The influence of self-regulatory focus on encoding of, and memory for, emotional words

Sharon R. Touryan, Marcia K. Johnson, and Karen J. Mitchell
Yale University, New Haven, CT, USA

Norman Farb
University of Toronto, Columbus, OH, Canada

William A. Cunningham
The Ohio State University, Columbus, OH, USA

Carol L. Raye
Yale University, New Haven, CT, USA

We investigated self-regulatory focus (Higgins, 1997, 1998) as one source of variation in encoding of, and memory for, emotional words. Participants wrote about their hopes and aspirations (promotion focus) or duties and obligations (prevention focus). In a subsequent incidental encoding task during functional magnetic resonance imaging (fMRI), participants evaluated emotional (positive and negative) and neutral words as either *good* or *bad*. A surprise memory test followed, outside the scanner. We observed a dissociation in posterior cingulate cortex (PCC), where activity during the evaluation task was greater when words were focus-consistent (positive for the promotion focus group, negative for the prevention focus group). Similarly, activity in a parahippocampal region was related to subsequent memory, but only for focus-consistent words. Given the role of the PCC in self-referential processing and episodic retrieval, and the parahippocampus in memory-related processing, these data suggest that regulatory focus influences which items are preferentially associated with self-referential information in memory. Such preferential processing may help explain why events are remembered differently by different individuals, which subsequently may influence interpersonal interactions.

INTRODUCTION

Reactions to emotional events can vary among individuals, both in strength and direction. For example, while many people enjoy the thrill of roller coasters, others find them aversive. The role of such individual differences in emotional responsiveness has been the focus of research in both patient and normal populations (e.g., Davidson, 1998; Freitas & Higgins, 2002; Gross & John, 2003; Leen-Feldner, Zvolensky, Feldner, & Lejuez, 2004; Lim & Kim, 2005; Maio & Esses, 2001). The neural bases of these differences have also received recent attention, and limbic and frontal regions have been implicated (Canli, Sivers, Whitfield, Gotlib, & Gabrieli, 2002;

Davidson, 2001; Hamann & Canli, 2004; Hamann, Herman, Nolan, & Wallen, 2004; Johnson, Raye, Mitchell, Touryan, Greene, & Nolen-Hoeksema, 2006; Ochsner et al., 2005). Just as interesting, however, is that emotional responsiveness to a particular event can also vary within an individual. For example, a traffic jam may induce resignation one day and aggression the next.

One potential source of intra-individual variation in emotional responsiveness is self-regulatory focus (RF). According to Higgins (1997, 1998), RF reflects how and why individuals approach pleasure and avoid pain. Two types of focus are distinguished based on individuals' motivations: a promotion focus reflects concerns surrounding rewards and accomplishments (positive stimuli) and a prevention focus reflects concerns surrounding safety and responsibility (negative stimuli). Numerous studies have supported a promotion–prevention distinction. For example, anticipated and experienced enjoyment increase when tasks are framed in a focus-consistent manner: positive outcomes for promotion focus, negative outcomes for prevention focus (Freitas & Higgins, 2002). Word ratings along focus-consistent dimensions also tend to be faster than those along focus-inconsistent dimensions (Shah & Higgins, 2001). As well, emotions related to goal attainment are stronger along focus-consistent compared to inconsistent dimensions (Higgins, Shah, & Friedman, 1997).

Although focus chronically varies across people in a trait-like manner, acute variations within a person also occur (Freitas & Higgins, 2002; Higgins, 1997). That is, healthy individuals can be in either a promotion or prevention state, depending on the situation. This is consistent with the dynamic and context specific nature of self-concepts (Markus & Wurf, 1987) and agendas. To illustrate, one may comment on a partner's tendency to complete an assigned task, such as making dinner. This focuses the partner's attention on their responsibilities, possibly inducing a prevention focus state. Alternatively, one may comment on a partner's tendency to meet personal goals, such as exercising daily. This focuses the partner's attention on their aspirations, possibly inducing a promotion focus state.

