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The Effects of Depression and Rumination on False Memory

Amy Turner
University of Colorado at Boulder

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Amy Turner

Cognitive Development Center

Department of Psychology and Neuroscience

University of Colorado at Boulder

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Honors Committee:

Dr. Yuko Munakata, Department of Psychology and Neuroscience (Thesis Advisor)

Dr. Mark Whisman, Department of Psychology and Neuroscience (Honors Representative)

Dr. Andrea Feldman, Department of Writing and Rhetoric

Abstract

Depression increases the likelihood of cognitive deficits, including memory impairments, but the effect of depression on false memories is debated. The current study investigated whether depressive symptoms are associated with increased negative false memories because participants generalize negativity (mood-generalization), or with accurate memory for negative materials (mood-congruency). Furthermore, the previous literature has not determined whether effects of depression on memory are due to depressive symptoms per se, or co-occurring rumination, and whether working memory is susceptible to memory errors in the same way as episodic memory. Therefore, the current study differentiated rumination from core depressive symptoms on memory measures, and investigated deficits in working memory. Results indicated that the mood-congruency theory was most consistent for depression, while rumination may lead to mood-generalization. Depressive symptoms showed non-significant trends toward poor recall of studied material, fewer false memories, less false recognition of new negative material, and greater awareness of false memories. Rumination showed non-significant trends toward poor recall of studied material, greater false recognition of new negative material, and less awareness of false memories. There were no significant correlations between working memory and depressive symptoms or rumination. In conclusion, rumination may be partly responsible for driving certain memory impairments often seen in depression.

Introduction

Depression is the "common cold" of disorders, affecting roughly 6.7% of the U.S. population age 18 and older annually (NIMH, 2008). It is a disorder associated with cognitive impairments, including impairments in memory, attention, and problem solving (Levin et al., 2007). Depression is associated with attentional deficits, especially in young adults, as well as short-term and working memory deficits in both verbal and visual tasks (see Castaneda, et al., 2007 for review). Memory deficits in depression are also present in autobiographical and episodic memory (see Levin et al., 2007 for a review). Although there are some conflicting findings, executive function impairment and recovery of these functions is mediated by depression severity (Castaneda, et al., 2007). The myriad of cognitive impairments seen in depression are thought to stem from neuroanatomical differences, including elevated glucocorticoids, reduced prefrontal cortex (PFC) functioning, and reduced hippocampal volume (Campbell & McQueen, 2004). Stress-induced elevated glucocorticoids, with a combination of other neurotransmitters, can lead to cell death in the hippocampal complex (Campbell & McQueen, 2004). The hippocampus is thought to be involved with important memory functions, such as the consolidation of explicit memories from short-term storage to long-term storage (Campbell & McQueen, 2004). Therefore, decreased hippocampal size in depression leads to memory impairments, and reduced PFC functioning explains deficits in attention and problem solving. Clearly, depression affects many important cognitive functions that have far reaching effects. The current study focuses on the memory impairments seen in depression.

First, I discuss the occurrence of false memories in depression, including the mixed findings in the literature regarding the generation of false memories (activation vs. retrieval). Second, I outline the two competing theories about false memories and depression, the negative

generalization theory and the mood-congruent theory, and discuss the gaps in literature regarding these theories. Third, I discuss the role of working memory in false memories, and the effect that rumination has on memories. Finally, I review the specific questions the current study addresses and the hypotheses are proposed.

Memory impairments in depression are clearly due to deficits at the level of encoding and retrieving information, but may also be associated with a tendency to remember differently, or inaccurately (Bower, 1981, and Blaney, 1986). An example of a frequent type of inaccurate remembering is false memory, when people recall something that was never actually present. False memory errors are common in normal populations, but are particularly common in depressive populations (Joorman, Teachman, & Gotlib, 2009, and Roediger, & McDermott1995).

False memories are thought to arise during encoding and retrieval, due to activation processes that schematically link words presented during a memory task to words that were not originally presented, therefore causing false memories during recall or recognition (Unsworth & Brewer, 2010). In other words, participants falsely recall words that were not presented because of implicit associations they make upon seeing the word and again upon recalling the word, in effect creating a memory of a nonexistent event (Roediger & McDermott 1995). An example of this process is illustrated in tasks requiring participants to remember, and later recall, words. For example, a subject may see the words “night”, “pillow”, “dream”, and so on, but never see the word “sleep”. Because “sleep” is closely associated with the words originally presented, participants may falsely recall seeing “sleep” initially (Roediger & McDermott, 1995). With the activation of associated concepts, in this case “sleep”, and a matching of the context in which the

other words were learned, false memories are established, generating a memory for an event that did not occur.

One prominent theory holds that false memories also arise due to a failure of the monitoring process (Unsworth & Brewer, 2010). The theory posits that this process ensures that the word being recalled is the correct one. It does this at encoding by ensuring participants are paying close attention to the actual word presented. However, if the participant is not warned to pay close attention to the qualities of each word, monitoring at encoding may produce errors. Additionally, the theory states that monitoring also works during retrieval by matching the context in which the word was learned with the context upon retrieval of the word. An example of a context would be the time and place a word was learned, along with the surroundings (e.g. the experiment room, and the experimenter). If there is overlap between these two contexts, the word is more likely to be either truly or falsely recalled by the participant (Unsworth & Brewer, 2010). Therefore, if monitoring at encoding fails and the contexts are the same between learning the word and retrieving the word, then more false memories usually occur. Thus, in theory, a failure of both the activation process and of the monitoring process at the level of encoding and retrieving must occur to lead to a falsely recalled word.

There has been research indicating that false memories occur more frequently in depression (Joorman, et al., 2009, Yeh & Hua, 2009, and Moritz, Glascher, & Brassen, 2005), but also contradictory research, indicating fewer false memories for individuals in negative moods (Storebeck & Clore, 2005). Storebeck & Clore (2005) also showed that false memories arise at encoding, rather than monitoring at retrieval. However, this study used induced negative mood, not naturally occurring chronic, negative mood states. Therefore, the literature is mixed with regards to whether higher rates of false memories in depression arise from differences in

activation or arise from differences in monitoring. The current study addresses this problem by introducing an externalized free-recall task (EFR). The EFR is a modified version of the DRM, discussed previously, that is designed to measure caught and uncaught false memories. If false memories arise from differences in activation, one would expect higher rates of false memories overall. Meaning, with the activation of related concepts, these related words are more often recalled, resulting in more false memories. However, if false memories arise from differences in monitoring, one would expect higher rates of uncaught errors only. Meaning that if participants are not paying attention to where they learned certain words, they are likely to make more errors, but also not catch them as easily. Thus, uncaught errors represent a failure of monitoring during retrieval.

There are two opposing theories of how false memories arise, and how memory differences contribute to the perpetuation of depression. The first theory posits that depression is associated with false recall of more negative information than in non-depressed people (Matt, Vazquez, & Campbell, 1992). This may lead to more negative information being accessible to memory than would otherwise be the case. This will hereafter be referred to as the negative-generalization theory. The second theory posits that people with depression actually have a mood-congruent memory bias, meaning they are more accurate in remembering negative material (Storebeck & Clore, 2005). In theory, this may lead them to falsely recall less negative information, but also more accurately remember negative occurrences in their chronic mood state. This will hereafter be referred to as the mood-congruent theory. In both cases, possible mood regulating strategies may be less efficient if negative information is more prevalent, regardless of whether they are real or false memories. This, in turn, may encourage ruminative

behavior, and exacerbate negative feelings. Understanding how memory functions in depression may influence treatments that rely on breaking this cycle.

