Research report

The enduring effects of depressive thoughts on working memory

Nicholas A. Hubbard a,*, Joanna L. Hutchison a, b, D. Zachary Hambrick c, Bart Rypma a, b

a School of Behavioral and Brain Sciences, University of Texas at Dallas, Richardson, TX, USA
b Department of Psychiatry, University of Texas Southwestern Medical Center, Dallas, TX, USA
c Department of Psychology, Michigan State University, East Lansing, MI, USA

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ABSTRACT

Background: Depressive thoughts are known to persist in persons with depressed mood leading to rumination and exacerbation of depressive symptoms. What has not yet been examined is whether this persistence of depressive thoughts can lead to impairment of working memory (WM).

Methods: We assessed whether receiving a WM task featuring depressive cues could bias performance on a subsequent, non-depressive WM task for dysphoric individuals (DIs) compared to non-DIs.

Results: DIs showed significantly attenuated performance on the WM task with depressive cues compared to non-DIs. Further, when DIs were given the WM task with depressive cues first, they showed deficits on a second WM task without depressive cues, compared to DIs given the non-depressive WM task first and non-DIs in either condition.

Limitations: Unselected recruitment procedures did not permit balanced sample sizes in each group. Future research is needed to assess whether these results extend to a clinically depressed sample and whether WM deficits are the consequence of depressed mood, or a risk factor for the development and maintenance of depressed mood.

Conclusions: Results suggest that, for DIs, the influence of depressive cues on performance transfers to subsequent tasks in which these cues are no longer present. These results support the hypothesis that when depressive thoughts are part of depressed persons’ conscious experience, cognitive deficits arise. Further, these results suggest an ecologically-relevant mechanism by which day-to-day cognitive deficits in depression can develop.

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1. Introduction

Intrusive, negative, and depressive thoughts are a ubiquitous part of everyday life for persons with depressed mood (see Nolen-Hoeksema et al., 2008). Thus, it is intuitive that depressed mood is associated with greater time spent on processing negative or depressive information, relative to other forms of information (e.g., Joormann, 2004, 2010; Joormann and Gotlib, 2008; Lyubomirsky et al., 2003; Koster et al., 2010; Levens and Gotlib, 2010; Siegle et al., 2002). Greater time spent on this information, to the neglect of rehearsing goal-relevant information in working memory, has been hypothesized to underlie day-to-day cognitive deficits in persons with depressed mood (Hubbard et al., 2015). Thus, an important step in understanding cognition in persons with depressed mood lies in examining how and when working memory might fail.

Working memory is a fundamental cognitive process which allows one to keep information “online” in an easily-accessible state, during concurrent processing of other information. This process is thought to underlie most higher-order cognitive abilities (e.g., decision making and reasoning) and predicts many ecologically-relevant behaviors (see Engle, 2010). For example, reading a paragraph requires that a reader must store semantic information from text they just read; and use this information to disambiguate subsequent text (Daneman and Carpenter, 1980).

It is known that dysphoric individuals (DIs) have deficits in working memory compared to non-DIs when depressive cues are present (Hubbard et al., 2015). For example, prior research in our laboratory used a modified working memory span task wherein DIs and non-DIs were required to remember lists of numbers (i.e., goal-relevant information) while also responding to depressive cues (i.e., D-span task; Hubbard et al., 2015). Results from this study showed that DIs had significantly decreased ability to remember the goal-relevant information compared to non-DIs when the depressive cues were present. This effect was not due to...
baseline working memory deficits as DIs and non-DIs remembered similar amounts of goal-relevant information when non-depressive cues were present within a standard working memory span task. This result suggests that DIs have selective deficits in working memory capacity. What remains unknown is whether such depressive cues can exert deleterious effects on working memory, after the cues are no longer present.