A recent study by Johnson et al. (2006) found that brain activity in medial areas reflects these acute regulatory states. They manipulated promotion and prevention focus both between (Experiment 1) and within (Experiment 2) participants.

In both cases, activity in the medial prefrontal cortex (MdFG), posterior cingulate cortex (PCC), and precuneus differed depending on whether participants thought about their "hopes and aspirations" (promotion focus) or "duties and obligations" (prevention focus).

Studies examining the processing of emotional and self-relevant events show involvement of the MdFG (Ochsner et al., 2005), PCC (Levine, Turner, Tisserand, Hevenor, Graham, & McIntosh, 2004; Ochsner et al., 2005), and precuneus (Cavanna & Trimble, 2006; Ochsner et al., 2005). Thus, we might expect that variations in RF would differentially bias emotional processing in such areas. Consistent with this, Cunningham, Raye, and Johnson (2005) reported that activity in the precuneus varied with trait levels of RF as participants evaluated emotional concepts. For example, as trait levels of promotion focus increased, precuneus activity in response to positive stimuli increased. One of the goals of the current study was to determine whether state focus (rather than trait differences in RF) would also predict sensitivity to emotional words, consistent with a dynamic view of RF.

A second goal of this study was to examine the impact of self-regulatory focus on memory. By influencing memory, RF could affect how people relate to both the current and future environment, which is likely to influence interpersonal dynamics. Returning to the previous example, in beginning a conversation by focusing on your partner's tendency to neglect a duty, such as washing dishes, one may induce a prevention state in the partner. According to our hypothesis, this would likely influence both how your partner perceives the remainder of the conversation (e.g., perceiving innocuous comments as further highlighting their failure to meet expectations) and their subsequent memory for that conversation (e.g., recalling the comments as weighted towards their shortcomings, and forgetting any compliments that were also offered). This could lead to later disputes about the nature of the conversation. Over time, such patterns of interaction could influence the nature of the relationship. That is, your partner may eventually feel they are always criticized and/or that their strengths are rarely acknowledged.

The impact of emotion on memory is well studied (Phelps & LeDoux, 2005; Reisberg & Hertel, 2004). Emotional events, from words to films, are typically remembered better than less emotional events (Brown & Kulik, 1977; Cahill

et al., 1996; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000; Doerksen & Shimamura, 2001; Hamann, Ely, Grafton, & Kilts, 1999; LaBar & Phelps, 1998; Strange, Hurlemann, & Dolan, 2003). Furthermore, individual differences can affect emotion-related memory. For example, avoidant adults (adults who are uncomfortable being close to, and dependent on, others) remembered less information about an emotional interview that they watched, compared to non-avoidant adults (Fraley, Garner, & Shaver, 2000). In addition, habitually using suppression as an emotion regulation strategy leads to worse performance on memory tests compared to habitually using a reappraisal strategy (Gross & John, 2003). There is also evidence that trait measures of RF can predict memory. Higgins and Tykocinski (1992) reported that individuals showed better memory for events described in a paragraph when the outcomes of those events were focus-consistent.

The hypothesized impact of RF on emotional memory (that is, memory for emotional information) is also supported by correlations between trait levels of promotion–prevention focus and amygdala activity during evaluation of focus-consistent concepts. Cunningham et al. (2005) reported that as trait levels of promotion focus increased, amygdala activity in response to positive stimuli increased. A similar relationship was observed for prevention focus and negative stimuli. Given these findings, as well as evidence of the amygdala's involvement in emotional memory (Cahill et al., 1996; Hamann, 2001; Phelps & LeDoux, 2005), one might predict interactions between memory performance and valence to be influenced by state RF, and reflected in activity in the amygdala and memory related structures (e.g., parahippocampus).

In this study, we investigate self-regulatory focus as a source of intra-individual variation (Higgins, 1997, 1998) in emotional responsiveness to positive and negative verbal stimuli. We manipulated focus between-groups, and measured brain activity using fMRI during an evaluative judgment task. After a 30 minute delay, participants were given a surprise old–new recognition test. We were primarily interested in brain regions showing interactions between state focus and valence during the encoding task, as well as regions showing interactions among focus, valence, and subsequent memory.