Interestingly, it is unclear if depressed individuals falsely recall more negative memories than positive ones, or exhibit a mood-congruent memory bias by remembering negative material more accurately than positive material. Generally, depressed patients both correctly and falsely remember more emotionally charged words, and remember fewer emotionally neutral words than healthy participants (Moritz, Glascher, & Brassen, 2005). The authors suggest that this is because hippocampus sizes are frequently decreased in depressed patients, however their overactive amygdalas may compensate. As reviewed previously, the hippocampus is critical for memory in general, and the amygdala is involved with emotional memory (Campbell & McQueen, 2004). This results in more emotional words being remembered, while neutral words are being forgotten. However, it is still uncertain which kinds of emotional words depressed patients more often remember (negative or positive), and how they are remembering these words (accurately or inaccurately).

The negative-generalization theory says that depression may be associated with increased false memories for negative material. Indeed, research shows that depressed patients do falsely recognize more negative words (Joorman et al. 2009). This could occur because depressed patients judge positive words as less positive than non-depressed participants, and over-generalize negative words, leading to an enhanced memory for depression-related words, even if they were not originally presented (Yeh & Hua, 2009). Therefore, it follows that depressed patients may also be more susceptible to falsely recognizing more negative words in a recognition task than positive or neutral words, compared with non-depressed participants.

On the other hand, the mood-congruent theory says that depression may be associated with sensitivity to depression relevant material, and therefore a better memory for negative material, due to depressed participants' negative mood state. Research shows that negative mood is associated with less false recall (Storebeck & Clore, 2005). It was also found that depressed subjects generated more negative words that they had seen before, and generated fewer positive words that they had already studied (Watkins, Vache, Verney, Muller, & Mathews, 1996). Similarly, in explicit memory tasks depressed subjects also show mood-congruent memory for studied words, whereas non-depressed subjects more often falsely recognize emotionally negative words (Watkins, Mathews, Williamson, & Fuller, 1992). Finally, depressed patients show a mood-congruent bias towards negative materials in an explicit free-recall memory task, as well as implicit priming tasks (Bradley, Mogg, & Williams, 1995). The previous findings show that depressed participants more accurately remember negative information, both explicitly and implicitly, possibly because negative words are more salient than positive words to their chronic negative mood (mood congruency). It intuitively follows that depressed participants may not falsely recognize emotionally negative words compared to their non-depressed counterparts, who do not have an enhanced memory for negative words. In the same way, depressed participants may more often falsely recognize emotionally positive words than non-depressed participants because positive emotion is not congruent with their negative emotional state. However, there is a lack of research investigating if mood-congruency seen in recall tasks generalizes to recognition tasks in which new material is presented, as well as previously studied material. The current study seeks to fill this gap in the literature by employing a recognition task containing emotional words.

Overall, there are mixed results regarding both theories of mood-generalization and mood-congruency for negative material. Some studies suggest that there may not be any emotional bias in depressed participants for recognition tasks (Ferre, 2003, Banos et al., 2001, Calev, 1996, Bazin et al. 1996, as cited in Moritz et al, 2005). Moreover, many studies did not find statistically conclusive results regarding negative false recognition in depressed participants, mostly due to small sample sizes (e.g. Yeh & Hua, 2009, Moritz et al. 2005). Similarly, there are mixed results concerning mood-congruent memory in depressed patients compared with non-depressed participants (Murray et al., 1999 as cited in Moritz et al., 2005). Therefore, the current study seeks to address this inconsistency in the literature. We seek to clarify if mood-congruent memory is present in participants with depressive symptoms, which would result in fewer false memories for negative material, or if negative material is more vulnerable to generalization, which would result in more false memories in depression.

Returning to false memories more generally, previous research has found that false memories occur in episodic memory in depressed populations, but has not investigated the effects of depression on false memories in working memory. Episodic memory is important for recalling specific personal past experiences. Conversely, working memory is a system that temporarily stores and manipulates information, and is important for higher level processing, such as language comprehension, learning, and reasoning (Baddeley, 1992). This project aims to determine if the same mechanism that leads to errors in episodic memory also contributes to errors in working memory in depression.

Finally, depression frequently occurs with comorbid symptoms, such as rumination. However, this fact has not been taken into account in previous research on depression and memory errors. Rumination means dwelling on negative experiences, events, and feelings and

their implications. Rumination has been shown to aggravate depression, predict the onset of depression, and is associated with other pathologies in addition to depression, such as anxiety, binge eating, binge drinking, and self-harm (see Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008 for review). Furthermore, according to the cited review, there is a deficit in problem solving in ruminative depression, making a change in circumstances difficult. For these reasons it is imperative to separate the effects rumination has on memory from the effects depression has on memory, in order to understand the underlying mechanisms of rumination. In fact, rumination is thought to extend to memory, meaning a fixation on negative memories which in turn fuels a negative conception of current life circumstances (Nolen-Hoeksema, et al., 2008).

There is limited evidence of the effect of rumination on memory, however there is some evidence that rumination may contribute to more impairments in tasks that induce rumination in already depressed groups (Herte, 1998). Since rumination has been found to decrease memory specificity, meaning it obscures the origin of memories, rumination may increase the tendencies to generate false memories that are perceived to be real memories (Yeh & Hua, 2009). Conversely, if the mood-congruent theory is correct, meaning a better memory for material that is negative, and depressive symptoms alone show increased accuracy for remembering negative material, trait rumination may show the opposite trend due to decreased memory specificity. This means that ruminative tendencies may lead to decreased accuracy for the recognition of new negative material. This could be because ruminative cognitive styles that lack memory specificity may lead participants to be unable to correctly identify the origin of the false memory, making new words appear to be old. Since the new words are thematically related to the old words, rumination may further inhibit the ability to correctly identify which words were learned and which words were not. As a result, ruminative styles would lead to an inability to

differentiate between words that previously appeared versus words that did not appear. Therefore, the theory is that depressive symptoms and rumination may have opposing effects when it comes to memory.

This theory is supported in the literature through a finding which indicates that depression and rumination may have opposite effects on executive control (Altamirano, Miyake, & Whitmer, 2010) and that rumination is characterized by an inflexible cognitive style (Davis & Nolen-Hoeksema, 2000). The former study found that trait rumination leads to better performance on tasks that required maintaining a goal, but worse performance on a fast-paced task that required switching rules. Because memory is thought to rely on components of executive function (EF), it is plausible that these EF results may generalize to memory (Levin et al., 2007). This mental inflexibility seen in goal-maintaining tasks may be due to a 'mental stickiness' present in ruminative styles that enables retaining the same rule over a long period of time (Altamirano et al., 2010). Therefore, the predictions for the current study include a 'mental stickiness' for the word themes in recall memory tasks. With maintenance of the themes, trait rumination may lead to confusing new words that adhere to the theme as being old words.

Previous research on memory impairments in depression does not often control for rumination. Thus, the interpretation of literature regarding depression and memory impairments is limited. It is possible that there are sub-symptoms of depression (like rumination) that actually drive memory deficits more than core depression symptoms, despite the frequency of research showing memory impairments in depression. This project aims to shed light on the impact ruminative behavior has on false memories and general memory impairments, when controlling for depression. If rumination alone does disrupt accuracy of memory, both in recall and

recognition situations, this could hold important implications in targeting ruminative patterns in therapy.

