Research Article

Suppression of Emotional and Nonemotional Content in Memory

Effects of Repetition on Cognitive Control

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ABSTRACT—***Two experiments utilized a think/no-think paradigm to examine whether cognitive control of memories differs depending on whether they contain information with negative or neutral emotional content. During a training phase, participants learned face-word pairs (Experiment 1) or face-picture pairs (Experiment 2). In a subsequent experimental phase, participants were shown faces and told to think of the items paired with some of the faces and to try not to think of the items paired with other faces. Finally, in a test phase, participants were again shown each face and asked to recall the item with which it had been paired previously. Results for both verbal (Experiment 1) and nonverbal (Experiment 2) items indicated that the facilitatory and inhibitory influences of cognitive control were larger for negative than neutral items.***

Cognitive control allows for the top-down selection and manipulation of task-relevant information. Research suggests that cognitive control mechanisms, such as top-down attention, can facilitate and enhance memory for certain information (Behrmann & Tipper, 1999; Kastner & Ungerleider, 2000). A less understood aspect of cognitive control that has been implicated as being dysfunctional in clinical disorders is the control mechanism used to suppress unwanted memories. Traditionally, suppressive mechanisms of cognitive control have been studied in the motor domain using the go/no-go task. In this task, individuals respond, or "go," to certain frequently occurring stimuli and withhold response to other, rare stimuli ("no go"). Many populations with deficits in cognitive control, such as individuals with attention deficit hyperactivity disorder (Vaidya et al., 1998) and frontal lobe damage (Drewe, 1975), exhibit an impaired ability to suppress responding in the no-go condition.

Recently, a modification of the go/no-go paradigm, aptly named the think/no-think paradigm, was designed to examine whether similar suppressive mechanisms can operate on memory representations (Anderson & Green, 2001). In the training phase, participants memorized cue-target word pairs, so they could accurately recall each target when presented with its cue. In the experimental phase, participants were shown only the cues. For some cues, participants had to suppress thinking about the associated target (no-think condition), whereas for other cues, they were to think of the associated target (think condition). These manipulations did not involve re-presentation of the targets, so cognitive control had to be applied to internal memory representations. In the final phase of the experiment, memory for each target item in response to its cue was assessed.

Anderson and Green's (2001) results indicated that cognitive control can extend to items in memory. Recall of target items in the think condition was superior to recall of items in a baseline condition. In the baseline condition, word pairs were presented only in the training phase, with no intervening presentation of the cue in the experimental phase. Conversely, recall for items in the no-think condition was worse than baseline. Moreover, the level of recall was directly related to the number of times cognitive control was exerted (Anderson & Green, 2001; Levy & Anderson, 2002). Recall of words whose cues were shown infrequently during the experimental phase deviated from baseline less than recall of words whose cues were shown often.

The main focus of the present research was to investigate whether the efficacy of these control mechanisms differs for

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emotional and nonemotional information. Previous research suggests that emotional information can automatically capture attention (Blaney, 1986), which enhances encoding (Cahill & McGaugh, 1998; Canli et al., 2001; Rolls, 2000) and retrieval (Hamann, 2001). Thus, memory representations of emotional material appear to be stronger than representations of nonemotional material, and if cognitive control mechanisms act similarly on emotional and nonemotional information, one would nonetheless observe differences in recall. More specifically, in the think condition, the recall of emotional information would be greater than the recall of nonemotional information. Furthermore, the reduction of recall in the no-think condition would be smaller for emotional than for nonemotional material (i.e., there would be better recall for emotional material). Both of these patterns would be a simple reflection of the heightened encoding of emotional information (see Fig. 1, top panel). Consistent with this possibility, studies have shown that individuals with post-traumatic stress disorder (PTSD) and obsessive-compulsive disorder (OCD) report that exerting suppressive control over uncontrolled intrusions of thoughts and images can be difficult (e.g., de Silva & Marks, 2001).