Evidence suggests that the processing of emotional and self-relevant information occurs for an extended period for persons with depressed mood, and can interfere with cognitive performance (e.g., Hertel, 1998; Lyubomirsky et al., 2003). For instance, Lyubomirsky et al. (2003) asked DIs and non-DIs to concentrate on self-focused, emotion-focused, and symptom-focused thoughts (rumination condition), or to concentrate on neutral thoughts unrelated to themselves or emotion (neutral condition). After these induction phases participants completed a series of academic tasks (e.g., reading text, watching a lecture, proofreading). DIs in the rumination condition reported more task-unrelated thoughts and showed reduced performance on the academic tasks compared to DIs in the neutral condition, and non-DIs in either condition. These results suggest that prior processing of personally-relevant and emotional cues can have adverse effects on DIs’ future cognitive performance. This affective transfer from initial cueing to subsequent task performance, is similar to the proactive transfer observed in skill learning (e.g., Verneau et al., 2015).

In the current study, we assessed whether the presence of a working memory task with depressive cues (D-span; Hubbard et al., 2015) could result in decreased performance on a subsequent working memory task without depressive cues (i.e., a reading span task [R-span; Conway et al., 2005; Daneman and Carpenter, 1980; Unsworth et al., 2005]) for DIs compared to non-DIs. Specifically, we administered both the D-span and R-span tasks, back-to-back, to DIs and non-DIs, and manipulated the order in which these tasks were given. That is, D-span then R-span (D–R) or R-span then D-span (R–D). Consistent with the notion of an affective transfer mechanism, we hypothesized that DIs in the D–R condition would perform significantly worse on the R-span task compared to DIs in the R–D condition and non-DIs in either condition.

2. Method

2.1. Participants and procedure

Eighty-three unselected (i.e., not prescreened) university undergraduate students were recruited for the current study. Five participants did not complete the depression inventory in its entirety, one did not complete the rumination scale in its entirety, and two did not complete the working memory tasks in their entirety. We limited our analyses to participants who completed the protocol (N=75). Participants were compensated with course credit in their undergraduate psychology courses. All procedures were approved by the governing Institutional Review Board.

Study procedures were similar to those described in Study 3 of Hubbard et al. (2015). However, the work presented here was part of a novel experiment. Consistent with our prior work, participants received subjective report measures, R-span and D-span tasks, as well as a fluid reasoning task. Inconsistent with Hubbard et al. (2015), the present study asked participants to complete the R-span and D-span tasks back-to-back, to assess whether receiving the D-span task first could affect performance on the R-span task for DIs compared to non-DIs.

Participants received study components in the following order: the subjective report measures, the fluid reasoning task, and the working memory tasks. The order of the working memory tasks was counterbalanced across participants, leaving approximately half of participants receiving the affective task variant first (D–R condition; n=39; n_{non-DI}=21) and the other half receiving the non-affective task first (R–D condition; n=36; n_{non-DI}=24).

Because unselected sampling methods do not necessarily permit proportional assignment to random conditions, all group distributions were scrutinized for homogeneity of variance violations. When necessary for parametric testing, degrees of freedom were adjusted using the Welch procedure to accommodate unequal variance between groups. Mixed effects models were also utilized, which are robust to deviations from such assumptions and to smaller sample sizes (e.g., Gupta et al., 2006).

2.2. Measures

2.2.1. Center for epidemiological studies depression inventory (CESD)

Participants completed the CESD (Radloff, 1977). This self-report inventory was designed to assess significant depressive symptomology in the general public, with an emphasis on the affective component of depression (i.e., depressed mood; Radloff, 1977). The CESD asks responders to report on their depression-related thoughts, feelings, and actions within the week prior to taking the test. The CESD was not intended to diagnose major depressive disorder, but was designed to classify those with significant depressive symptoms (i.e., DIs) in the general population. We utilized the score suggested by Radloff (1977) to classify DIs (i.e., CESD score ≥ 15) and non-DIs (i.e., CESD score ≤ 15). This procedure classified 30 participants as dysphoric (n_DI=30 [39.5%]) and 45 participants as non-dysphoric (n_{non-DI}=45 [60.5%]).

2.2.2. Ruminative responses scale (RRS)

Participants also completed the RRS (Treynor et al., 2003). This self-report scale was designed to assess how often responders used specific rumination strategies when coping with negative mood (Treynor et al., 2003). We used this measure to ensure that DIs in each condition did not significantly differ in their tendencies for rumination.