To better understand memory errors and their relationship with depressive symptoms in a non-clinical sample, the current study addresses 1) how depressive symptoms affect false memory, 2) if there is a bias towards negative false memories associated with depressive symptoms or 3) if there is a bias towards mood congruent memories associated with depressive symptoms and 4) if false memories are experienced in working memory, similar to episodic memory. Previous research leads us to believe that: (1) Rumination will lead to increased false memory, compared with just depressive symptoms, (2) participants with depressive symptoms may recognize more negative (emotional) valence words that were never shown (generalized mood theory) or 3) participants with depressive symptoms may recognize fewer negative valence words that were never shown compared to normal participants (mood-congruent theory), and 4) participants with depressive symptoms will exhibit similar deficits in working memory, as are seen in episodic memory.

Methods and Procedure

Participants

Participants were 34 undergraduates from the Department of Psychology and Neuroscience subject pool, who received course credit for participation. Participants gave informed consent, following procedures approved by the Institutional Review Board of the University of Colorado, Boulder. All participants spoke English as their first language. All participants received a debriefing sheet explaining the intent of the study, and the nature of the tests and questionnaires they completed. Additionally, participants received referrals in case any issues arose during the study that may have caused them to want to speak to a mental health professional.

Tasks and Procedure

Participants completed three tasks assessing memory; the Deese, Roediger, McDermott (DRM) task, the externalized free recall task (EFR), and the recent probes task, as well as two control measures (the NAART task and the Choice RT task). Participants then completed two self-report questionnaires relating to rumination and depression.

DRM task

The DRM task was used to measure memory errors and to manipulate the emotional content of words in order to determine their effect on false memory. In this task, participants read lists of thematically related words. There were five lists, each containing 15 words from the original DRM task (Roediger & McDermott, 1995). The list themes included river, shirt, army, smell, and music. The words were shown one at a time for 200 ms each, with 15 words in each trial Participants were instructed to keep their eyes on the screen and try to remember as many words as possible for each list. After viewing each list, they were given 30 seconds to recall as many words as possible in any order, known as *free recall*. The dependent variables for the free recall task were 1) correct responses, 2) *critical lure words* reported, and 3) incorrect responses. Critical word lures are words that are closely associated with the original words the participants were asked to remember. For example, participants may be shown the following words: "soldier, rifle, draft, marines, uniform" and so on. Then on the recall task, the participant may write down the word "army", a word that is extremely related, but was never actually shown. The critical lure words for each list is the same as the list theme (e.g. army is the theme of the list, and also the lure word).

After studying and performing the free recall task on all lists, participants completed a recognition task. For this task, participants saw a list of words, and were asked to indicate if the word was old (from the list) or new (not from the list). They were then asked to indicate their confidence in their response on a scale from 1-not confident, to 5-very confident. Participants were instructed to respond as quickly as possible without making mistakes. The recognition list was comprised of 75 old words that the participant saw, and 75 new words that they had not seen. The new word list was comprised of 25 positive words, 25 negative words, and 25 neutral words. The dependent variables for the recognition DRM was 1) accuracy for old words, 2) accuracy for new negative words, 3) accuracy for new positive words, and 4) accuracy for new neutral words. An example of the recognition task is illustrated below, which contains neutral, negative, and positive lists for the theme word ARMY:

Neutral (unstudied)	Negative (unstudied)	Positive (unstudied)	Studied words		
Headquarters	Force	Loyalty	Navy	Draft	Captain
Recruitment	Destruction	Aid	Soldier	Military	War
Battalion	Conflict	Defend	U.S.	Marines	Uniform
Ranks	Struggle	Liberation	Rifle	March	Pilot
Army	Battle	Victory	Air Force	Infantry	Combat

Neutral words included the original critical word lures from Roediger and McDermott (1995), plus four additional neutral words generated by the author. The four additional words were other neutral words closely associated with the studied words from Roediger and McDermott (1995).

The negative and positive lists used for the recognition task were generated for the current study. All generated words were evaluated using two psycholinguistic databases to ensure that negative, positive, and neutral words were matched on (1) association strength with the studied word lists, (2) frequency, and (3) word length. Association strength was evaluated using latent semantic analysis (LSA - *http://lsa.colorado.edu/*) which analyzes large bodies of texts to (1) calculate the co-occurrence of each new word to its corresponding studied word list and (2) to calculate the similarity in meaning of the new word and each word on the studied word list by analyzing contexts in which they both occur separately from one another (Landauer & Foltz, 1998). For example, synonyms, like "happy" and "glad," would not frequently occur in the same sentence together (co-occurrence), but would occur in the same contexts (similarity). For each word the LSA cosine is calculated which can have a range of -1.0 to 1.0. A low value corresponds to low similarity and low co-occurrence. Conversely, a high value signifies a high amount of similarity and high co-occurrence. Words with cosines 0.1 and above were considered for construction of word lists. Kucera-Francis written frequency and word length were evaluated using the MRC Psycholinguistic Database (Kucera & Francis, 1967; *http://www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm*).

Externalized free-recall

This task was administered as in Unsworth and Brewer (2010) and was designed to measure rates of false memory and to manipulate the emotional content of words in order to determine their effect on false memory. In addition, this task was designed to measure how well participants could catch potential false memories. Participants studied five lists of thematically linked words, similar to the DRM task, with 15 words in each list. The themes are lion, king,

sleep, doctor, and fruit. Participants were instructed to keep their eyes on the screen and to remember as many words as they could. Words were shown one at a time for 200ms each, with 15 words in each trial. After each list was studied, the participants were given 30 seconds to recall the words on the list, and note any other words that came to mind, even if they were aware that those words did not appear on the list. Additionally, the participants were asked to indicate with an X if they reported a word they knew did not appear on the list. In the recall phase of the task, participants are given the chance to write down any words that come to mind and then mark the ones they know did not appear in the lists. For example, participants may see "shoe", "collar", "iron", "sweater", etc. When recalling these words, participants may think of related words such as, "shirt" or "pants". If they write these words down and are aware of their incorrectness, they are then able to indicate that these words did not appear on the list (caught errors). However, if they do not indicate that these words are correct, these are uncaught false memories. The number of errors that were correctly identified as being false (successful monitoring) and those that were not identified (false memories) were measured. The dependent variables in the externalized free recall task were 1) correct responses, 2) lured words reported, 3) incorrect responses, and 4) number of memory errors caught.

After studying and performing the externalized free recall task on all lists, participants completed a recognition task. For this task, participants saw a list of words, and were asked to indicate if the word was old (from the list) or new (not from the list). They were then asked to indicate their confidence in their response on a scale from 1-not confident, to 5-very confident. Participants were instructed to respond as quickly as possible without making mistakes. The recognition list was comprised of 75 old words that the participant saw, and 75 new words that they had not seen. The new word list was comprised of 25 positive words, 25 negative words,

and 25 neutral words. The dependent variables for the recognition EFR version of the DRM was 1) accuracy for old words, 2) accuracy for new negative words, 3) accuracy for new positive words, and 4) accuracy for new neutral words. The new words used for the recognition EFR version of the DRM were calculated in the manner described above.

