Research Article

IMPAIRED SELECTION OF RELEVANT POSITIVE INFORMATION IN DEPRESSION

Sara M. Levens, Ph.D.,* and Ian H. Gotlib, Ph.D.

Background: *A hallmark characteristic of depression is the inability to regulate the effect of emotional material on cognition. Previous research has demonstrated that depressed individuals are less able than are nondepressed persons to expel irrelevant negative information from working memory (WM), thereby exacerbating the effects of negative content on cognition. The primary goal of this study was to examine whether depressed individuals are also impaired at selecting relevant positive content in the context of representations competing for resources in WM; such an impairment would limit depressed persons' ability to use positive material to ameliorate the cognitive effects of negative information.* **Methods:** *We administered a Recency-probes task with neutral, positive, and negative words to 20 currently depressed and 22 never-depressed participants. This task assesses the selection of relevant content in WM by inducing interference between current and prior representations of a stimulus in WM. Reaction times to interference and noninterference trials were compared across valence and group to assess how effectively depressed individuals select task-relevant emotional content to resolve interference.* **Results:** *Compared to never-depressed controls, depressed individuals were impaired in selecting task-relevant positive stimuli; the performance of the two groups was comparable for selecting task-relevant neutral and negative stimuli.* **Conclusions:** *Findings indicate that a valence-specific deficit in WM may contribute to the inability of depressed individuals to regulate emotion, and provide empirical support for formulations that implicate positive insensitivity in the maintenance of depression. Depression and Anxiety 26:403–410, 2009.* *Published 2009 Wiley-Liss, Inc.*†

Key words: *depression; interference resolution; working memory; positive insensitivity*

INTRODUCTION

Major depressive disorder (MDD) is characterized by a wide range of symptoms. Depressed people report recurrent and often unintentional and uncontrollable thoughts that involve negative, self-deprecating statements and pessimistic ideas about the self, the world, and the future.[1] A critical question in understanding depression, therefore, is why depressed individuals have difficulty controlling intrusive task-irrelevant emotional thoughts.[2] One explanation is that depressed individuals are less able than are their nondepressed counterparts to select and attend to task-relevant emotional content.

Information in the environment and material recalled from long-term memory continually compete for

Department of Psychology, Stanford University, Stanford, California

Contract grant sponsor: National Institute of Mental Health; Contract grant number: MH59259.

*Correspondence to: Sara M. Levens, Department of Psychology, Bldg. 420, Jordan Hall, Stanford University, Stanford, CA 94305. E-mail: slevens@stanford.edu

Received for publication 31 October 2008; Revised 17 February 2009; Accepted 25 February 2009

DOI 10.1002/da.20565
Published online 3 April 2009 in Wiley InterScience (www.interscience.wiley.com).

representation and cognitive resources in working memory (WM[3,4]) WM reflects the focus of attention, holding those representations of which a person is aware at any given moment.[5–7] It is through WM that we are able to sift through the plethora of information we encounter in our daily lives to isolate the stimuli that are relevant to a specific task or situation. WM has been implicated in the regulation of emotion; indeed, maintaining emotional content in WM has been found to affect both positive and negative mood.[8,9] To control the effects of emotional content on cognition, individuals must regulate the activation of emotional material in WM so that only task-relevant emotional information is represented. Given that WM is a limited-capacity system,[5] there are two principal components involved in regulating the effect of emotional content on cognition. First, *relevant* content must be selected from a range of competing alternatives so that cognitive resources can be directed at the proper relevant content. Second, *irrelevant* emotional content must be effectively expelled from WM, preventing the activation of a more enduring mood state and allowing cognitive resources to be devoted to task-relevant information. Given these requirements, depressed individuals may experience intrusive emotional thoughts that foster rumination because they have difficulty selecting task-relevant emotional content on which to focus their cognitive resources, and/or because they cannot expel task-irrelevant emotional content from WM.

To date, there has been one study that specifically examined the effectiveness with which depressed individuals are able to expel irrelevant negative and positive content from WM. Joormann and Gotlib[10] administered a modified Sternberg task to depressed and nondepressed individuals that required them to memorize a list of positive and a list of negative emotional words and then ignore one of the lists. Participants then indicated whether a probe was or was not a member of the relevant to-be-remembered list. To assess the ability to remove irrelevant stimuli from WM, Joormann and Gotlib compared response latencies to probes from the irrelevant lists, to latencies to novel probes of the same valence. These investigators found that although depressed and nondepressed participants exhibited equivalent responses to negative and positive relevant words, depressed participants showed greater intrusion effects for negative irrelevant words, indicating that they have difficulty deactivating and expelling negative content material that was once relevant and is now irrelevant from WM.

