worrisome thought enters into their consciousness (Hirsch & Mathews, 2012). Recent evidence suggests that training to bolster working memory for non-emotional material (e.g. Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015; Sari, Koster, Pourtois, & Derakshan, 2015) or to inhibit negative distractors (e.g. Daches & Mor, 2014) could decrease the level of rumination in a non-clinical population. Thus, training to increase WMC particularly in the presence of negative distractors could facilitate or augment the effects of traditional cognitive behaviour therapy by helping individuals disengage from irrelevant negative stimuli, leading to less perseverative thinking. Future studies should investigate this proposition.

There are a few limitations to the current study. First, the GAD group consisted of participants with other comorbid conditions, including MDD. It is well established that MDD is associated with an increased tendency to ruminate (see Nolen-Hoeksema et al., 2008, for a review). MDD also seems to be associated with a deficit to inhibit irrelevant negative distractors (Koster et al., 2011). Thus, the association between lower WMC in the presence of negative distractors and higher levels of state rumination in GAD might be due to the presence of comorbid depression. In the current study, however, the association was found while the levels of depressive symptoms were controlled for. Nevertheless future studies with GAD participants without comorbid MDD could clarify the relation between WMC and rumination in GAD.

Second, the stimuli used in the study do not necessarily reflect concerns or worries of individuals with GAD. Employing negative sentences that reflect personal concerns might elicit a more pronounced reduction in WMC in the GAD group, resulting in a stronger relation between WMC and perseverative thinking. It is of note that we were still able to demonstrate the relation between low WMC in the presence of negative distractor and greater state rumination in the GAD group, even though we did not use personally relevant negative stimuli. Third, only negative and neutral distractors were employed. Thus, it is not clear whether the association between state rumination and reduced WMC is specific to negative distractors or whether the relation extends to all emotional distractors (i.e. both negative and positive distractors). Lastly, the current study is correlational in nature and, thus, we cannot draw any causal conclusions about the relation between WMC and perseverative thinking.

Despite these limitations, this is the first study, to our knowledge, to examine the association between spontaneous state rumination and WMC in the presence of emotional information in GAD. Current findings highlight the importance of examining state (i.e. in-vivo) rumination, which might reflect more accurately the level of rumination in a given situation. Individuals with GAD have a tendency to engage in rumination in response to stressful events, and in this population, lower WMC in the presence of negative distractors was associated with higher levels of state rumination. That is, the inability to ignore irrelevant negative distractors puts individuals with GAD at a particular risk for rumination following stressful events.

Notes

1. The two groups' state anxiety levels differed at baseline, which might account for the findings reported here. Thus, we also controlled for levels of anxiety at baseline when predicting state rumination, and we obtained the same pattern of results. Block 1 was significant, F (4, 41) = 13.08, $p < .001$, $R^2 = .56$, 95%CI [.39–.73], and the group × RSpan-Negative interaction term significantly improved the prediction of state rumination, $\Delta R^2 = .09$, $\Delta F(1, 40) = 10.27$, $p = .003$. Furthermore, the association between RSpan-Negative scores and state rumination remained significant in the GAD group, $t(15) = -2.41$, $\beta = -.40$, $p = .029$, but not in the CTL group, $t(23) = .51$, $\beta = .09$, $p = .61$.
2. Removing outliers did not change the findings, and, thus, we report findings based on the analyses including outliers.

Disclosure statement

No potential conflict of interest was reported by the authors.

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