Recent negatives task

The recent negatives task assesses working memory, and was administered similar to Jonides & Nee (2006). Participants viewed a set of 4 letters on a computer screen for 1500ms on each trial and were instructed to remember them. After the letters were presented there was a delay of 8 seconds, after which a probe letter was presented. Participants indicated whether the letter appeared in the last set of letters they saw or if it was new. There were four types of trials used in this task: recent negative, recent positive, non-recent negative, and non-recent positive. Critically, the *recent negative trials* did not match any of the letters on the most recent trial, but did occur in the previous two trials. For example, a participant first saw "j, p, m, and s" (see Figure 1 for an illustration of the examples that follow). After a delay, they saw the probe letter "J" on the computer screen; a letter that was shown on the previous trial. The next set of letters may be "l, s, j, and f." After a delay, the participant saw the probe letter "M", a letter that recently appeared on the first trial, but not the second, most recent trial (A). Recent positive trials (B) are the same as recent negative trials except the probe letter occurred on the current trial as well as the previous trial. In the non-recent negative trial (C), the probe did not appear on the current trial or the previous trial. In the non-recent positives trial (D), the second probe letter appeared in the most recent trial, but not the previous trial. In this task, it is common for participants to show slower reaction times in the recent-negative trials, because the probe letter is

familiar, similar to false memories for semantically familiar words in the DRM task. The dependent variable on this task was an interference number for each participant. The interference number was calculated by subtracting the mean RT of the recent negative trial from the mean RT of the non-recent negative trial and dividing by the mean RT of the non-recent negative trial. This calculation controlled for any differences in motor speed between participants.

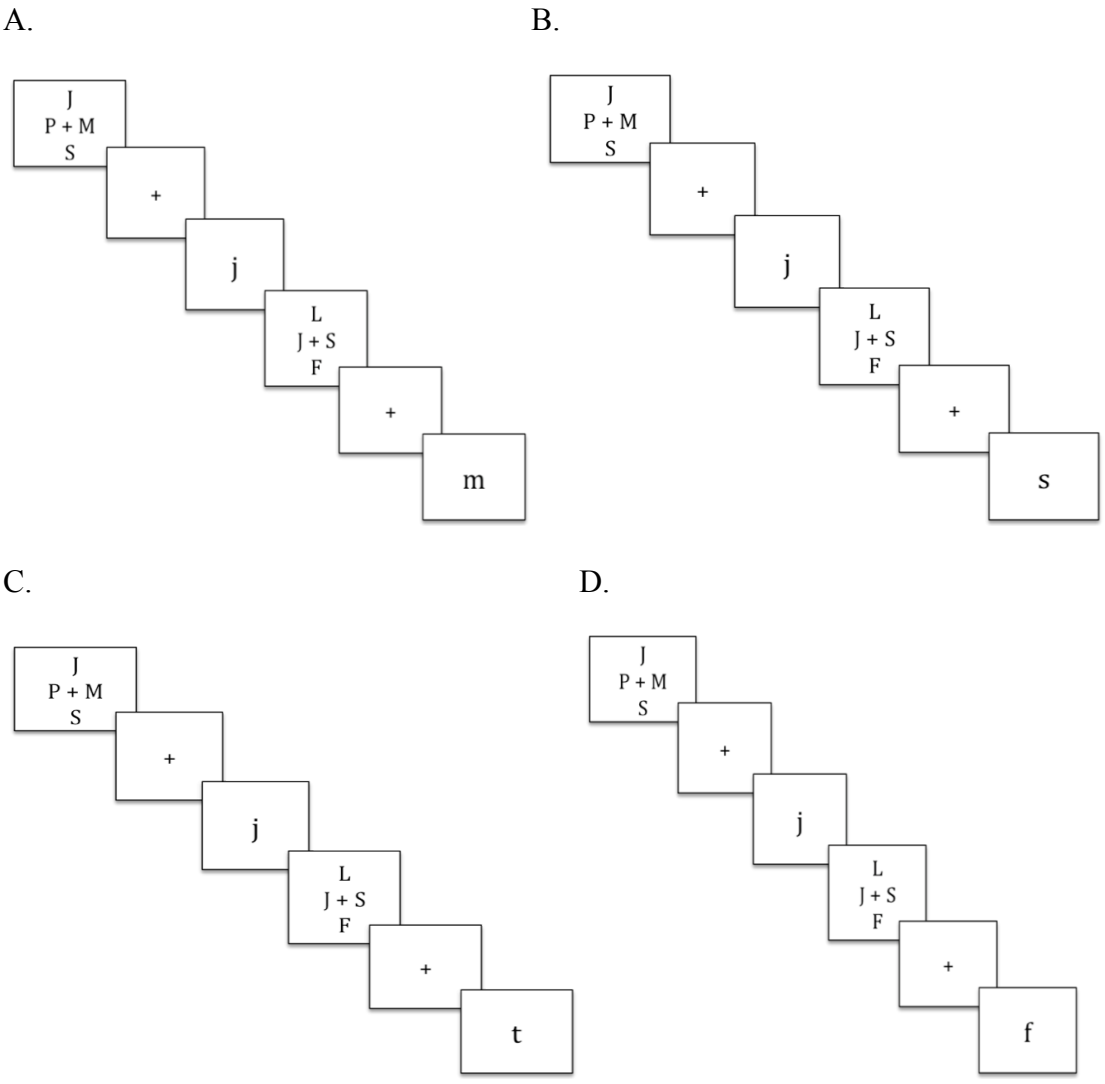

Figure 1: Example sequence of trials in the recent negatives task. A. Recent negative trial. B. Recent positive trial. C. Non-recent negative trial. D. Non-recent positive trial. Diagram reproduced from Jonides and Nee (2006)

NAART

This task was used to control for crystallized (verbal) intelligence, to ensure that any correlations between the dependent measures and depressed and rumination were not due to differing intellectual levels. The North American Reading Test (NAART) is a widely used index used to estimate intellectual ability (Blair & Spreen, 1989). Participants were asked to read a list of irregular words aloud, that were shown on a computer screen. Correct pronunciation indicated that the participant had previously learned this word, and therefore measures verbal IQ. If they were unsure of the pronunciation, they were instructed to say the words the way they thought the word should sound. Sixty words were included, which increased in difficulty (e.g. "reign" and "demesne"). The number of incorrect pronunciations was summed, and was transformed into estimated IQ scores by the established NAART calculations (Blair & Spreen, 1989).

Choice RT

This speed task was used to control for processing speed, to ensure that any differences seen between the dependent measures and depressed and rumination were not due to processing speed. Participants saw a triangle pointing to the left or to the right on the computer screen, and were asked to press either the left and right arrow buttons, depending on the direction the triangle was pointing. Participants were instructed to respond as fast as they could without making mistakes.

Self-report Questionnaires

After the memory tasks were complete, each participant completed two questionnaires relating to depression and rumination.

The Beck Depression Inventory – Second Edition (BDI-II) (Beck, Steer, & Brown, 1996) consists of 21 groups of statements and is designed to measure depression. Each group of statement corresponds to a feeling or sentiment. For instance, one item of one group may be "pessimism" and the participant had to choose the most personally appropriate statement:

1. I am not discouraged about my future
2. I feel more discouraged about my future than I used to be
3. I do not expect things to work out for me
4. I feel my future is hopeless and will only get worse

Other items include "sadness", "loss of interest", and "difficulty concentrating." The participants were instructed to choose the answer that corresponds to how they have felt in the past two weeks, including the current day. All responses were summed to calculate the participants' total score. Low scores indicate the absence of depressive symptoms, whereas high scores indicate the presence of depressive symptoms. The scores ranged from 0-63.