Another possibility is that greater cognitive control can be exerted over emotional information than over nonemotional information. This is a possibility because evidence suggests that increased strength of a representation may make the memory more accessible to cognitive control mechanisms (Norman, Newman, Detre, & Polyn, 2004). In addition, research involving memory reconsolidation suggests that as a memory representation is accessed or recalled, it once again becomes labile. This allows for the possibility that the strength of the memory may be modified—either enhanced or reduced (Abel & Lattal, 2001; Dudai, 2002; Walker, Brakefield, Hobson, & Stickgold, 2003). Thus, if emotional memories are easier to recall than nonemotional memories are, they may be more susceptible to mechanisms of cognitive control. If this were the case, then one would expect greater recall for emotional than nonemotional material in the think condition, but more suppression (i.e., less recall) for emotional than nonemotional material in the no-think condition (see Fig. 1, bottom panel).

A secondary focus of the present research was to examine whether the control mechanisms observed by Anderson and his colleagues (Anderson & Green, 2001) generalize to different types of material. Therefore, we utilized pairings of verbal and nonverbal information (Experiment 1) and of two types of nonverbal information (Experiment 2), rather than word-word pairs. This issue is significant because emotional events are experienced both verbally and nonverbally (Adolphs, Tranel, & Damasio, 2003; LeDoux, 1998a, 1998b).

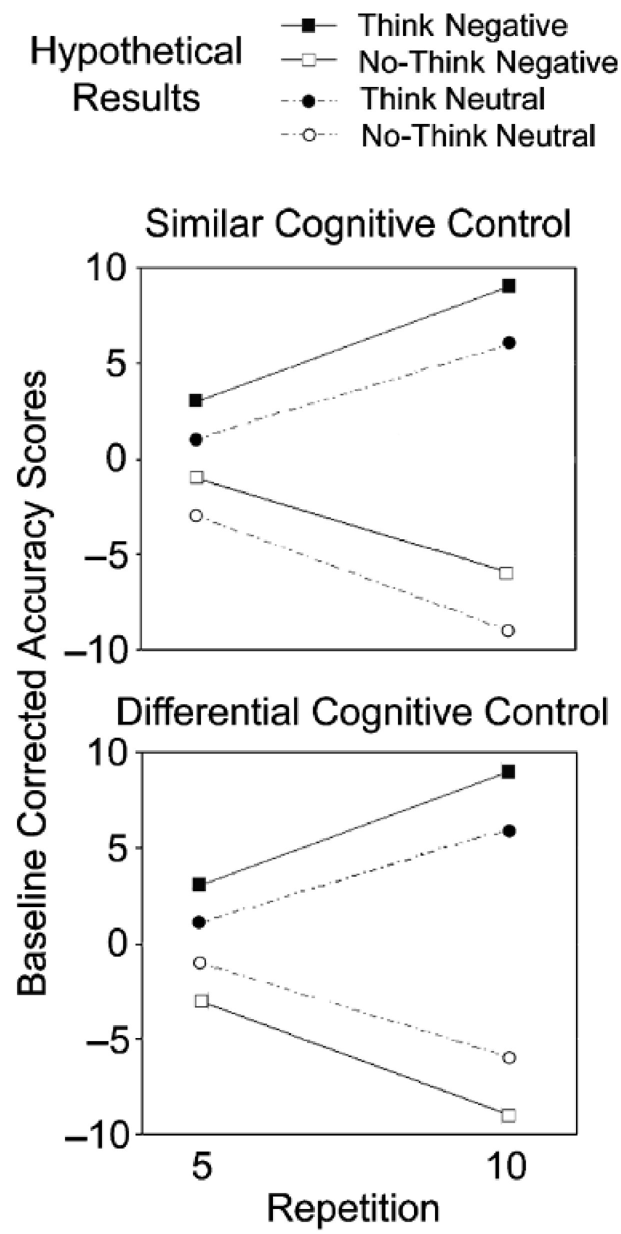

Fig. 1. Hypothetical results: baseline-corrected accuracy scores as a function of think/no-think condition and number of repetitions during the experimental phase. The top panel shows the expected pattern of recall if cognitive control does not vary for emotional (in this case, negative) and nonemotional (neutral) information (given heightened encoding of emotional information). The bottom panel shows the expected pattern of recall if cognitive control differs for emotional and nonemotional information, regardless of encoding strength.