2.2.3. Raven’s advanced progressive matrices (RAPM)

This test was designed to measure inductive reasoning ability with novel content (Raven et al., 1998). Each of the questions consists of a series of geometric patterns that change along rows and down columns. The bottom right pattern is always missing, and the participant’s task is to choose the correct response of eight to complete the pattern. The score reflects the number of correct items out of a possible 36. RAPM has been shown to be associated with a variety cognitive abilities (e.g., Marshalek et al., 1984), and thus it is often used as a measure of general fluid intelligence (cf. Carpenter et al., 1990). This measure was utilized to ensure that our groups did not differ in general fluid ability.

2.3. Working memory tasks

2.3.1. Affective working memory task (D-span)

The D-span task is a computer administered, complex span measure that assesses participants’ ability to encode, maintain, and subsequently retrieve varying loads of goal-relevant information, in spite of interference from depressive cues (Hubbard et al., 2015). In this task, participants were asked to respond “TRUE” or “FALSE” regarding whether or not a sentence was indicative of their recent thoughts, feelings, and behaviors (i.e., the interference task). Interference sentences were based on self-referential, mood items adapted from depression inventories (Beck et al., 1996; Radloff, 1977; Rush et al., 2003). For example, one interference sentence read, “I am sad all of the time.” All sentences were unique and probed thoughts, feelings, or behaviors related to
depression (Fig. 1A). Interference sentences were scored as either depressive-relevant or depressive neutral. Depressive-relevant endorsements were those typical of depressive thoughts. For example, a response of "True" to the sentence "I am sad all of the time," or "False" to the sentence "People generally like me" would be coded as depressive-relevant. Depressive-neutral endorsements were given a score of one and depressive-relevant were given a score of zero. Scores were summed for each participant with lower values representing more depressive-relevant responding. Response time was also collected for each sentence.

Participants practiced the interference sentences for five trials. During this time, average response time was gathered and participants were told that during the actual task if they exceeded this time (by +2.5 SD) their current trial would be skipped and they would not receive credit for that trial. This procedure was utilized so as to minimize the use of strategic rehearsal procedures (e.g., Unsworth et al., 2005).

Within the actual task, after a participant responded to an interference sentence, he or she was instructed to remember a number (i.e., the goal-relevant stimulus; numbers 0–9). This process of responding to an interference sentence and encoding a goal-relevant stimulus continued three to eight times depending on load size (i.e., load sizes 3–8). There were three trials for each load size presented in random order (18 total trials). At the end of each trial, participants were asked to recall numbers from the encoding portion of the trial, in the order the numbers were presented. A trial was considered accurate if all numbers were recalled in the order presented; these accurate trials were given credit proportional to the load size of the trial (Conway et al., 2005; Daneman and Carpenter, 1980).

2.3.2. Reading span task (R-span)

The computer administered R-span task (Kane et al., 2004; Unsworth et al., 2005) was built on the same program shell as the D-span task. Thus, goal-relevant stimuli, instructions for recall, and scoring procedures were equivalent to those used in the D-span task. The difference between the R- and D-span tasks was the interference cues. For the R-span task, participants were asked to make a judgment on the semantic sensibility of a non-affective sentence. Participants responded "TRUE" or "FALSE" to a prompt reading, "This sentence makes sense." For example, one nonsensical sentence read, "George comet a tall man," whereas one sensible sentence read, "It was a clear and starry night" (Fig. 1B). Each response to these interference sentences was scored as either correct (1) or incorrect (0). Interference scores were summed for each participant and percent accuracy was calculated. Both groups in each condition scored significantly above chance response rates (i.e., 50%; all means > 82% accuracy, p’s > .001; see Supplementary Material for expanded analyses and discussion). Response time was also collected for each interference sentence. Working memory performance was evaluated in this task by the summation of load-weighted, accurate trials (Conway et al., 2005; Daneman and Carpenter, 1980). To remain consistent with the D-span task, no trial was discarded due to incorrect interference sentence responding on the R-span task. Sentence length of the interference stimuli was equivalent across R- and D-span tasks (p > .05).