The Rumination-Reflection Questionnaire (RRQ) (Trannell & Campbell, 1999) consists of 24 statements that measure rumination and reflection tendencies. However, for this study only the rumination subscale was included in analysis. An example of a rumination statement is, "Long after an argument or disagreement is over with, my thoughts keep going back to what happened." The participant was instructed to respond on a scale of 0-4, zero meaning strongly disagree and four meaning strongly agree. Twelve statements represented the rumination subscale. The responses for the rumination subscale were summed to calculate each participant's rumination score. High scores on the rumination subscale indicate greater rumination, while low scores

indicate less ruminative tendencies. Scores on the rumination subscale range from 12-48. Three statements on the rumination subscale were reversed scored to ensure validity.

Results

For each participant, reaction time data were screened for 1) incorrect responses, 2) large reaction times (RTs), and 3) short RTs. Response times greater than three standard deviations above the participants mean were excluded from analysis, along with response times less than 200ms. The remaining RTs were log transformed, and the mean for each participant was calculated for use in analysis.

Control Tasks

The NAART task, used to control for IQ, was marginally positively correlated with depression (BDI), ($r(34)=.306$, $p=.079$), but was not correlated with rumination (RRQrum), ($r(34)=.142$, $p=.423$), see Figure 1. The NAART was also correlated with trends nearing significance with several dependent measures. Therefore, IQ was controlled for in all subsequent analyses. This ensures that the correlations between performance on the recall and recognition tasks and depressive symptoms and rumination were not due to IQ.

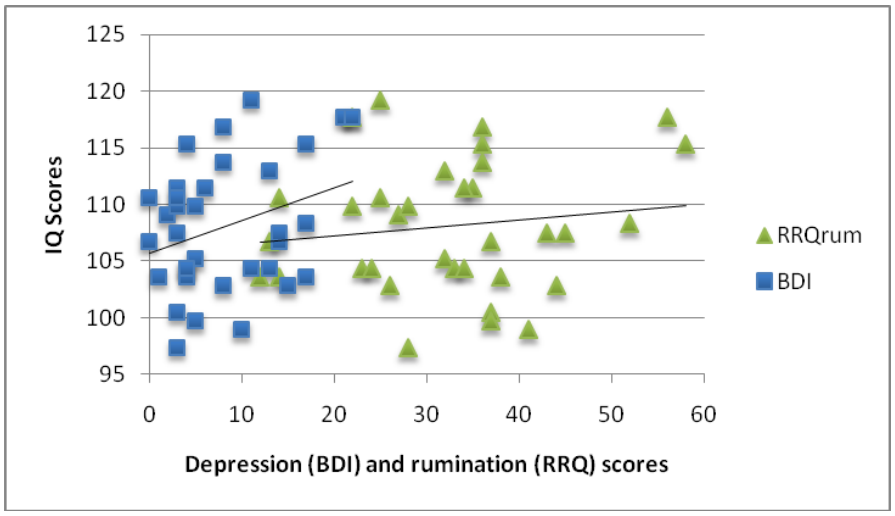

Figure 1: Correlations between NAART (IQ) and depression and rumination. There is a marginal correlation between IQ and depression, but not between IQ and rumination.

The Choice RT task, used to control for processing speed, showed no correlation with depression or rumination ($r(34)=.007$, $p=.967$, and $r(34)=.039$, $p=.826$, respectively. Since there were not significant correlations between these variables, any correlation between performance on the recall and recognition tasks and depressive symptoms or rumination were not due to differences in processing speed.

DRM and EFR-DRM

Recall

Data were excluded for poor performers, which was defined as any accuracy of 30% or less. Outlier analysis was performed for depressive symptoms and rumination, separately, for each condition and for both recall tasks (dfBeta>$2/\sqrt{n}$). Therefore, participants were excluded from recall tasks if they were a poor performer, an outlier, or both. In order to observe the effects of rumination and depression separately, all partial correlations were performed controlling for depression or rumination appropriately. The key, yet non-significant, findings for the recall tasks were: participants with depressive symptoms and rumination recalled fewer studied words,

depressive symptoms led to fewer false memories and to more caught errors, whereas rumination did not affect number of false memories but led to more uncaught false memories.

Accuracy for studied items. DRM and EFR-DRM recall mean accuracy for studied words was calculated out of the total words on the list (75). Participants who exhibited elevated depression and rumination recalled fewer studied items correctly on the DRM and EFR version of the DRM (EFR-DRM) recall task. On the DRM task, depressive symptoms indicated a non-significant trend for poor performance on the recall task ($r(28)=-.268$, $p=.169$). When controlling for rumination, this effect became stronger and marginally significant ($r(24)=-.352$, $p=.084$), see Figure 2. On the DRM task, rumination also showed a non-significant trend for poor performance ($r(28)=-.250$, $p=.199$). When controlling for depression, this effect became stronger, ($r(24)=-.319$, $p=.129$), see Figure 2. There was no trend for a correlation between depression and accuracy on the EFR-DRM task ($r(29)=-.120$, $p=.536$). However, when controlling for rumination, there was a non-significant trend towards a negative correlation between depressive symptoms and accuracy ($r(25)=-.234$, $p=.249$), see Figure 3. There was no trend for a correlation between rumination and accuracy on the EFR-DRM recall task ($r(30)=-.120$, $p=.536$), even when controlling for depression, $r(25)= -.122$, $p=.552$), see Figure 3.

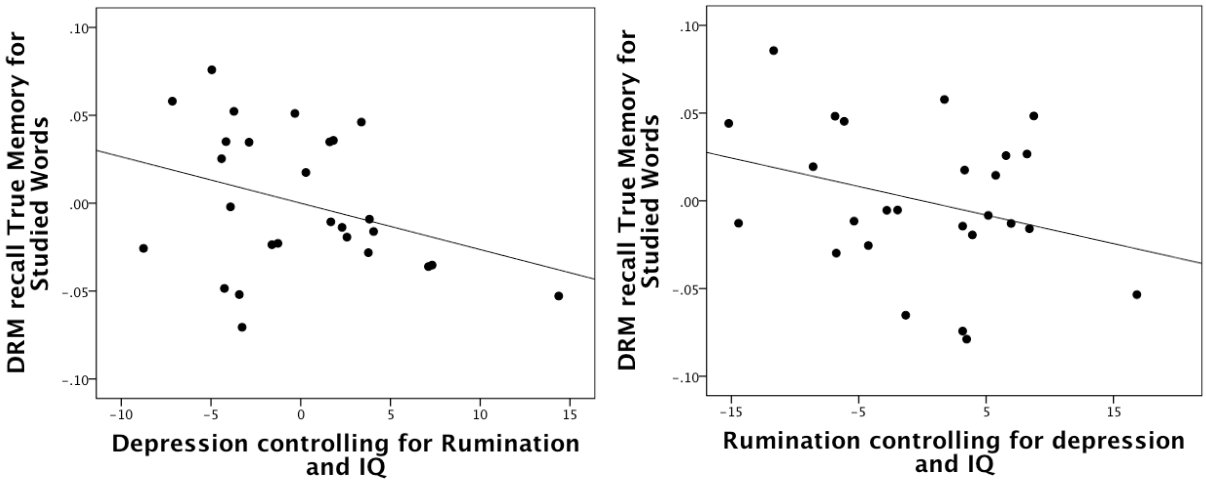

Figure 2: Correlation between DRM recall accuracy for studied words and depression and rumination. Both depressive symptoms and rumination showed non-significant trends towards poorer recall of studied words.