METHOD

Participants

Fifteen healthy young adults (4 males, mean age = 21.5 years) affiliated with Yale University were recruited and received a small monetary compensation for their participation (two additional participants were excluded due to excessive head movement). Participants were right-handed, spoke English as their first language, and reported being in good health with no history of neurological impairment or head trauma. Informed consent was obtained from all participants. The protocol was approved by the Human Investigation Committee of Yale University Medical School.

Stimuli and procedure

Before entering the scanner, RF was manipulated by having participants write an essay on how their "hopes and aspirations" (*Promotion focus*: $N = 7$, 2 males) or "duties and obligations" (*Prevention focus*: $N = 8$, 2 males) had changed since they were a child (Farb, Cunningham, & Anderson, 2006a; Freitas & Higgins, 2002; Johnson et al., 2006). This took an average of 7 minutes (range 5 to 10 minutes). Participants were then given instructions for the evaluative task, and allowed to practice (task details below). To ensure that the RF manipulation was active for the evaluative task in the scanner, participants were asked to think about the essay that they had previously written—elaborating on those ideas if they wished—during the last 3.5 minutes of the structural scans (elapsed time from the initial essay was approximately 15 minutes).

During the functional scans, participants performed the evaluative (incidental encoding) task. For this task, two word lists (Sets A and B) were created, each with 180 words varying in valence and arousal (valence scale: 1 (low pleasure) to 9 (high pleasure); arousal scale: 1 (low arousal) to 9 (high arousal); words and norms from the ANEW database, Bradley & Lang, 1999). Within each list, 60 words were positive (e.g., *comedy*, *joy*; means: valence $= 7.63 \pm 0.50$ *SD*, arousal $= 5.45 \pm 1.28$), 60 were negative (e.g., *corpse*, *torture*; valence $= 2.56 \pm 0.64$, arousal $= 5.49 \pm 1.11$) and 30 were neutral (e.g., *humble*, *salute*; valence $= 5.02 \pm 0.65$, arousal $= 3.77 \pm 0.54$). Thirty ambivalent

words used in Cunningham et al. (2005) were also included, but are not relevant for the current report. Across valence categories and lists, words were equated for frequency ($M = 31.1$; Francis & Kucera, 1982), concreteness ($M = 435.7$; MRC Psycholinguistic Database, http://www.psy.uwa.edu.au/mrcdatabase/mrc2.html), and number of syllables ($M = 1.98$). Participants viewed one word set during the encoding phase, and the other set was used as distracters during the recognition test; sets were counterbalanced across participants.

Words were projected onto a screen in the magnet room, and viewed by participants via mirrors mounted on the head coil. Words were presented randomly (without replacement) with 36 words in each of five runs, using E-Prime 1.1 (www.pstnet.com/eprime). Valence categories were equally distributed across runs.

Participants were instructed to evaluate each word as either *good* or *bad* (Cunningham et al., 2005) using two button boxes, one in each hand. Words were presented for 1700 ms, preceded by a 300 ms orienting label which remained onscreen above the word. The orienting label reminded participants whether the left or right button box designated good or bad. Good–bad laterality was counter-balanced across participants. Interstimulus intervals were 2, 4, or 6 s (pseudo-randomly ordered) during which a crosshair was presented. Additionally, 45 null trials (appearing to the participants as longer fixation periods) were distributed over the runs, to space out experimental trials. The evaluative task lasted approximately 25 minutes.