EXPERIMENT 1

Experiment 1 examined whether the effects of cognitive control vary for emotional and nonemotional information. To introduce a nonverbal aspect to the paradigm, we used face-word pairs rather than the word-word pairs used by Anderson and his colleagues (Anderson & Green, 2001). To address the influence of emotion, we included emotional target words (e.g., *deformed*, *corpse*) and nonemotional target words (e.g., *carriage*, *lantern*). We predicted that the efficacy of cognitive control would differ for emotional as compared with nonemotional information.

Method

Participants

Fifty-two native English-speaking adults (33 women) 19 to 29 years of age participated in the study. Ten participants (4 female) were omitted from analyses because of noncomprehension of instructions (answering inappropriately on recall forms, $n = 6$) or ceiling or floor effects (100% or 0% accuracy in more than half of the conditions, $n = 4$), leaving a final sample of 42.

Procedure

We utilized Anderson and Green's (2001) think/no-think paradigm, but with face-word pairs. Eighty faces (half male, half female) with neutral expressions (N. Cohen, personal communication, February 3, 2003) were used. Eighty words (half neutral, half emotionally negative) were selected from the Affective Norms for English Words (M.M. Bradley & Lang, 1999) database. Ratings of word valence and arousal were tested with item t scores to make sure that the negative words had significantly more negative affect than the neutral words ($p < .05$), and that the two groups of words did not differ significantly on arousal ($p > .05$). The selected words were at a median level of arousal on a scale from 1 to 10 (negative words: $M = 5.2$, $SD = 0.4$; neutral words: $M = 5.1$, $SD = 0.3$), and the two groups of words differed in valence on a scale from 1 to 10 (negative words: $M = 1.4$, $SD = 0.8$; neutral words: $M = 5.3$, $SD = 0.6$). Furthermore, the two groups of words were also matched on semantic relatedness and frequency. The experiment was designed with E-Prime software (Psychology Software Testing, Pittsburgh, PA), which was used to display the stimuli and record performance on a Dell laptop computer.

Blocked testing for each valence of stimuli (negative, neutral) was divided into three phases: training, experimental, and testing. In the training phase of each block, participants learned to remember 40 face-word pairs (either negative or neutral), which were displayed side by side for 4,000 ms. Participants viewed each of 20 pairs and were then shown only the faces and asked to select which of two words had been originally paired with each face (each of the 20 faces was tested once to assess training). All the words came from the training phase, so that novelty of one choice could not be used as a potential alternative cue for recognition. This procedure continued in sets of 20 until the participants could recognize the words previously paired with the faces with 97% accuracy over all 40 pairs in the block. In the training phase, the average number of training cycles was smaller for negative words ($M = 2.04$, $SD = 0.69$) than for neutral words ($M = 2.31$, $SD = 0.84$), $t(41) = 2.7$, $p_{rep} = .99$, $\eta^2 = .15$.

In the experimental phase, participants saw the faces from 32 of the 40 pairs, half of these being assigned to the think condition and half to the no-think condition. In both conditions, a trial consisted of a fixation cross for 1,500 ms, followed by a face for 4,000 ms, and then a 500-ms intertrial interval. The color of the fixation cross indicated the condition: green for think trials and red for no-think trials. As in Anderson and Green (2001), in the think condition, participants were told, "Think of the word previously associated with the face," whereas in the no-think condition, they were told, "Try not to let the previously associated word come into consciousness." Within each condition (think, no-think), participants viewed half (16) of the faces 5 times and the other half 10 times. The 8 faces not shown in the experimental phase served as a 0-repetition baseline.

During the test phase, participants were shown each of the faces and told to write down the word associated with it. These data provided the accuracy measures reported here. This entire procedure was then repeated for pairs in which the words were of the other valence (i.e., neutral or negative).

To minimize possible interference between faces in the two valence conditions, we used only female pictures for one valence and only male faces for the other. The order of the valence conditions, the pairs used in each condition, the pairing of gender and valence, the pairings of face and word, and the side of the monitor on which the face was displayed were all counterbalanced across participants.