3. Results

3.1. Sample characteristics, subjective reporting and fluid reasoning performance

DIs did not significantly differ from non-DIs in age (M_{D} = 22.30 [SE = 1.04] vs. M_{non-D} = 22.76 [SE = .85], t(73) = −3.4, p = .734) or sex
(DI = 66.67% female vs. non-DI = 53.55% female, Pearson \( \chi^2 (1) = 1.32, \ p = .251 \)). Further, groups did not significantly differ in their reporting of race/ethnicity (i.e., African/African American [DI = 66.7% vs. non-DI = 11.11%], Hispanic [DI = 30.00% vs. non-DI = 17.78%], Indian or East Asian [DI = 43.33% vs. non-DI = 22.22%], Middle Eastern [DI = 33.33% vs. non-DI = 22.22%], Non-Hispanic Caucasian [DI = 16.67% vs. non-DI = 42.72%], or Other [DI = 0.00% vs. non-DI = 4.44%]). Pearson \( \chi^2 (5) = 9.27, \ p = .10 \). DIs had significantly higher CESD scores (M\(_D\) = 26.77 [SE = 1.48]) than non-DIs (M\(_{non-DI}\) = 8.33 [SE = 0.70]), t(42.09) = 11.28, \( p < .001 \). DIs also had significantly greater RRS scores (M\(_D\) = 54.50 [SE = 2.28]) than non-DIs (M\(_{non-DI}\) = 40.73 [SE = 1.71]), t(73) = 4.92, \( p < .001 \). DIs did not differ significantly from non-DIs on RAPM performance (M\(_D\) = 20.43 [SE = 1.15]) vs. M\(_{non-DI}\) = 20.67 [SE = .82]), t(73) = .17, \( p = .866 \).

Because we sought to assess possible differences between DIs receiving the affective working memory task first (D-R condition) and those receiving the non-affective working memory task first (R-D condition), we also tested for possible differences in sample characteristics, subjective reporting, and RAPM performance between these two groups. DIs in the D-R condition did not differ significantly from DIs in the R-D condition on age (M\(_{D-R}\) = 21.67 [SE = .133] vs. M\(_{R-D}\) = 23.25 [SE = 1.62], t(14.02) = .66, \( p = .522 \)) or set (R = 72.22% female vs. R = 58.33% female, Pearson \( \chi^2 (1) = 625, \ p = .429 \)). These groups did not significantly differ in their reporting of race/ethnicity (i.e., African/African American \( [R = 11.11 \% \ vs. R-D = 0.00\%] \), Hispanic \( [R-D = 38.89\% \ vs. R-D = 16.67\%] \), Indian or East Asian \( [R-D = 38.89\% \ vs. R-D = 50.00\%] \), Middle Eastern \( [R-D = 0.00\% \ vs. R-D = 8.33\%] \), Non-Hispanic Caucasian \( [R-D = 11.11\% \ vs. R-D = 25.00\%] \)).

### 3.2. Interference sentence responding

We sought to assess whether DIs and non-DIs differed in responding on the D-span and R-span tasks. As expected, DIs (M\(_{D}\) = 53.80 [SE = 3.96]) responded to the D-span interference sentences in a significantly more depressive manner compared to non-DIs (M\(_{non-D} = 79.87 [SE = 2.04]\), t(44.28) = 5.85, \( p < .001 \). DIs (M\(_{D}\) = 83.11% [SE = .01]) and non-DIs (M\(_{non-D}\) = 83.20% [SE = .01]) did not significantly differ in their number of correct responses on the R-span interference sentences, t(73) = .07, \( p = .948 \).

DIs (M\(_{D}\) = 1025.08 [SE = 40.01]) did not significantly differ in their response time on the D-span interference sentences compared to non-DIs (M\(_{non-D}\) = 949.52 [SE = 50.13]), t(73) = 1.09, \( p = .281 \). DIs (M\(_{D}\) = 798.75 [SE = 37.24]) and non-DIs (M\(_{non-D}\) = 768.42 [SE = 30.41]) did not significantly differ in their response time on the R-span interference sentences, t(73) = .63, \( p = .531 \).