The evaluative task was immediately followed by another short (approximately 10 minute) functional task described elsewhere (Johnson et al., 2006). After these scans were completed, participants moved to a quiet testing room and were given a distraction task (math problems) until a total of 30 minutes had elapsed since the end of the evaluative task. A self-paced recognition test was then administered, where all 360 words (Sets A and B) were presented on a computer. Participants were instructed to designate each word as *old* (presented during the study phase) or *new* (not presented during the study phase) using the keyboard. Word order was pseudo-random such that no more than three old or new words were presented sequentially. At the end of the study, a Prevention–Promotion Questionnaire (PPQ; Farb, Nezlek, & Cunningham, 2006b), measuring chronic RF tendencies, was also administered. (Example questions: ''It's very important for me to avoid missing out on opportunities.'' [Promotion]; ''It's very important for me to make safe decisions.'' [Prevention]). Participants rate their agreement with such statements on a 1 (*Does not describe me*) to 6 (*Really describes me*) scale, and scores range from 1 (low trait) to 6 (high trait). The entire study lasted no more than four hours.

fMRI data acquisition and analysis

Anatomical images were acquired on a 1.5-T Siemens Sonata scanner at the Magnetic Resonance Research Center at Yale University. Functional scans were acquired with a single-shot echoplanar gradient-echo pulse sequence (TR = 2000 ms, TE = 35 ms, flip angle = 80 degrees, FOV = 24). Twenty-six oblique axial slices, parallel to the AC-PC line (12th slice on AC–PC line), were 3.8 mm thick with an in-plane resolution of 3.75×3.75 mm. Runs began with 14 s of fixation allowing steady state magnetization of tissue, and ended with 12 s of fixation. Rest periods between runs were approximately 1 minute.

Functional data were preprocessed and analyzed using SPM2 (Wellcome Department of Imaging Neuroscience). Data were corrected for slice acquisition time, realigned to the first slice, and co-registered to the mean image. Data were then normalized to the standard EPI MNI brain with a resampled voxel size of 4 mm^3, and smoothed with a Gaussian filter (8 mm full width at half maximum). To correct for drifts within session, a high-pass filter was applied, with a cutoff period of 128 s.

In a fixed-effects analysis at the individual level, contrasts modeled event-related responses to the words using a canonical hemodynamic response function with a temporal derivative. A general linear model analysis as implemented in SPM2 was used to generate individual contrast maps summarizing differences between categories of interest: valence (negative, positive, neutral) and memory (hits, misses). These maps were then used in random-effects analyses at the group level, comparing activity between RF groups using two-sample *t*-tests or examining activity within a group using one-sample *t*-tests. Significance levels for these analyses were set at $p < .005$, with a more lenient threshold of $p < .01$ used for planned comparisons. Maxima from whole-brain analyses are reported in MNI

co-ordinates, as given by SPM2. Determination of Brodmann areas and anatomical labels were aided by conversion of MNI co-ordinates to Talairach co-ordinates (Brett, 2002; http://www.mrc-cbu.cam.ac.uk/Imaging/Common/mnispace.shtml) for use in the Talairach Daemon Client 2.0 (Lancaster et al., 2000; http://ric.uthscsa.edu/projects/talairachdaemon.html), and then manually compared to the Talairach and Tournoux (1988) atlas.

RESULTS

Behavioral results

As indexed by the PPQ, chronic promotion focus did not differ between groups, Prevention group: $M = 4.75 \pm 0.58$ SEM, Promotion group: 4.69 ± 0.84; $t(13) = 0.16$, $p > .10$, nor did chronic prevention focus, Prevention group: 4.79 ± 0.65, Promotion group: 4.36 ± 0.73; $t(13) = 1.22$, $p > .10$. This suggests that effects of the RF manipulation were independent of chronic focus.

Response times (RTs) during the encoding phase (Table 1, top) were analyzed in a 2 (RF: prevention, promotion) $\times 2$ (memory: hit, miss) $\times$ 3 (valence: positive, negative, neutral) ANOVA, in which RF was a between-subjects factor, and subsequent memory performance (hits, misses) and word valence were within-subject factors. There was a main effect of valence, $F(2, 26) = 12.13$, $MSE = 24862$, $p < .001$, such that responses

to neutral words ($M = 1079.7$) were significantly slower compared to negative (929.2, $p < .001$) or positive (889.1, $p < .01$) words which were not different from each other ($p > .10$). This pattern is likely due to the difficulty in designating a neutral word as either good or bad. There was also a trend towards slower responses for subsequently remembered words (Hits: 993.2) compared to forgotten words (Misses: 938.8) $F(1, 13) = 3.65$, $MSE = 18154$, $p = .08$, indicating that increased processing during the evaluative judgments may have contributed to memory performance. There were no other main effects or interactions, suggesting that both groups found the encoding task equally challenging.