Although these results are informative, they do not address the question of whether depressed persons are able to choose relevant emotional material on which to focus their attention from competing alternatives—an ability critical for effectively regulating affect.[11,12] Information in WM is continually competing for cognitive resources.[13] Therefore, to direct attention away from negative content and toward positive content to repair mood, individuals must be able to select relevant positive content on which to focus their attention.[14] When people feel sad and want to improve their negative mood, for example, they will search for available positive stimuli in their environment that are relevant to this task, such as watching a favorite TV program, calling a friend, or eating a desired food. All of these alternatives compete for representation in WM, and the content most relevant to the task would be selected and acted on.

To examine the selection of emotional stimuli in the context of interference in WM in a sample of nonpsychiatric participants, Levens and Phelps[15] conducted an Emotion Recency-probes task using neutral, negative, and positive stimuli. The Recency-probes task examines the selection of relevant content in WM by inducing interference between current and prior representations of a stimulus in WM. Participants are asked to indicate whether a probe word is a member of a target set of three words. On interference trials, the probe word is not a member of the current target set, but was a member of the preceding two target sets—creating interference between a "familiarity" based response of "yes" and a "source" response of "no." Although both the source and familiarity representations inform participants how to respond to the current trial, to respond correctly on interference trials participants must select the source representation rather than the familiarity representation. Levens and Phelps found that participants were able to select the correct relevant source representation and respond faster on positive and negative interference trials (i.e., emotional trials) than they were on neutral interference trials.

One reason why depressed individuals are not able to regulate their mood as effectively as are nondepressed individuals may be because they are less able to select relevant positive content material on which to focus their attention and cognitive resources. To assess this formulation, we administered the Emotion Recency-probes task to depressed and nondepressed participants as an index of their ability to select and attend to task-relevant positive content in the context of competition. Previous research has found that, compared to nondepressed controls, depressed individuals are insensitive to positive stimuli, regardless of the relevance of the material. For example, depressed individuals have been found to show attenuated reactivity to positive scenes[16] and diminished neural activity in response to positive words,[17] and to be less behaviorally responsive to reward contingencies.[18] These findings suggest that depressed individuals are less able than are nondepressed persons to select relevant positive content in the face of competing alternatives in WM. Previous investigators have also found depressed individuals to show a potentiated response to *irrelevant* negative stimuli, but similar response patterns as nondepressed persons to *relevant* negative stimuli.[10–19] Because the emotion Recency probes task

assesses the selection of the most relevant representation (i.e., the correct source representation), based on previous findings depressed individuals may well select the relevant source representation for negative content in WM as effectively as do controls. We predicted, therefore, that depressed participants would be impaired in selecting relevant positive content in the context of interference, but would not differ from nondepressed participants in their ability to select relevant neutral and negative content.

METHODS

PARTICIPANTS

Forty-six individuals, 20 diagnosed with MDD and 22 never-disordered controls, participated in this study. Participants were solicited from advertisements posted on Internet bulletin boards. Participants' responses to a telephone interview provided initial selection information. This phone screen established that participants were fluent in English and were between 18 and 60 years of age. Individuals were excluded if they reported severe head trauma or learning disabilities, bipolar disorder, or alcohol or substance abuse within the past 6 months. Eligible persons were invited to come to the laboratory for a more extensive diagnostic interview. Participants were then scheduled for a second session within 2 weeks after the interview, during which they completed the modified Recency-Probes task.

Trained interviewers administered the Structured Clinical Interview for the DSM-IV (SCID[20]) to these individuals during their first session in the study. All interviewers had extensive training in the use of the SCID, with inter-rater reliability κ coefficients of .93 for the MDD diagnosis and .92 for the "never-disordered" diagnosis (i.e., the absence of current or lifetime psychiatric diagnoses[21]). Participants were included in the depressed group if they met the *Diagnostic and Statistical Manual of Mental Disorders*, 4th ed.[22] criteria for current MDD, and in the nondepressed group if they had no current or past Axis I disorder. All participants completed the Beck Depression Inventory-II (BDI[23,24]), a 21-item, self-report measure of the severity of depressive symptoms.

STIMULI

Two hundred and sixty emotional and 330 neutral words from the Affective Norms for English Words (ANEW) battery developed by Bradley and Lang[25] were selected as stimuli. Each set of words was selected based on ANEW valence and arousal ratings. The neutral words (e.g., "chair") formed one large category of words; the emotional words were separated into two categories: one consisting of negative valence, high arousal words (e.g., "mutilation," "terror," "murder"), and the other consisting of positive valence, high arousal words (e.g., "desire," "treasure," "erotic"). Words within the neutral and emotional categories were balanced for frequency of use and concreteness. The means, ranges, and standard deviations of ratings of the stimuli in each category are presented in Table 1.