Results and Discussion

Inspection of the data for the 0-repetition condition suggested that more items were recalled in the neutral condition ($M = 73.2\%$, $SD = 3.7\%$) than the negative condition ($M = 63.7.2\%$, $SD = 2.9\%$), $t(1, 41) = -1.91$, $p_{rep} = .91$, $\eta^2 = .08$. This may have been due to the significantly greater number of training cycles for neutral than negative words (see Procedure). Therefore, as in Anderson and Green's (2001) study, we analyzed the number of items recalled in the 5- and 10-repetition conditions after first subtracting out the baseline level of recall (i.e., 0-repetition condition). This was done separately for neutral and negative words. The resulting accuracy scores are shown in the top panel of Figure 2. Positive scores represent recall above baseline, and negative scores represent recall below baseline.

We performed an analysis of variance that included the factors of condition (think, no-think), valence (neutral, negative), and repetition (5, 10). This analysis yielded a significant difference between the number of items recalled in the think versus no-think conditions (i.e., a main effect of condition), $F(1, 41) = 21.39$, $p_{rep} = .99$, $\eta^2 = .34$, and an increasing difference in recall between these conditions as repetition increased (i.e., a Condition × Repetition interaction), $F(1, 41) = 11.52$, $p_{rep} = .98$, $\eta^2 = .22$. Most important, we obtained a significant interaction of Condition × Repetition × Valence, $F(1, 41) = 3.91$, $p_{rep} = .87$, $\eta^2 = .09$. The effect of valence was more prominent for the 10-repetition trials than the 5-repetition trials and was also dependent on condition. For 10-repetition think trials, recall increased 8.93% from baseline for negative words but only 3.87% from baseline for neutral words. Similarly, for 10-repetition no-think trials, recall decreased 7.74% from

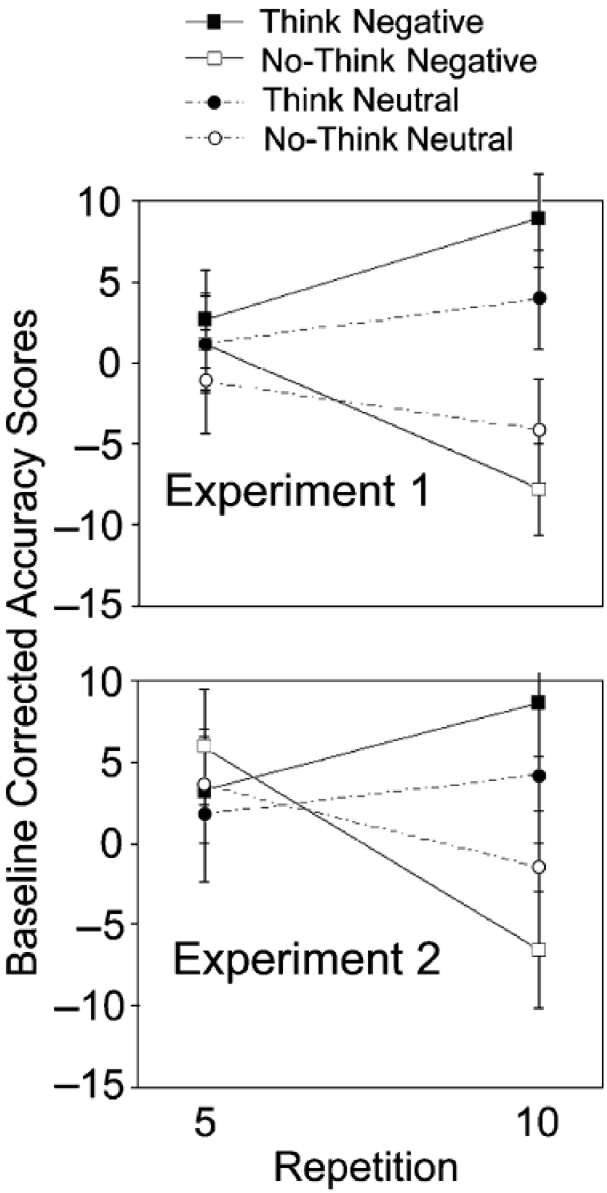

Fig. 2. Baseline-corrected accuracy scores for Experiments 1 (top) and 2 (bottom). Results for negative and neutral stimuli in the think and no-think conditions are shown as a function of number of repetitions during the experimental phase. Error bars indicate ±1 standard error of the mean.

baseline for negative words but only 4.17% from baseline for neutral words.