The recognition data are presented in Table 1 (bottom). Corrected recognition rates (hits minus false alarms) were analyzed using a 2 (RF) $\times 3$ (valence) ANOVA. There was a main effect of group, Prevention: $0.80 >$ Promotion: 0.67; $F(1, 13) = 4.61$, $MSE = 0.04$, $p = .05$, that resulted from more hits and fewer false alarms in the prevention group. A main effect of valence, $F(2, 26) = 26.62$, $MSE = 0.004$, $p < .0001$, was driven by better memory for neutral words (0.83) compared to positive (0.70; $p < .0001$) or negative (0.68; $p < .0001$) words, which were not different from each other ($p > .10$). Together with the RT data, this finding suggests that the relatively extended processing required to judge neutral items as good or bad led to improved recognition of these words (for another example of an orienting task affecting relative memory of emotional and

TABLE 1
Mean (SEM) response times (ms) during encoding, and mean (SEM) recognition performance, by focus group and valence

	Negative words	Positive words	Neutral words
Response times during encoding			
Prevention			
Hits	957.7 (54.8)	905.8 (45.4)	1132.5 (55.7)
Misses	869.7 (40.9)	854.0 (41.2)	1005.0 (169.8)
Promotion			
Hits	943.8 (46.4)	903.9 (42.5)	1115.5 (60.1)
Misses	945.6 (60.8)	892.7 (27.0)	1065.8 (61.1)
Recognition performance			
Prevention			
Hits	0.83 (0.05)	0.86 (0.04)	0.92 (0.02)
FA	0.09 (0.02)	0.08 (0.02)	0.03 (0.01)
H−FA	0.74 (0.04)	0.78 (0.04)	0.89 (0.03)
Promotion			
Hits	0.75 (0.02)	0.75 (0.04)	0.83 (0.04)
FA	0.13 (0.02)	0.13 (0.04)	0.06 (0.02)
H−FA	0.62 (0.03)	0.62 (0.07)	0.78 (0.05)

Notes: H = hits, FA = false alarms.

neutral words see Johnson, Mitchell, Raye, McGuire, & Sanislow, in press).

fMRI Results

General group differences: Words vs. fixation. To locate areas sensitive to the focus manipulation generally, we first compared the RF groups in a contrast of all the words relative to fixation (Table 2, top). The prevention group showed greater activity than the promotion group in regions throughout the brain at $p < .005$, extent threshold $(k) = 10$, thus we imposed a stricter threshold $(p < .0001, k = 15)$, which narrowed the differences to areas in the thalamus and brainstem. The thalamus gates information on its way to cortical regions, and is also involved in memory formation and executive function (Van der Werf, Witter, Uylings, & Jolles, 2000). The better memory observed in the Prevention group suggests that greater activity in the thalamus may

have contributed to their performance. There were no areas where Promotion > Prevention, even at a more lenient threshold of $p < .01$ $(k = 6)$.

Emotion and RF. We contrasted activity related to judgments of emotional and neutral words to determine areas that were sensitive generally to either emotion (Table 2, bottom). Across RF groups, we observed greater activity in response to emotional compared to neutral words in areas including the precuneus, consistent with findings from Cunningham et al. (2005) showing activity in this area in response to emotional words.

We also investigated whether brain activity differed depending on word valence (positive or negative) and focus (Table 3). In a series of two-sample *t*-tests we compared the Prevention and Promotion groups on activity related to positive and negative words separately. For the negative words (relative to neutral words), the Prevention > Promotion contrast (focus-consistent)

TABLE 2

Areas showing group differences in response to all words (top), and areas showing activity in comparisons of emotional and neutral words across focus groups (bottom)