TASK DESIGN

The Recency-probes paradigm, based on research by Monsell[26] was modified by adding emotional stimuli to the task. The experiment was divided into two 30-min segments: the Positive segment consisted of positive and neutral words as stimuli, and the Negative segment consisted of negative and neutral words as stimuli. The presentation order of the two segments was counterbalanced across subjects. The experimental procedure was similar for each segment. Instructions about the experiment were given to participants both orally and in writing. The experiment consisted of 360 trials separated into 12 blocks of 30 trials, as well as an additional 16 practice trials that were not scored. For each segment, participants completed 8 practice trials followed by 180 experimental trials separated into six blocks of 30 trials. Each trial consisted of a target set of three words displayed on the computer screen for 2,000 ms, followed by a delay of 2,000 ms. During which a fixation cross was presented, followed by the presentation of a single probe word for 2,000 ms. Participants were instructed to indicate as quickly and as accurately as possible whether or not the probe word matched a word in the current target set by pressing buttons corresponding to "Yes" or "No" on the computer keyboard.

TABLE 1. Stimuli characteristics

	Arousal		Valence	
	Mean (*SD*)	Range	Mean (*SD*)	Range
Neutral	4.1 (0.52)	2.5–4.7	5.2 (0.67)	2.9–7.4
Positive high arousal*	6.94 (0.78)	5.0–8.5	7.81 (0.63)	5.6–8.9
Negative high arousal*	6.34 (0.61)	5.2–8.3	2.07 (0.61)	1.1–4.3

Standard deviations are shown in parentheses. *Significant difference between neutral and emotional stimuli, $P<.01$.

Emotional words within the Positive and Negative segments were placed strategically to permit an examination of the effects of emotional content on response selection in the context of interference. Trial target sets had a minimum of one emotional word and a maximum of three emotional words; most trials had two emotional words. To delineate the effect of emotional content on interference resolution when the emotional information is the focus of the trial versus when it is not the focus of the trial, two emotion conditions were defined: the Emotion Focus condition, and the Emotion Nonfocus condition. The Emotion Focus condition consisted of trials in which the emotional content was the focus of the trial, i.e., the probe words were emotional. In contrast, the Emotion Nonfocus condition consisted of trials in which the emotional content was not the focus of the trial, i.e., the probe words were neutral and the emotional words were presented only as stimuli in the target set (see Fig. 1 for trial examples). Emotion Focus and Emotion Nonfocus trials were pseudo-randomly intermixed in emotion blocks within each valence segment.

To analyze response selection in the context of interference, the experimental trials were further separated into four trial types: (1) *Recent No-response* trials, in which the probe does not match any items in the target set of the present trial but does match an item from the target set of the past two trials; (2) *Nonrecent No-response* trials, in which the probe does not match items from either the current or the past two target sets; (3) *Recent Yes-response* trials, in which the probe matches an item from the current target set as well as an item from each of the two preceding target sets; and (4) *Nonrecent Yes-response* trials, in which the probe matches an item from the current target set but not from the preceding two target sets.

Interference was present in the *Recent No-response* trials because the probe word was not a member of the current target set, but was a member of the preceding two target sets, thereby creating interference between a "familiarity"-based response of "yes" and a "source" response of "no." Familiarity and source recognition, though normally in concert, were placed in conflict in this task: whereas source recognition supported a correct "No" response, familiarity supported an incorrect "Yes" response. Both the source and familiarity representations inform participants how to respond to the current trial. To respond correctly on interference trials, however,

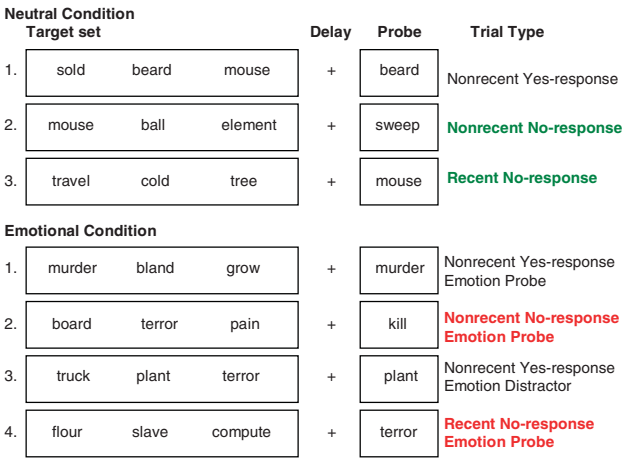

Figure 1. Sample trials and trial types are shown from the Neutral condition, all neutral words, and the Emotion condition, neutral and emotional words. The Emotion condition trials above are examples of Negative segment trials. Positive segment trials would show the same type of emotion word distribution throughout the trials, yet positive and neutral words would be used as stimli. The trial types necessary for determining interference resolution (Nonrecent and Recent No-response trials) are shown in bold green font in the Neutral condition and bold red font in the Emotion condition.