To examine the three-way (Condition × Repetition × Valence) interaction further, we tested the interaction of Valence × Condition at 5 and 10 repetitions separately, expecting that the more times cognitive control was implemented, the greater the likelihood of a valence effect. There was no significant interaction for the 5-repetition condition ($F < 1$). However, for the 10-repetition condition, the difference between recall on think and no-think trials was significantly greater for negative than for neutral information, $F(1, 41) = 6.17$, $p_{rep} = .92$, $\eta^2 = .13$.

Our results demonstrate that the efficiency of cognitive control mechanisms differs for negative and neutral information. Given the heightened suppression effect for emotional information in the no-think condition, we speculate that the manner in which control mechanisms act on emotional information is at least partially distinct from the manner in which control is exerted over neutral information. We explored this difference in the suppression effect again in Experiment 2.

Experiment 1 also suggests that the cognitive control mechanisms involved in the think/no-think paradigm are robust with respect to variations in methodology. In their initial study, Anderson and Green (2001) utilized word-word pairs and assessed initial learning of pairings via cued recall. In contrast, we utilized face-word pairs and assessed initial learning via a recognition paradigm.

EXPERIMENT 2

The goal of Experiment 2 was to further investigate differences in cognitive control for negative as compared with neutral information. This time, we used pictorial, rather than verbal, stimuli as the targets. We speculated that the effects of valence observed in Experiment 1 might be accentuated by pictorial stimuli, because such stimuli can lead to more salient memory representations than words (e.g., Grady et al., 1998). Furthermore, cognitive control over pictorial stimuli has clinical relevance, as individuals with PTSD and OCD report that disturbing mental images impinge upon consciousness, often uncontrollably (Grillon, Southwick, & Charney, 1996; van der Kolk, Burbridge, & Suzuki, 1997).

Method

Participants

Fifty-six native English-speaking adults (34 women) 19 to 29 years of age participated in the study. Data from 14 participants (10 females) were omitted because they failed to understand instructions ($n = 7$), found the material too offensive ($n = 1$), or exhibited a ceiling or floor effect ($n = 6$), leaving a total sample of 42.

Procedure

All procedures were identical to those of Experiment 1 with the following exceptions. Rather than face-word pairs, face-picture pairs were employed. Eighty images, half neutral and half negative in emotional content, were selected from the International Affective Picture Series (IAPS; Lang, Bradley, & Cuthbert, 1995). Ratings of image valence and arousal were tested with item t scores to ensure that the negative pictures had a significantly more negative rating of affect than the neutral pictures ($p < .05$) but that the two sets were equal on arousal ($p > .05$). The selected pictures were at a median level of arousal on a scale from 1 through 9 (negative pictures: $M = 4.1$,

$SD = 0.55$; neutral pictures: $M = 4.1$, $SD = 0.40$), and the two groups of pictures differed in valence on a scale from 1 through 9 (negative pictures: $M = 2.4$, $SD = 0.51$; neutral pictures: $M = 4.4$, $SD = 0.23$). The IAPS has no relatedness scores, so to eliminate grouping effects, we asked two independent raters to make the selections of the pictures, choosing for each valence group pictures that would have as minimal relatedness in content as possible.

The average number of training cycles differed significantly between negative pictures ($M = 1.76$, $SD = 0.61$) and neutral pictures ($M = 2.0$, $SD = 0.54$), $t(41) = 2.68$, $p_{rep} = .95$, $\eta^2 = .15$, suggesting that individuals learned the negative associations more quickly than the neutral associations. In the test phase, individuals were asked to produce three or four words that described each picture. These descriptions were then scored as correct or incorrect by two independent judges (interrater reliability was .98).