We also assessed these measures for DIs in the D-R and R-D condition. DIs in the D-R condition (M\(_{D-R}\) = 56.33 [SE = 5.15]) did not significantly differ from DIs in the R-D condition (M\(_{R-D}\) = 50.00 [SE = 6.31]) on D-span interference sentence responding, t(28) = .78, \( p = .443 \). Further, DIs in the D-R condition (M\(_{D-R}\) = 83.33% [SE = .02]) did not significantly differ from DIs in the R-D condition (M\(_{R-D}\) = 82.78% [SE = .02]) on the number of correct responses on the R-span interference sentences, t(28) = .22, \( p = .828 \). These groups also did not significantly differ in D-span interference sentence response time (M\(_{D-R}\) = 1028.95 [SE = 52.55] vs. M\(_{R-D}\) = 1019.27 [SE = 64.37]), t(28) = .12, \( p = .908 \); nor did they significantly differ in D-span interference sentence response time (M\(_{D-R}\) = 783.62 [SE = 47.65] vs. M\(_{R-D}\) = 821.44 [SE = 69.69]), t(20.75) = .45, \( p = .659 \). These results showed that responding on the D-span task was consistent with dysphoria status; that is, DIs responded more depressive-relevant than non-DIs. Further, DIs in both conditions responded similarly to these sentences. These results showed that participants were responding to the D-span interference stimuli in a mood-congruent manner. These results also showed that both DIs and non-DIs were placing similar emphasis on responding accurately to the interference sentences on the R-span task. These effects were similar for DIs in both conditions. Taken together with the relative equivalence between groups in response times on both tasks, it is likely that all groups placed similar emphasis on reading, comprehending, and responding to the interference sentences (see Supplementary Material).

### 3.3. Group, task, and condition effects on working memory performance

To assess the effect that dysphoria status and task order had on working memory performance, we used mixed-effects general linear modeling to assess the effects of Group (DI, non-DI), Task (D-span, R-span), and Condition (D-R, R-D) on the number of items recalled in each working memory task.

There were no significant Task, Condition, Group \times Condition, Task \times Group, Task \times Condition effects (all \( p > .05 \)). There was, however, a significant effect of Group, \( F(1,71) = 6.02, \ p = .017, \ η^2_p = .08 \) and a significant Group \times Task \times Condition interaction, \( F(1,71) = 4.52, \ p = .037, \ η^2_p = .06 \) (Fig. 2A).

The main effect of Group revealed that DIs (L\(S\M = 44.73 [SE = 2.90] \)) had overall lower scores on both working memory tasks compared to non-DIs (L\(S\M = 53.86 [SE = 2.33] \)). However, this effect was influenced by the Group \times Task \times Condition interaction. Decomposing this interaction by Group, there were no effects of Task, Condition, or Task \times Condition on working memory performance for non-DIs (all \( p > .05 \)). Also, there were no effects of Task or Condition on working memory performance for DIs (all \( p > .05 \)). However, for DIs, there was a significant Task \times Condition interaction, \( F(1,28) = 4.69, \ p = .039, \ η^2_p = .14 \), indicating that the change in working memory performance from one task to the next was influenced by Condition. A follow-up test revealed that DIs in the R-D condition showed a significant increase in performance from the D-span task to the R-span task, compared to DIs in D-R condition (M\(_{D-R}\) = 75.8 [SE = 5.07] vs. M\(_{R-D}\) = 6.39 [SE = 4.05]), t(28) = 2.16, \( p = .039, \ d = .80 \). Assessing working memory by Group showed that, consistent with our prior results, DIs remembered fewer items on the R-span (L\(S\M = 44.43 [SE = 3.30] \)) compared to non-DIs (L\(S\M = 53.57 [SE = 2.64] \)), t(73) = −2.31, \( p = .024, \ d = −.56 \) (Fig. 2B). Assessing this effect using pairwise comparisons on Condition did not reveal significant differences between DIs in the R-D condition and DIs in R-D condition, nor non-DIs in the R-D condition and non-DIs in R-D condition (all \( p > .05 \)). DIs remembered fewer items on the R-span (L\(S\M = 45.03 [SE = 3.30] \)) than non-DIs (L\(S\M = 54.16 [SE = 2.64] \)), t(73) = −2.44, \( p = .017, \ d = −.57 \). However, assessing Group by Condition on the R-span task (Fig. 2C) indicated that the Group effect for working memory performance on the R-span task was driven by DIs in the D-R condition, \( F(3, 71) = 4.54, \ p = .006, \ η^2_p = .16 \). Consistent with our hypothesis, Fig. 2C illustrates that DIs in the D-R condition performed worse than non-DIs in both conditions (all \( p < .05 \)). Also consistent with our hypothesis, DIs in the D-R condition also performed worse than DIs in the R-D condition (\( p < .05 \)). DIs in the R-D condition performed similarly to non-DIs in both conditions (all \( p > .05 \)).
4. Discussion