participants must select the source representation rather than the familiarity representation to inform their response. Because the interference must be resolved before the individual can respond, reaction times (RTs) in Recent No-response trials, or interference trials, are longer than in Nonrecent No-response trials, or noninterference trials.[27] The difference between Recent No-response and Nonrecent No-response trials, therefore, represents the amount of interference that must be resolved in Recent No-response trials to select the correct source representation required to make a response.

The creation of the Emotion Focus and Emotion Nonfocus conditions resulted in a total of three trial conditions for each valence segment (e.g., Positive valence session: Positive Emotion Focus, Positive Emotion Nonfocus, and Neutral condition trials) with four trial types each (e.g., Positive Emotion Focus Recent No-response trials). The presentation order of neutral and emotion blocks within each valence segment was counterbalanced, as were individual trials within a block, so that "No" and "Yes" responses were equally likely to precede/follow each other.

RESULTS

PARTICIPANT CHARACTERISTICS

Demographic and clinical characteristics of the MDD and nondepressed participants are presented in Table 2. As is evident from the Table, the two groups of participants did not differ significantly in age, $t(40) = 0.9$, or education, $t(40) = 0.77$, both Ps $> .05$; as expected, depressed participants obtained significantly higher scores on the BDI than did nondepressed participants, $t(40) = 18.4$, $P < .001$. Finally, 10 of the 20 MDD participants were diagnosed with a comorbid disorder: three participants reported a diagnosis of panic disorder, three reported a diagnosis of dysthymia, and one participant each reported generalized anxiety disorder, bulimia, social phobia, and obsessive compulsive disorder.

TABLE 2. Demographic and clinical characteristics of participants

	Group	
	Depressed	Nondepressed
N (*N* female)	20 (13)	22 (12)
Age in years	40.2 (12.1)	38 (9.7)
% College education	88%	95%
Beck Depression Inventory*	32.5 (7.88)	1.98 (2.4)

Standard deviations for age and Beck Depression Inventory are shown in parentheses. *Significant difference between depressed and nondepressed participants, $P < .01$.

RESPONSE SELECTION IN THE CONTEXT OF INTERFERENCE

Incorrect trials and individual subject trial reaction times (RTs) that were more than 2.5 standard deviations from the trial type mean were excluded from analyses. Depressed and nondepressed participants did not differ with respect to the number of excluded trials, $t(40) = 0.66$, $P > .05$, overall RT,[1] or error rates.[2] RTs for nondepressed and depressed participants for each trial type in each condition are presented in Table 3. To examine response selection in the context of interference, difference scores were calculated for each participant for each condition by subtracting Nonrecent No-response trial reaction times from Recent No-response trial reaction times (see Fig. 2). These difference scores, hereafter referred to as interference levels, represent the

[1]To examine group differences in RTs, a four-way (Group by Recency by Condition by trial type) analysis of variance (ANOVA) was conducted on RTs. This analysis yielded a main effect of Recency, $F(1,40) = 90$, $P < .001$ $\eta 2 = .69$, a Condition by Recency interaction, $F(2,80) = 5.8$, $P < .01$ $\eta 2 = .12$, and a Condition by Recency by Group interaction, $F(2,80) = 8.8$, $P < .01$ $\eta 2 = .18$; there was not a significant main effect for group, $F(1,40) = .67$, $P > .1$ $\eta 2 = .01$.

[2]A four-way (group by condition by valence by trial type) ANOVA conducted on accuracy rates yielded significant main effects and lower-order interactions, all of which were qualified by a significant three-way interaction of condition, valence, and trial type, $F(6, 240) = 10.05$, $P < .001$ $\eta 2 = .22$. No significant main effect or interactions involving group were obtained. Follow up two-way (Condition by Valence) ANOVAs and *t*-tests for each trial type indicate that the three-way interaction was due to significantly lower Nonrecent No-response accuracy rates in the Negative segment Emotion Focus trials than Neutral trials, $t(41) = 7.9$, $P < .001$ and , and Emotion Nonfocus trials, $t(41) = 11.71$, $P < .001$, and, significantly lower Nonrecent Yes-response accuracy rates in the Negative segment Emotion Focus trials than Emotion Nonfocus trials, $t(41) = 2.96$, $P < .01$, which were in turn lower than Neutral trials, $t(41) = 4.01$, $P < .001$. There were no group or trial type accuracy differences in the Positive segment.