Results and Discussion

As in Experiment 1, accuracy differed significantly between the neutral ($M = 70.5\%$, $SD = 3.6\%$) and negative ($M = 62.8\%$, $SD = 2.6\%$) stimuli, $t(1, 41) = -1.59$, $p_{rep} = .87$, $\eta^2 = .06$, so we analyzed the data for the 5- and 10-repetition conditions after subtracting out the baseline level of recall for each valence; these accuracy scores are presented in the bottom panel of Figure 2. The pattern of results was the same as in Experiment 1: There was a significant difference between the number of items recalled in the think versus no-think conditions (i.e., a main effect of condition), $F(1, 41) = 5.80$, $p_{rep} = .92$, $\eta^2 = .12$, and an increasing difference in recall between these conditions as repetition increased (i.e., a Condition × Repetition interaction), $F(1, 41) = 16.55$, $p_{rep} = .99$, $\eta^2 = .29$. Also as in Experiment 1, we obtained a significant Condition × Repetition × Valence interaction, $F(1, 41) = 4.53$, $p_{rep} = .89$, $\eta^2 = .10$. The effect of valence once again was more dramatic for the 10-repetition condition than the 5-repetition condition and was dependent on condition. For 10-repetition think trials, the mean increase in recall from baseline was 8.64% for the negative stimuli and only 4.17% for the neutral stimuli. Similarly, for 10-repetition no-think trials, the mean decrease from baseline was 6.55% for the negative stimuli and only 1.49% for the neutral stimuli.

To explore this pattern further, we tested the Condition × Valence interaction for the 5- and 10-repetition conditions separately. As in Experiment 1, the interaction was not significant for the 5-repetition condition ($F < 1$), but was significant for the 10-repetition condition, $F(1, 41) = 7.59$, $p_{rep} = .95$, $\eta^2 = .16$. As shown in the bottom panel of Figure 2, the difference in recall between think and no-think trials was significantly greater for negative stimuli than neutral stimuli in the 10-repetition condition.

The results of Experiment 2 support those of Experiment 1 and are consistent with the hypothesis that control mechanisms have a differential effect on negative as compared with neutral information. Also, comparison of results from Experiment 2 with previously reported results (Anderson & Green, 2001, and our Experiment 1) indicates that control mechanisms work similarly for nonverbal and verbal information.

GENERAL DISCUSSION

The present results indicate that both the facilitative and the suppressive aspects of cognitive control are heightened for emotional as compared with nonemotional information. Specifically, relative to memory for neutral information, memory for emotional information was enhanced in the think condition and reduced in the no-think condition. This effect was observed in both Experiments 1 and 2, demonstrating that it did not vary with the type of information (verbal or nonverbal) on which cognitive control was exerted.

The observed effect of emotion is important because it speaks to the ways in which memory mechanisms may differ for emotional versus nonemotional information. Both behavioral (M.M. Bradley, 1994; Reisberg & Heuer, 1992) and neuroimaging (B.P. Bradley et al., 1997; Pessoa, Kastner, & Ungerleider, 2002; Vuilleumier, Armony, Driver, & Dolan, 2001) research suggest that emotional memories are retrieved better than nonemotional memories because they are more salient and in turn better encoded or consolidated. If emotional and nonemotional memories differed only in their strength (because of differential encoding or consolidation), then recall for emotional items should have been superior to that for nonemotional items overall, regardless of condition (i.e., there should have been a main effect of valence and no interaction between valence and condition). More specifically, we should have observed enhanced retrieval for emotional information (relative to nonemotional information) in the think condition and less of a degradation in recall for emotional information (relative to nonemotional information) in the no-think condition. Although enhanced recall for negative information was indeed observed in the think condition, there was decreased recall for negative information, relative to neutral information, in the no-think condition (Fig. 2). Thus, cognitive control can serve either to enhance information presented during training or to reduce it.

It is notable that we found differences in cognitive control for emotional and nonemotional information even in the face of evidence that the information may have been encoded differently. Consistent with prior work, our results suggest that encoding of emotional information, compared with nonemotional information, is heightened or easier. We found that it took fewer training cycles to learn the cue-target pairings for the emotional information. Nonetheless, we still obtained evidence that suppression of emotional information was more effective than suppression of nonemotional information.