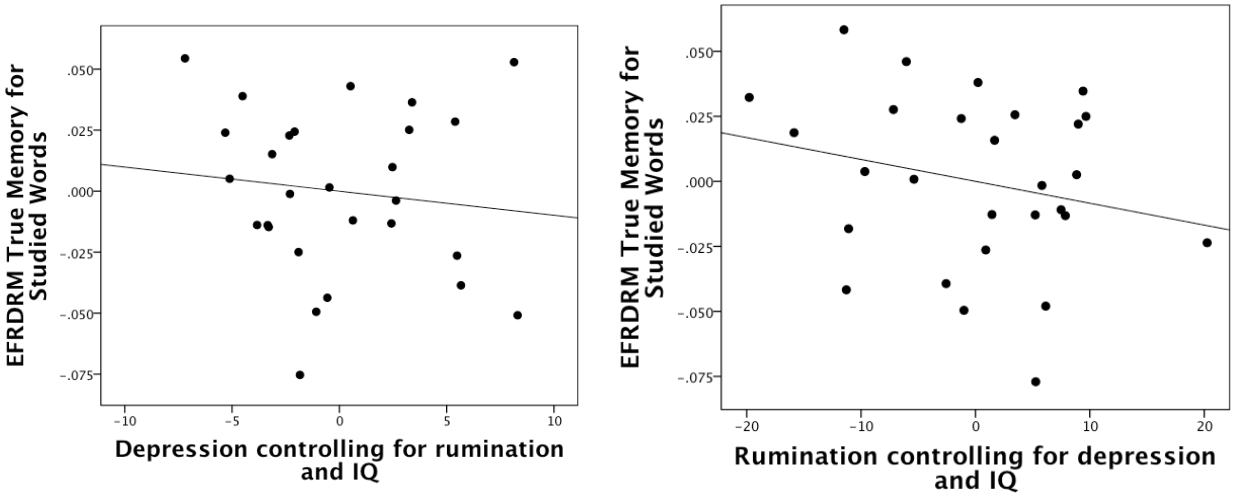

Figure 3: Correlation between EFR-DRM recall accuracy for studied words and depression and rumination. Depressive symptoms showed non-significant trends towards poorer recall of studied words. There was no correlation between rumination and poor recall of studied words on the EFR-DRM.

False memories. False memories were calculated out of total words reported and included incorrect responses and lured words for the DRM task. For the EFR-DRM task, false memories were calculated out of total words reported and included incorrect responses, lured words, and incorrectly marked words.

There was no trend between depression and false memories on the DRM task ($r(28)=-.137$, $p=.488$), even when controlling for rumination ($r(24)=-.084$, $p=.691$).Similarly, there was no trend between rumination and false memories on the DRM recall task ($r(28)=-.04$,

p=.841), even when controlling for depression (*r*(24)=-.143, *p*=.486). Participants with more depressive symptoms showed a non-significant trend towards fewer false memories on the EFR-DRM (*r*(29)=-.265, *p*=.164). When controlling for rumination, this effect became marginally significant (*r*(27)=-.340, *p*=.076), see Figure 4. There was no correlation between rumination and false memories on the EFR-DRM task (*r*(29)=.033, *p*=.867), even when controlling for depression (*r*(24)=-.097, *p*=.637), see Figure 4.

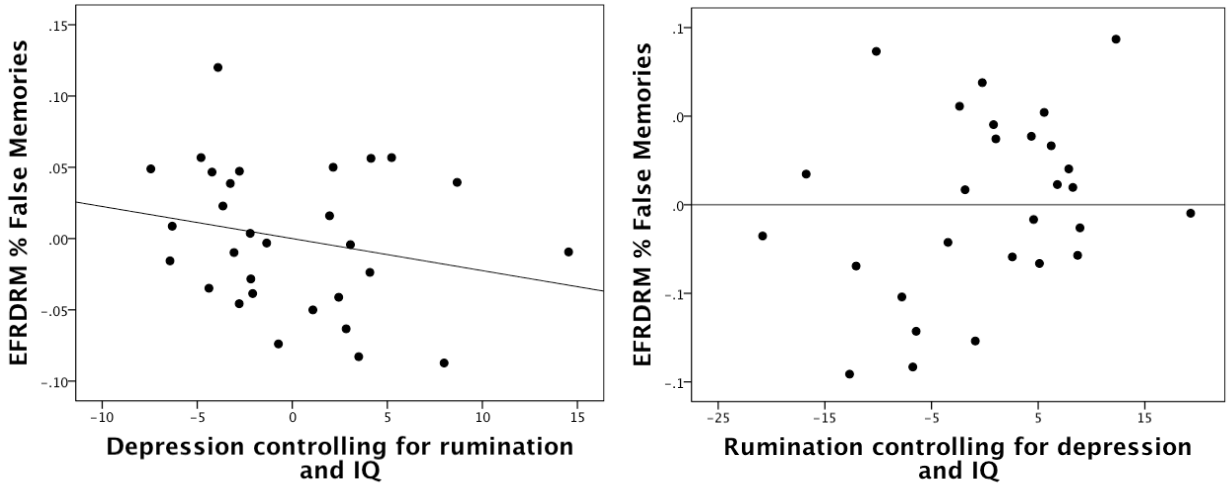

Figure 4: Non-significant trend between EFR-DRM false memories and depression and rumination. Depressive symptoms are non-significantly associated with fewer false memories, whereas rumination showed no effect on false memories.

On the externalized free recall task, false memories were calculated as percentage of errors caught out of total errors made. There was a non-significant trend for depressive symptoms to predict more caught false memories (*r*(29)=.285, *p*=.134); when controlling for rumination, this effect became stronger (*r*(25)=.306, *p*=.128), see Figure 5. On the other hand, rumination did not predict false memories alone (*r*(29)=-.157, *p*=.415), but when controlling for depression higher rumination marginally predicted more uncaught false memories (*r*(25)=-.371, *p*=.062), see Figure 5.

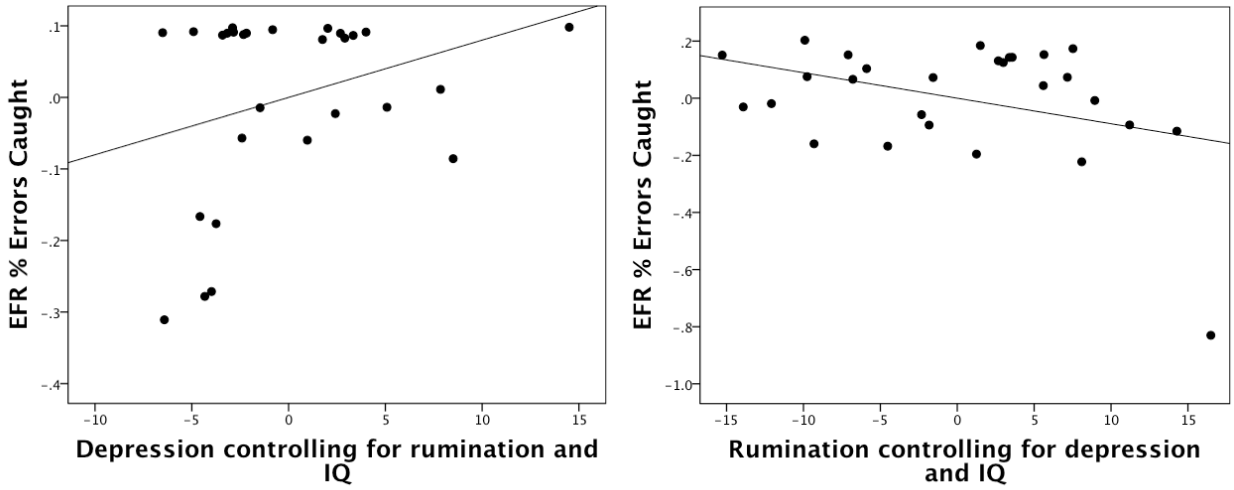

Figure 5: Opposite non-significant trends between EFR errors caught and depression and rumination. Depressive symptoms non-significantly indicated more errors caught, whereas rumination non-significantly indicated more uncaught false memories.