TABLE 3. Nonrecent and recent no- and yes-response trial reaction times for each condition

	Controls		Depressed			Controls		Depressed	
Trial type	*M* (*SD*)	Accuracy	*M* (*SD*)	Accuracy	Trial type	*M* (*SD*)	Accuracy	*M* (*SD*)	Accuracy
Negative segment									
Neutral: yes-responses					Neutral: no-responses				
Nonrecent	839 (190)	92%	865 (184)	91%	Nonrecent	806 (178)	93%	812 (192)	93%
Recent	869 (217)	93%	896 (208)	92%	Recent	919 (199)	91%	933 (195)	91%
Emotion probe: yes-responses					Emotion probe: no-responses				
Nonrecent	854 (213)	83%	852 (181)	78%	Nonrecent	848 (195)	84%	836 (226)	80%
Recent	896 (218)	93%	884 (215)	90%	Recent	877 (188)	93%	900 (219)	93%
Emotion distractor: yes-responses					Emotion distractor: no-responses				
Nonrecent	865 (205)	87%	895 (217)	83%	Nonrecent	815 (180)	94%	835 (227)	94%
Recent	877 (202)	93%	922 (222)	90%	Recent	925 (191)	90%	941 (228)	88%
Positive segment									
Neutral: yes-responses					Neutral: no-responses				
Nonrecent	816 (234)	93%	799 (286)	94%	Nonrecent	819 (186)	94%	845 (253)	92%
Recent	830 (195)	94%	858 (228)	94%	Recent	925 (208)	94%	948 (260)	91%
Emotion probe: yes-responses					Emotion probe: no-responses				
Nonrecent	855 (217)	95%	931 (248)	94%	Nonrecent	834 (202)	95%	852 (232)	91%
Recent	863 (202)	93%	938 (243)	91%	Recent	873 (201)	92%	976 (263)*	93%
Emotion distractor: yes-responses					Emotion distractor: no-responses				
Nonrecent	850 (191)	93%	912 (229)	90%	Nonrecent	812 (180)	94%	836 (231)	92%
Recent	884 (200)	95%	969 (264)	90%	Recent	910 (199)	93%	931 (244)	91%

*Significant difference between depressed and nondepressed participants, $P<.01$.

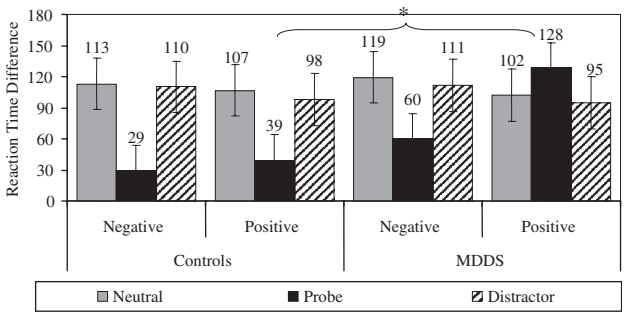

Figure 2. Interference levels for depressed and nondepressed participants across condition for each valence. For nondepressed participants interference levels are significantly lower in the Emotion Probe conditions than the Neutral and Emotion Distractor conditions in both the Negative and Positive segments. Depressed participants, in contrast, show decreased interference levels in the Emotion Probe condition Negative segment, similar to nondepressed participants, yet no difference in interference levels between the Emotion Probe and Neutral conditions in the Positive segment. *Significant difference between depressed and nondepressed participants, $P<.01$. Error bars reflect standard error mean.

degree of interference present in the Neutral, Emotion Focus, and Emotion Nonfocus conditions, and consequently how quickly the correct source representation is selected over conflicting representations. Because "Yes" response trials had no interference, only "No" response trials were included in this analysis.

A three-way (group by condition by valence) analysis of variance (ANOVA) conducted on interference levels yielded a significant main effect of condition, $F(2, 80) = 13.61$, $P<.001$ $\eta^2 = .25$, and significant interactions of condition and group, $F(2,80) = 7.66$, $P<.001$ $\eta^2 = .16$, and condition and valence, $F(2,80) = 5.02$, $P<.01$ $\eta^2 = .11$, all of which were qualified by a significant interaction of group, valence, and condition, $F(2,80) = 3.9$, $P<.05$ $\eta^2 = .09$. To examine the source of this three-way interaction, separate two-way (group by condition) ANOVAs were conducted for each valence.