Anatomical regions	BA	MNI co-ordinates x	y	z	Cluster size	Max T
All words > fixation						
Prevention > Promotion*****						
Thal (Putamen)		16	−4	4	24	8.27
Thal		−20	−20	12	71	11.75
Brainstem		0	−20	−24	32	8.27
Promotion > Prevention						
	No significant effects observed.					
Emotional versus neutral words						
Emotion > Neutral***						
PCU, PCC	7, 31	−16	−56	36	108	5.88
PCC	31	12	−28	40	14	5.33
PCC	31	−8	−24	40	13	3.74
IPL	40	56	−36	28	13	3.67
Neutral > Emotion***						
Lateral OFC	11, 47	40	36	−8	15	4.11
MFG, IFG	46	56	36	20	14	3.98
IFG, MFG, Ins (STG)	45, 44, 46, 47, 6, 8, 9, 13 (38)	−56	32	4	239	5.87
MdFG, cingulate	8, 32	−4	20	48	11	4.58
Ins, IFG	13, 44	36	20	8	28	3.93
Thal	—	−8	−12	4	47	4.20
Thal	—	−8	−28	−4	10	3.97

Notes: ***$p < .005$. *****$p < .0001$. In each table, for each area of activation, the first anatomical region and Brodmann Area (BA) listed corresponds to the local maximum, with subsequent regions listed in descending order of approximate size (parentheses indicate a small extent relative to the other areas listed). MNI co-ordinates (x, y, z) are shown for the local maximum in each area of activation (activations in the left hemisphere denoted by negative x values). *Max T* = maximum *t*-statistic in the cluster for the reported difference. The following anatomical abbreviations will be used for all tables: ACC = anterior cingulate cortex, IFG = inferior frontal gyrus, Ins = insula, IPL = inferior parietal lobule, MdFG = medial frontal gyrus, MFG = middle frontal gyrus, MTG = middle temporal gyrus, OFC = orbital frontal cortex, paraHG = parahippocampus, PCC = posterior cingulate cortex, PCU = precuneus, SFG = superior frontal gyrus, STG = superior temporal gyrus, Thal = thalamus.

TABLE 3
Areas showing group differences in response to emotional information

| Anatomical regions | BA | MNI co-ordinates | | | Cluster size | Max T |
		x	y	z		
Negative >Neutral						
Prevention >Promotion (focus-consistent activity)						
PCU, PCC***	7, 31	−12	−72	28	15	4.26
(PCC second maximum)	**31**	**−16**	**−52**	**28**	**—**	**4.25**
ACC, OFC***	32, 11	−4	32	−12	10	4.18
MdFG, SFG**	6, 8	12	8	52	10	5.12
paraHG**	36	24	−28	−24	6	3.81
IPL**	2, 1	64	−32	44	10	3.01
IPL***	40	−40	−36	48	12	4.80
MTG**	39	56	−72	20	6	3.60
Promotion >Prevention (focus-inconsistent activity)						
OFC**	11, 47	16	36	−20	9	3.62
Positive >Neutral						
Prevention >Promotion (focus-inconsistent activity)						
Ins, STG, IFG***	13, 22, 44	44	0	12	30	4.22
IPL, STG***	40, 42	−52	−32	28	22	4.10
Ins**	13	−44	12	0	13	3.29
Ins**	13	−40	−12	12	10	4.23
STG, Ins, IFG**	22, 38, 13, 44	64	4	−4	67	4.59
STG, IPL**	22, 42, 40	−60	−20	16	28	3.89
STG (IPL)**	42, 40	64	−28	16	16	3.47
Precentral gyrus, IFG**	6, 44	−60	4	12	7	4.36
Precentral gyrus**	6	44	−12	40	9	3.98
paraHG**	36	24	−32	−16	9	4.05
Promotion >Prevention (focus-consistent activity)						
PCC	**31**	**12**	**−32**	**40**	**7**	**3.49**

Notes: **p <.01. ***p <.005. **Bolded** areas displayed in Figure 1.

revealed activity in the precuneus/PCC, anterior cingulate (ACC) extending into orbital frontal cortex (OFC), and inferior parietal cortex. No activity was observed at $p <.005$ for the Promotion >Prevention contrast (focus-inconsistent). For the positive words (relative to neutral words), the Prevention >Promotion contrast (focus-inconsistent) revealed activity in insula, inferior parietal, and superior temporal regions. No activity was observed at $p <.005$ for the Promotion >Prevention contrast (focus-consistent).