Our findings are consistent with neuroimaging studies suggesting that cognitive control mechanisms, most notably those associated with prefrontal cortex, co-occur with modulations in activation of regions involved in memory processing, such as the hippocampus and amygdala (Anderson, Ochsner, & Kuhl, 2004; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000; Clark & Wagner, 2003). Furthermore, manipulation of emotional information, compared with manipulation of nonemotional information, is associated with greater activity of prefrontal and orbitofrontal cortices (Gray, Braver, & Raichle, 2002; Hamann, 2001; Maratos & Rugg, 2001), as well as additional cortical and subcortical regions (Canli, 2000; Maratos & Rugg, 2001). It has also been suggested that neural systems associated with the encoding of emotional information may differ for emotional and nonemotional information (Kensinger & Corkin, 2004). More specifically, during encoding there is greater activation of regions implicated in cognitive control (i.e., regions in the left inferior prefrontal cortex) for emotional as compared with nonemotional words. These findings are consistent with our behavioral results in suggesting that emotional information may be more accessible to cognitive control mechanisms than nonemotional information is.

Our findings provide tentative means of interpreting some clinical phenomena associated with PTSD and OCD. We speculate that individuals with these disorders may lack the cognitive control mechanisms that allow for the modulation of emotional memories. Specifically, these individuals appear to show enhanced memory for emotional information and an inability to suppress that information. This pattern is what one would expect to observe if cognitive control mechanisms do not act differentially on emotional material: The pattern of recall could be driven entirely by the effect of heightened encoding of emotional information (Fig. 1, top panel). Hence, although the mechanisms that ensure better encoding of emotional information (e.g., Dolan, 2002) may be intact in these individuals, the mechanisms that specifically allow for cognitive control of the well-encoded memories may be dysfunctional. Alternatively, these individuals might have such hypersensitivity to traumatic or threatening stimuli (Michael, Ehlers, & Halligan, 2005) and encode this information to such an extensive degree that normal cognitive control mechanisms are ineffective in modulating the retrieval of these memories.

Our results are also important in that they extend the findings of Anderson and his colleagues (Anderson & Green, 2001; Levy & Anderson, 2002) by demonstrating that the think/no-think paradigm is robust against variations in initial learning and the type of stimulus material on which control is exerted. These findings suggest that cognitive control mechanisms, although they vary in their impact on emotional and nonemotional information, are general in that they do not vary by stimulus type.

Although intriguing, the current study does have some limitations. First, the data cannot provide a detailed characterization of how recall for think and no-think trials varies as a function of repetition. Even though our data indicate a greater effect for emotional cognitive control (heightened facilitation and suppression) than nonemotional cognitive control, we do not know if the trends we observed are linear or nonlinear. Use of more repetition conditions (e.g., 2, 4, 6, and 8) would allow for better characterization of recall as a function of repetition. Similarly, the number of opportunities for cognitive control and the salience of the stimuli might be expanded to further examine how cognitive control varies as a function of repetition. For example, in the case of particularly negative or gruesome material, more than 10 repetitions may be required to suppress the memory. Second, our results could be due to either a single cognitive control mechanism that operates on both negative and neutral information but to varying degrees or to distinct cognitive control mechanisms for emotional versus nonemotional information. Furthermore, our results are limited to a contrast between nonemotional information and negative information. Thus, we do not know whether similar findings would be observed for positive emotional information as well.

In sum, the present results are important in demonstrating that cognitive control appears to be more effective for emotional than nonemotional memories. Furthermore, they indicate that when cognitive control mechanisms are directed toward suppression, their effect on memory representations is heightened for emotional compared with neutral stimuli. Our results raise the possibility that cognitive control mechanisms specifically circumscribed to emotional information may be disrupted in the disorders of PTSD and OCD, leaving other mechanisms of cognitive control for nonemotional information unaffected. Further research is warranted to explore this possibility. In any case, it is likely that a better understanding of the nature of cognitive control over internal representations of information may have important clinical implications.

Acknowledgments—Support for the third author was provided by a grant from the National Institute of Mental Health (MH648412).

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(RECEIVED 10/12/04; REVISION ACCEPTED 7/19/05;
FINAL MATERIALS RECEIVED 7/27/05)