The group by condition ANOVA conducted for the negative valence trials yielded a significant effect only for condition, $F(2,80) = 16.64$, $P<.001$ $\eta^2 = .29$; neither the main effect for group, $F(1,40) = 0.44$ $\eta^2 = .01$, nor the interaction of group and condition, $F(2,80) = 0.63$ $\eta^2 = .01$, was significant, both Ps $> .05$. The main effect for condition was due to significantly lower levels of interference in the Emotion Focus condition than in the Neutral, $t(41) = 5.1$, $P<.001$, and Emotion Nonfocus, $t(41) = 4.87$, $P<.001$, conditions across all participants. It appears, therefore, that depressed and nondepressed individuals do not differ from each other with respect to their ability to resolve interference for negative stimuli.

In contrast, the group by condition ANOVA conducted for the positive valence trials yielded a significant interaction of group and condition, $F(2,80) = 8.67$, $P<.001$ $\eta^2 = .18$; no significant main effects were obtained for either condition, $F(2,80) = 1.21$ $\eta^2 = .03$, or group $F(1,40) = 1.0$ $\eta^2 = .025$, both Ps $> .05$. A follow-up one-way ANOVA and *t*-tests across condition indicated that, for the nondepressed

participants, interference levels differed significantly across conditions, $F(2,42) = 8.70$, $P < .001$ $\eta^2 = .29$; specifically, nondepressed participants exhibited significantly lower levels of interference in the Emotion Focus condition than in the Neutral, $t(23) = 2.97$, $P < .001$, and the Emotion Nonfocus, $t(23) = 3.36$, $P < .001$, conditions. In contrast, for the depressed participants, interference levels did not differ across conditions, $F(2,38) = 1.32$, $P > .05$ $\eta^2 = .11$. Moreover, depressed participants exhibited significantly higher interference levels than did their nondepressed counterparts in the Emotion Focus condition, $t(40) = 3.4$, $P < .01$; the two groups of participants did not differ significantly in either the Neutral, $t(40) = 0.15$, $P.05$, or the Emotion Nonfocus, $t(40) = 0.6$, $P > .05$, conditions. Thus, whereas nondepressed participants showed less interference for positive than for neutral information, depressed participants showed equivalent levels of interference for positive and neutral stimuli.

DISCUSSION

This study was designed to test the hypothesis that compared with nondepressed persons; depressed individuals would be impaired in selecting relevant positive stimuli in the context of interference. The results of this study support this hypothesis: depressed individuals exhibited greater interference for positive stimuli than did nondepressed persons. Although at first glance this finding appears counter to the positive attenuation hypothesis by suggesting that depressed individuals have a greater sensitivity to positive stimuli and, therefore, more difficulty overriding a familiarity-based response than do nondepressed individuals, this is not the case. Rather, depressed individuals do not exhibit the emotional facilitation of interference resolution that nondepressed individuals show, but instead, exhibit positive interference levels that are similar to neutral interference levels, indicating that they are processing salient positive words more like they do neutral words.

Why is this so? What properties of the positive stimuli have been lost for depressed individuals to merit poorer interference resolution with these stimuli than is found for nondepressed individuals? Both in previous research[15] and in this study, nondepressed individuals show lower levels of interference for emotional than for neutral stimuli. The design of the Recency-probes task dictates that for interference levels to decrease, either familiarity signals must decrease or source recognition signals must increase. In this context, there is no evidence to suggest that emotional context may decrease familiarity; considerable research has documented, however, that emotion improves source recognition.[28,29] Thus, the lower levels of emotional interference on this task may be due to an enhanced signal for emotional content that improves source recognition to facilitate interference resolution in WM (for additional discussion, see Levens and Phelps[15]). Depressed individuals may lack this enhanced emotional signal for positive content material, impairing their ability to select relevant positive content in the face of competing alternatives. Importantly, depressed participants in this study were not slower to respond to positive stimuli under *non*interference conditions, demonstrating that they are impaired only when positive stimuli compete for representation.

It is also important to note that depressed and nondepressed participants did not differ in their performance in the Emotion Nonfocus condition. One might have expected, based on depressed individuals' bias to attend to negative content[30,31] that depressed participants would focus more on the negative emotional words in the target set, leading to poorer encoding of the neutral words and, therefore, worse performance when the probes were neutral words. Importantly, however, it appears that negative stimuli presented simultaneously with neutral and/or positive stimuli do not impair the encoding of these latter stimuli. In Joormann and Gotlib's[10] study, for example, participants memorized two lists of positive and negative words presented simultaneously, after which they were asked to ignore one of the lists. Participants were then probed with relevant words from the to-be-remembered list, intrusion words from the to-be-forgotten list, or novel words, and were asked to indicate whether the probe word came from the to-be-remembered list. Consistent with the results of this study, the encoding of the negative words did not affect responding to the positive words. It appears, therefore, that negative stimuli capture attention when they are presented as distractors to neutral or positive stimuli at the point a response is required (e.g.,[30–32]) but not before.