Recognition

Data were excluded for poor performers, which was defined as accuracy of 65% or less on the condition measuring recognition for old words. Outlier analysis was performed for depressive symptoms and rumination, separately, for each condition for both recognition tasks (dfBeta>2/$\sqrt{n}$). Therefore, participants were excluded from recall tasks if they were a poor performer, an outlier, or both. The key non-significant trends for the recognition tasks showed poorer recognition of old words for both depressive symptoms and rumination, depressive symptoms showed a slight non-significant trend towards better accuracy when recognizing negative new words, and rumination showed a slight non-significant trend towards poorer recognition of new negative words.

Accuracy of old words. On the DRM task, there was no correlation between depressive symptoms and correct recognition of old words ($r(30)=-.084$, $p=.658$). However, when controlling for rumination, there was a trend for depressive symptoms to indicate worse memory of old words on the DRM task ($r(26)=-.248$, $p=.212$).There was no correlation between

recognition of old words and rumination ($r(30)=-.021$, $p=.913$), even when controlling for depression ($r(26)=-.021$, $p=.916$). Likewise, there were no correlations between depressive symptoms and rumination and recognition of old words on the EFR-DRM, ($r(28)=-.127$, $p=.520$) and ($r(28)=.022$, $p=.913$, respectively). Even when controlling for rumination, there were no trends between depressive symptoms and correct recognition of old words on the EFR-DRM ($r(24)=-.076$, $p=.718$) and no trend for rumination, when controlling for depression ($r(25)=.107$, $p=.604$).

Accuracy of new words. There was no correlation between depressive symptoms and correct recognition for negative word on the DRM task ($r(30)=.140$, $p=.460$) even when controlling for rumination ($r(27)=-.033$, $p=.867$). Likewise, there was no correlation between rumination and negative word accuracy on the DRM recognition task ($r(30)=.186$, $p=.324$) even when controlling for depression ($r(25)=-.012$, $p=.954$).

Interestingly, there was a non-significant trend for depressive symptoms to correlate with better accuracy for correctly recognizing negative words as new on the EFR-DRM task ($r(28)=.236$, $p=.227$). When controlling for rumination, this non-significant trend remained ($r(24)=.208$, $p=.319$), see Figure 6. There was no correlation between rumination and accuracy for correctly recognizing negative words as new on the EFR-DRM task ($r(28)=-.075$, $p=.705$). However, when controlling for depression, there was a non-significant trend for rumination to correlate with poorer accuracy for correctly recognizing negative words as new ($r(25)=-.230$, $p=.257$), see Figure 6.

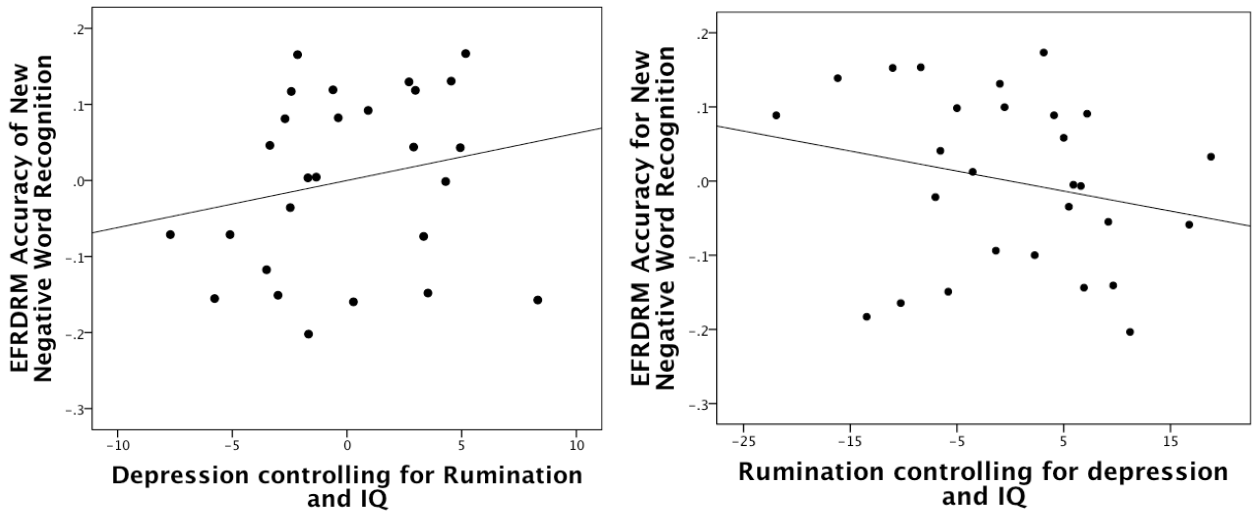

Figure 6: Opposite non-significant trends between correct EFR negative word recognition and depression and rumination. There was a non-significant positive trend between depressive symptoms and correctly recognizing new negative words as new. There was a non-significant negative trend between rumination and correctly recognizing new negative words as new.

Recent Probes

Recent negatives. Analysis of the recent probes task focused on the recent negative condition because this is the core measure of working memory. In order to control for any differences in motor speed between subjects, an interference score was calculated for each participant by subtracting the mean RT of the recent negative trials from the mean RT of the non-recent negative trials and dividing by the mean RT of the non-recent negative trials.

There was no correlation between recent negatives interference and rumination (r(29)=.153, p=.429), even when controlling for depression (r(26)=.131, p=.514). There was also no correlation between depressive symptoms and recent negatives interference (r(34)=.025, p=.887), even when controlling for rumination (r(31)=-.068, p=.713).

Discussion

Everyone experiences memory errors, but people with depressive symptoms may be more susceptible to some, but less susceptible to others, like false memories. Rumination, a symptom of depression, may be a key mechanism that is driving memory deficits in depression. The current study found that rumination seems to lead to mood-generalization, and, therefore, to more negative false memories. Additionally, when compared with depressive symptoms, rumination seems to disrupt memory retrieval and monitoring, resulting in less awareness of false memories.

Memories for studied words seemed to be equally impaired with rumination and depressive symptoms. In the tasks that required participants to recall a set of words that had been previously shown, both rumination and depressive symptoms were associated with poorer recall accuracy of studied items in the DRM task. These findings are consistent with the previous literature that found that depression is associated with core memory impairments, such as recall impairments (Levin, et al., 2007, and Campbell & McQueen, 2004). However, in the EFR-DRM task this effect was only seen for depressive symptoms; there was no relation between accuracy and rumination. This difference between the tasks may be due, in part, to the design of the EFR task. The nature of the task alerts people to the possibility of errors, which may change their behavior in some way. Also, rumination tends to show less robust effects for studied items, than depression, which could account for weak results of recall of studied words. Yet, it is unclear why current results differ across tasks, and whether the same patterns will emerge with more subjects.