Based on findings from Cunningham et al. (2005) and Johnson et al. (2006) we expected focus-related activity for both groups in areas such as the MdFG, PCC, and amygdala. To explore this possibility, we reduced our threshold to $p <.01$ ($k =6$; Table 3). For the negative words, activity in the Prevention >Promotion contrast included the MdFG, parahippocampus, and inferior parietal lobe. Additionally, within the precuneus/PCC cluster noted at $p <.005$, there was a second maximum of activity in the PCC (Figure

1A). The Promotion >Prevention contrast revealed activity in the OFC. For the positive words, cluster sizes in the Prevention >Promotion contrast expanded, but no midline activity was apparent. The Promotion >Prevention contrast revealed activity in the PCC (Figure 1B).

In sum, there was a dissociation between focus and valence in the PCC such that greater activity was observed for the prevention group in response to negative words (Figure 1A), and for the promotion group in response to the positive words (Figure 1B). Additionally, regions including the ventral ACC (extending to the OFC) and precuneus showed greater sensitivity in the prevention group, and the OFC showed greater sensitivity in the promotion group, when stimuli were negative. Finally, greater parahippocampal activity was observed in the prevention group regardless of stimulus valence, consistent with the enhanced recognition we observed in this group.

Memory-related processing. In terms of memory processing, we were primarily interested in
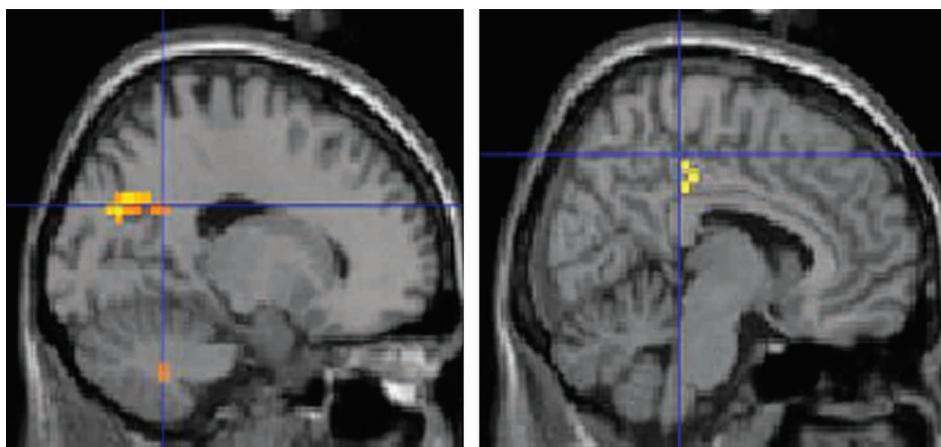
Figure 1.   Focus-consistent activity observed in the PCC. (A, left panel) Prevention > Promotion contrast for negative > neutral words (BA 31; MNI co-ordinates: -16, -52, 28). (B, right panel) Promotion > Prevention contrast for positive > neutral words (BA 31; MNI co-ordinates: 12, -32, 40). Details and complete list of activations in Table 3.

areas showing subsequent memory effects as a function of RF. To test this, we created individual contrast maps capturing the interaction of memory and valence, entering these maps into random-effects, one-sample t-tests. Memory related activity for positive words (PosMem: Positive Hits > Positive Misses) versus negative words (NegMem: Negative Hits > Negative Misses) for each focus group is listed in Table 4. These regions were then used in ROI analyses, wherein beta values for hits and misses for the positive, negative, and neutral words were extracted (sphere diameter for beta extraction $=3$ voxels). Extracted values were analyzed in a 2 (RF) $\times 2$ (memory: hits, misses) $\times 3$ (valence) ANOVA using Statistica (vs. 7.1, StatSoft, Inc.). One participant from the prevention group was excluded due to a lack of misses for negative words.