The consequences of an impairment in selecting relevant positive stimuli are substantial. The decrease in the level of interference from neutral to emotional stimuli for nondepressed individuals suggests that they select correct relevant emotional content twice as quickly as they do correct relevant neutral content. In the context of decision making, therefore, relevant emotional representations will be allocated more cognitive resources than will relevant neutral content, and will be selected to be acted on twice as quickly as will relevant neutral representations. The fact that depressed individuals do not show the same level of positive interference resolution facilitation suggests that they do not accord positive stimuli representations in WM the preferential treatment that they should, subsequently preventing the appropriate allocation of cognitive resources to positive information. This, in turn, hinders elaboration of positive stimuli, and prevents them from utilizing the positive stimuli to repair negative mood. Thus, findings that depressed individuals experience lower levels of positive affect and behavior in response to various types of stimuli than do nondepressed persons[33,34] may be due to their relative inability to select relevant positive

stimulus representations in the face of competing alternatives in WM.

Although the specific neural mechanisms that underlie the selection of relevant positive stimuli in depression have not yet been elucidated, it is likely that the amygdala, because of its involvement in the processing of relevant[35] and emotional stimuli,[36–38] and the prefrontal cortex (PFC), which has been shown to regulate amygdala function,[39,40] play a role in this process. In particular, the left dorsolateral PFC (DLPFC) region, which has been implicated in cognitive control,[41,42] has been shown to affect the experience of negative emotion by recruiting the amygdala in accord with regulatory goals.[40] It is possible, therefore, that in depressed persons the amygdala is not processing positive stimuli as arousing and relevant, which in turn prevents its recruitment by the DLPFC. Alternatively, the amygdala may process the positive stimuli as relevant, but neural signals from the amygdala to PFC are not being integrated into response selection. Both of these possibilities would impair depressed individuals' selection of relevant positive material in WM. Certainly, future research is necessary to elucidate the neural regions that are involved in this process and to extend the present findings to other types of positive stimuli (e.g., low arousing positive words, positive pictures) and to other clinical populations. Nevertheless, it appears that the ability to process and select relevant positive emotional content in the context of competing alternatives is impaired in depression, and it is likely that these impairments contribute to the ineffective emotion regulation that is the hallmark of this disorder.

Acknowledgments. The authors thank Lauren Anas and Paul Aguilar for their assistance in running the subjects in this study. This research was supported by National Institute of Mental Health grant MH59259 awarded to Ian H. Gotlib.