When looking at false memories rather than accuracy for studied words, there was some evidence that depressive symptoms led to fewer false memories. Results for total false memories

on both DRM and EFR-DRM tasks were fairly inconclusive, indicating only slight, yet non-significant, trends for depressive symptoms. Depressive symptoms may lead to fewer false memories overall only on the EFR-DRM task, but not on the DRM task. This could be explained by considering the implications of the design of the EFR-DRM task; participants may be alerted to the need to monitor because they are asked to mark errors. Therefore, when participants with higher depressive symptoms are alerted to the possibility of making errors, they may be more attentive in monitoring for errors than those with lower depressive symptoms. Rumination did not seem to have an effect on the total number of false memories in either the EFR-DRM or the DRM task.

However, when false memories caused by monitoring failures are considered separately from total false memories, opposing effects of depressive symptoms and rumination become apparent. The externalized recall-task required participants to recall words they remembered as well as other words that came to mind, and then indicate which words they knew did not appear on the task (caught errors). Those with higher depressive symptoms caught a larger percentage of potential false memories that could have occurred, though not significantly, while those with higher rumination caught a lower percentage of their false memories, though not significantly. Previous literature on this task suggests that catching errors depends on both search constraints and source monitoring processes (Unsworth & Brewer, 2010). This could mean that rumination may be associated with recalling a broad range of possible words (poor search constraints) as well as an unawareness of the origin of the word (poor source monitoring). This theory is supported by findings that ruminative thinking leads to an over general thinking style in patients with depression and a lack of memory specificity (Watkins & Teasdale, 2001). Therefore, over general memory could lead to broader search constraints and more words available for recall,

while a lack of memory specificity could lead to poor source monitoring. Thus, rumination may cloud the source of the memory for a word, leading the participant to recall a word that was not originally seen in the study, but may be related.

It is not clear if these monitoring deficits associated with rumination during recall extend to recognition. Results for the recognition of old words were inconclusive. Higher depressive symptoms were associated with poorer correct recognition of old words as old, but this effect was only found for the DRM task, not the EFR-DRM task. Rumination showed no effect on accuracy of old word recognition on either the DRM or the EFR-DRM. The large differences seen between accuracy of studied words on the recall task (poor for both rumination and depressive symptoms) and accuracy of recognition of old words may be explained by different cortical mechanisms used to process different types of information. Effects of depressive symptoms on recall are possibly stronger because recall relies heavily on the hippocampus. Hippocampus activation is stronger than the medial temporal lobes, which are activated during recognition tasks, but are relatively weak (Montaldi & Mayes, 2010). Therefore, this finding may account for less conclusive results on the recognition tasks compared to the recall tasks.

The results for recognition of new words indicated that depressive symptoms may lead to better new word recognition and rumination may lead to poorer new word recognition. Depressive symptoms were associated with increased recognition of negative words as being new whereas rumination were associated with a tendency to incorrectly identify new negative words as being old. This may show a mood-congruency effect for depressive symptoms because a sad mood leads to remembering emotionally negative words better. Conversely, these results may show a mood-generalization effect for rumination because more negative words were

incorrectly recognized as being old. However, these patterns were only found for the EFR-DRM task, but not the DRM task.

Among the recognition tasks, for old and new words, there were several inconclusive results between the DRM and the EFR-DRM task. The differences between the results on each task may be due to the design of the EFR recall task interacting with separate memory deficits in depressive symptoms versus rumination. The design of the EFR task alerts participants to the possibility of errors, which may change behavior in higher depressive participants. Previous research shows that negative affect, which is related to depression, leads to higher sensitivity to errors, particularly under pressure to perform accurately on tasks (Hajcak, McDonald, & Simons, 2004). Therefore, upon being alerted to the possibility of error, participants with higher depressive symptoms may deliberately pay more attention to the words presented on the EFR task.

On the working memory task, there were no trends for either depressive symptoms or rumination, even when controlling for each other. It is likely that either more participants are needed to see any effect on working memory, or depression and rumination do not affect working memory in the same way they affect episodic memory.

Although the current study has interesting implications for understanding the core differences between the effects of depressive symptoms and rumination on false memories, there are some limitations. Clearly, more subjects are needed to achieve statistical significance, and to attain a clearer picture of the relations between rumination, depression, and memory. More power, obtained through more participants, allows for greater detection of correlations, if they are present. Furthermore, a larger sample size would allow us to look at other comorbid disorders of depression, such as anxiety. It would also be interesting to look at effects of depression and

rumination on other aspects of executive functioning, like planning, problem solving, and organization. In the current study, participants often mistook correct answers as false memories (meaning they put an X next to words that actually appeared in the trials). These sorts of errors may reflect a lack of memory specificity, discussed earlier, in which participants may mistake the origin of the word. No significant effects were seen for this phenomenon, however, more subjects could lead to more frequent mistakes of this sort. Since there seemed to be a pattern in the current study that rumination may direct mistakes, future studies should differentiate between different mistakes that are being made, instead of looking simply at total mistakes made by each participant.

Generalizability of this study may be limited given the sample consisted of undergraduate college students. On one hand, using non-clinical samples allowed us to see the effects of rumination and depressive symptoms without the interference of as much medication that may be present in clinical samples. It also allows us to capture a broader range of depressive symptoms and rumination than possible in a clinical sample. On the other hand, there would be greater effects of depression and rumination present in clinical samples, and therefore results would be more helpful in aiding actual patients. Future research should account for the implications of different sample populations.

In summary, although the results are non-significant and only at trend level, they uncover interesting possibilities. Results show that depressive symptoms and rumination may lead to memory deficits on recall of old material, as expected. However, it appears that depressive symptoms may lead to fewer false memories, a greater awareness when those false memories occur, and more accurate recognition of negative new information versus old neutral material. Conversely, rumination may lead to poorer awareness when false memories occur, and poorer

recognition of new negative material versus old material. This indicates that rumination may be partly driving higher rates of false memories in participants with depression. Therefore, different symptoms of depression could lead to different impairments. For example, rumination is a symptom of depression, along with others, such as anhedonia. Anhedonia is the loss of interest in daily activities, and has been related to decreased sensitivity to reward in depression (Bogdan & Pizzagalli, 2006). For example, anhedonia, in theory, may drive other important aspects of the disorder that are not associated with rumination, just as rumination seems to drive particular impairments in depression that may not be seen in anhedonia alone. Therefore, future research should focus on teasing apart the contributions to depression and their effects on memory within the context of depression.

These results also suggest that depressive symptoms alone may lead to a more inhibited manner of recalling and recognizing, meaning instead taking the chance of reporting wrong words, participants refrain from reporting many words altogether. On the other hand, rumination may lead to a less inhibited, less aware, and more confused manner of recalling and recognizing. This reflects the theory that rumination may interfere with either encoding or retrieval in the memory process. Keeping in mind the idea of a lack of memory specificity in rumination discussed earlier, non-specific ruminative memory may lead to later incorrect recollection of new words as being old.

To conclude, rumination tendencies in depression have been conclusively linked to self-harm behavior, suicidal ideation, and other serious symptoms of depression, possibly due to rumination over past events and experiences (see Nolen-Hoeksema et al. 2008 for review). Given the impact rumination may have on perpetuating depression and other disorders through

inaccurate memory, these results support a need to further investigate memory and rumination in the context of depression.

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