We investigated whether depressive cueing could have enduring, adverse effects on DIs’ working memory performance. We hypothesized that if affective transfer was occurring from the D-span (depressive cues) to the R-span task (non-depressive cues), we would observe decreases in performance on the R-span task for DIs who received the D-span task first (i.e., D–R condition), compared to DIs in the R–D condition or non-DIs in either condition. Our results supported this prediction. Importantly, baseline changes to working memory capacity were not a factor for DIs in either condition; it was observed that DIs in the R–D condition performed similarly to non-DIs on the R-span task, and that DIs in the D–R condition performed similarly to DIs in the R–D condition on the D-span task. Further, the present results were consistent with our previous work showing that DIs in both conditions performed worse than non-DIs on the D-span task (Hubbard et al., 2015).

Our finding, that exposure to depressive cueing can produce enduring deficits in working memory for persons with depressed mood, suggests implications for the nature of cognitive deficits in depression. In a previous study we showed distinct deficits in working memory performance for DIs compared to non-DIs on the D-span task, but not on the R-span task (Hubbard et al., 2015). The present study extended these results by showing that deficits in DIs’ working memory performance were not merely task-specific; rather, their working memory performance was adversely affected after depressive cueing. This result suggests that, for persons with depressed mood, depressive cues are maintained after cueing is removed. For these individuals, more time spent attending to depressive cues in working memory could result in decay of goal-relevant information and decreased performance on the D-span task (Hubbard et al., 2015). Here we have shown that this processing insufficiency for goal-relevant information may extend to working memory deficits when external cues are no longer present.

Affective transfer and processing insufficiency are complementary mechanisms by which cognitive deficits could arise in the day-to-day lives of persons with depressed mood. Environmental and internal cues that trigger depressive thoughts do not occur in the real world with the same systematic repetition as they often do in laboratory tasks. However, our results suggest that, despite the intermittent occurrence of depressive cues in the real world, their effect might endure over time. This affective transfer from a previous cue to current cognitive processes could lead to insufficient processing of ongoing tasks and goals, loss of this information in working memory, and broad-spread deficits in cognitive ability for persons with depressed mood (cf. Engle, 2010).

5. Limitations

The present study has two limitations pertaining to sample selection. The first is that the unselected sampling procedure did not permit a balanced design. Thus, the DI groups were smaller than the non-DI groups. A second limitation is in the generalizability of DI samples to those with clinical depression. It is possible that dysphoric samples represent a milder form of depressed mood. Thus, future work is needed to explore the extent to which the present results extend to a clinically depressed population.

One could also ask whether the observed deficits in working memory for DIs are the consequence of their depressed mood, or a risk factor for the development and maintenance of depressed mood (cf. Demeyer et al., 2012; De Lissnyder et al., 2011). For example, Joormann et al. (2007) assessed whether children at high-risk for developing depression showed information processing biases for negative information. These researchers showed that, compared to children at lower-risk levels, those at high-risk for depression spent more time attending to negative information and less time attending to positive information. A similar risk-based sampling procedure might be employed with the present paradigm to assess whether the results observed here are the
consequence of depressed mood, or a possible marker for depressed mood, which could lend support for a novel endophenotype in depression (see Gottesman and Gould, 2003; Gotlib et al., 2006).

6. Conclusions

The present work demonstrates that depressive cues can have persistent effects on DIs’ working memory. Future work should assess under which conditions affective transfer can be mitigated and whether therapeutic or training techniques might be employed to reduce this effect. Our results support the notion that when depressive thoughts are part of conscious experience, cognition is adversely affected for persons with depressed mood.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jad.2015.06.056.

References