REFERENCES

1. Beck AT. Cognitive Therapy and the Emotional Disorders. New York: New American Library; 1976.
2. Joormann J. Inhibition, rumination, and mood regulation in depression. In: Engle RW, Sedek G, von Hecker U, McIntosh DN, eds. Cognitive Limitations in Aging and Psychopathology: Attention, Working Memory, and Executive Functions. Cambridge University Press, New York; 2005:275–312.
3. Kan IP, Thompson-Schill, SL. Selection from perceptual and conceptual representations. Cogn Affect Behav Neurosci 2004;4: 466–482.
4. Nelson JK, Reuter-Lorenz PA, Sylvester CYC et al. Dissociable neural mechanisms underlying response based and familiarity based conflict in working memory. Proc Natl Acad Sci USA 2003;100:11171–11175.
5. Baddeley AD. Working Memory. New York: Oxford University Press, New York; 1986.
6. Cowan N. The differential maturation of two processing rates related to digit span. J Exp Child Psych 1999;72:193–209.
7. Miyake A, Shah P. Models of Working Memory: Mechanisms of Active Maintenance and Executive Control. New York: Cambridge University Press, New York; 1999.
8. Isen AM. Toward understanding the role of affect in cognition. In: Wyer RS, Srull TS, eds. Handbook of Social Cognition. Hillsdale, NJ: Erlbaum; 1984:179–236.
9. Russell JA. Core affect and the psychological construction of emotion. Psychol Rev 2003;110:145–172, review.
10. Joormann J, Gotlib IH. Updating the contents of working memory in depression: interference from irrelevant negative material. J Abnorm Psychol 2008;117:182–192.
11. Joormann J, Siemer M. Memory accessibility, mood regulation, and dysphoria: difficulties in repairing sad mood with happy memories? J Abnorm Psychol 2004;113:179–188.
12. Lischetzke T, Eid M. Why extraverts are happier than introverts: the role of mood regulation. J Pers 2006;74:1127–1161.
13. Jonides J, Nee DE. Brain mechanisms of proactive interference in working memory. Neuroscience 2006;139:181–193, review.
14. Josephson BR, Singer JA, Salovey P. Mood regulation and memory: repairing sad moods with happy memories. Cogn Emot 1996;10:437–444.
15. Levens SM, Phelps EA. Emotion processing effects on interference resolution in working memory. Emotion 2008;8: 267–280.
16. Sloan DM, Strauss ME, Quirck SW, Sajatovic M. Subjective and expressive emotional responses in depression. J Affect Disord 1997;46:135–141.
17. Canli T, Sivers H, Thomason M et al. Brain activation to emotional words in depressed versus healthy subjects. Neuroreport 2004;15:2585–2588.
18. Henriques JB, Davidson RJ. Decreased responsiveness to reward in depression. Cogn Emot 2000;14:711–724.
19. Erikson K, Drevets WC, Clark L et al. Mood-congruent bias in affective go/no-go performance of unmedicated patients with major depressive disorder. Am J Psychiatry 2005;162: 2171–2173.
20. First MB, Spitzer RL, Gibbon M, Williams JBW. Structured Clinical Interview for DSM-IV Axis I Disorders-Clinician Version (SCID-CV). Washington, DC: American Psychiatric Press; 1996.
21. Gotlib IH, Kasch KL, Traill SK et al. Coherence and specificity of information-processing biases in depression and social phobia. J Abnorm Psychol 2004;113:386–398.
22. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders. 4th ed. Test Revision. Washington, DC, American Psychiatric Association, 2000.
23. Beck AT, Steer RA, Brown GK. Manual for the Beck Depression Inventory-II. San Antonio, TX: Psychological Corporation; 1996.
24. Beck AT, Steer RA, Garbin MG. Psychometric properties of the beck depression inventory: twenty-five years of evaluation. Clin Psychol Rev 1988;8:77–100.
25. Bradley MM, Lang PJ. Affective Norms for English words (ANEW): Technical Manual and Affective Ratings. Gainesville FL: The Center for Research in Psychophysiology, University of Florida; 1999.
26. Monsell S. Recency, immediate recognition memory, and reaction time. Cogn Psychol 1978;10:465–501.
27. D'Esposito M, Postle BR, Jonides J, Smith EE. The neural substrate and temporal dynamics of interference effects in working memory as revealed by event-related functional MRI. Proc Natl Acad Sci USA 1999;96:7514–7519.
28. Doerksen S, Shimamura AP. Source memory enhancement for emotional words. Emotion 2001;1:5–11.

29. Tabert MH, Borod JC, Tang CY et al. Differential amygdala activation during emotional decision and recognition memory tasks using unpleasant words: an fMRI study. Neuropsychologia 2001;39:556–573.
30. Gotlib IH, Krasnoperova E, Neubauer Yue D, Joormann J. Attentional biases for negative interpersonal stimuli in clinical depression. J Abnorm Psychol 2004;113:127–135.
31. Joormann J. Attentional bias in dysphoria: the role of inhibitory processes. Cogn Emot 2004;18:125–147.
32. Mogg K, Bradley BP. Attentional bias in generalized anxiety disorder versus depressive disorder. Cogn Ther Res 2005;29:29–45.
33. Rottenberg J, Gross JJ, Gotlib IH. Emotion context insensitivity in major depressive disorder. J Abnorm Psychol 2005;114: 627–639.
34. Sloan DM, Strauss ME, Wisner KL. Diminished response to pleasant stimuli by depressed women. J Abnorm Psychol 2001;110:488–493.
35. Sander D, Grafman J, Zalla T. The human amygdala: an evolved system for relevance detection. Rev Neurosci 2003;14:303–316.
36. Adolphs RA. The human amygdala in social judgment. Nature 1998;393:470–474.
37. LeDoux JE. The Emotional Brain. New York: Simon & Schuster New York; 1996.
38. Stalnaker TA, Franz TM, Singh T, Schoenbaum G. Basolateral amygdala lesions abolish orbitofrontal-dependent reversal impairments. Neuron 2007;54:51–58.
39. Ochsner KN, Bunge SA, Gross JJ, Gabrieli JD. Rethinking feelings: an FMRI study of the cognitive regulation of emotion. J Cogn Neurosci 2002;14:1215–1229.
40. Ochsner KN, Ray RD, Cooper JC et al. Better or for worse: neural systems supporting the cognitive down-and up-regulation of negative emotion. Neuroimage 2004;23:483–499.
41. Knight RT, Staines WR, Swick D, Chao LL. Prefrontal cortex regulates inhibition and excitation in distributed neural networks. Acta Psychol (Amst) 1999;101:159–178, review.
42. Smith EE, Jonides J. Storage and executive processes in the frontal lobes. Science 1999;283:1657–1661, review.