A region of right parahippocampus showed an interesting and interpretable pattern of activation. A three-way interaction that approached significance was observed, $F(2, 24) =2.70$, $MSE = 4.74$, $p <.09$; Figure 2. Planned comparisons showed greater activity for hits than misses for negative words for the prevention group, $F(1, 12) =5.47$, $MSE =2.72$, $p <.05$, but conversely, greater activity for hits than misses for positive words for the promotion group, $F(1, 12) =4.75$, $MSE =3.26$, $p <.05$. In neither group did activity in this region differ for hits versus misses for neutral words. No other main effects or interactions were significant in this region.

Another interesting pattern of activity was observed in an area in the left middle/inferior frontal cortex. This area showed activity in the

NegMem > PosMem contrast for the promotion group, but further analysis of the extracted beta values revealed a striking effect related to the neutral words. A memory $\times$ valence interaction, $F(2, 24) =6.34$, $MSE =4.05$, $p <.01$, resulted from enhanced activity for neutral hits relative to all other words ($p <.001$; Figure 3). Main effects of memory, $F(1, 12) =7.66$, $MSE =6.78$, $p <.05$, and valence, $F(2, 24) =4.21$, $MSE =8.15$, $p <.05$, were driven by this interaction. No other effects were significant.

We also conducted a focused ROI analysis of amygdala activity based on Cunningham et al.'s (2005) finding of RF related activity in this area, as well as the emotional memory literature (Hamann, 2001; Phelps & LeDoux, 2005). Beta values from the left and right amygdala (centered on co-ordinates: $+20$, 0, -20) were averaged together, as there were no statistical differences in their patterns of activity. There was a focus $\times$ memory interaction, $F(1, 12) =8.44$, $MSE = 12.29$, $p <.05$. Subsequent analysis revealed that amygdala activity predicted memory in the promotion group (Hits: $M =3.06 \pm 0.73$ $SEM >$ Misses: -0.46 ± 1.2, $p <.05$), but not the prevention group (Hits: 3.8 ± 0.7, Misses: 4.62 ± 1.2). There was also a main effect of focus, $F(1, 12) =5.85$, $MSE =29.29$, $p <.05$, with higher activity in the prevention group.

DISCUSSION

The aim of this study was to examine the influence of state regulatory focus on sensitivity

TABLE 4
Areas showing valence × memory interactions in each focus group

Anatomical regions	BA	MNI co-ordinates			Cluster size	Max T
		x	*y*	*z*		
NegMem >PosMem						
Prevention group						
paraHG	**20**	**32**	**−20**	**−20**	**19**	**4.82+**
MdFG, ACC	10, 9, 32	4	52	16	33	6.58
MFG	9, 10	36	44	32	10	5.13
Ins, IFG	13, 47	−28	16	−8	13	7.98
Promotion group						
MFG, IFG	**9**	**−40**	**8**	**32**	**11**	**5.74++**
MdFG	9, 10	8	56	20	34	5.99
MdFG	8	16	44	40	12	5.74
MTG	9, 46	44	32	32	15	8.08
MTG	21	64	−40	−8	17	9.42
PosMem >NegMem						
Prevention group						
No significant effects observed at this threshold						
Promotion group						
No significant effects observed at this threshold						

Notes: NegMem: Negative Hits >Negative Misses; PosMem: Positive Hits >Positive Misses.
$p <.005$ for all contrasts. Beta values for **bolded** area with + are displayed in Figure 2; Beta values for **bolded** area with ++ are displayed in Figure 3.

to, and memory for, emotional words and to identify related brain regions. We expected interactions between focus and valence, such that the prevention group would show greater sensitivity during encoding to negative words, and the promotion group to positive words. Such a dissociation at encoding was observed in the PCC. We also observed an analogous subsequent memory-related dissociation in the right parahippocampus, supporting the idea that increased sensitivity to information leads to changes in memory-related processing.

Emotional processing

The PCC showed greater sensitivity to words when they were focus-consistent. Given the involvement of the PCC in episodic retrieval and self-referential processing (Johnson et al.,
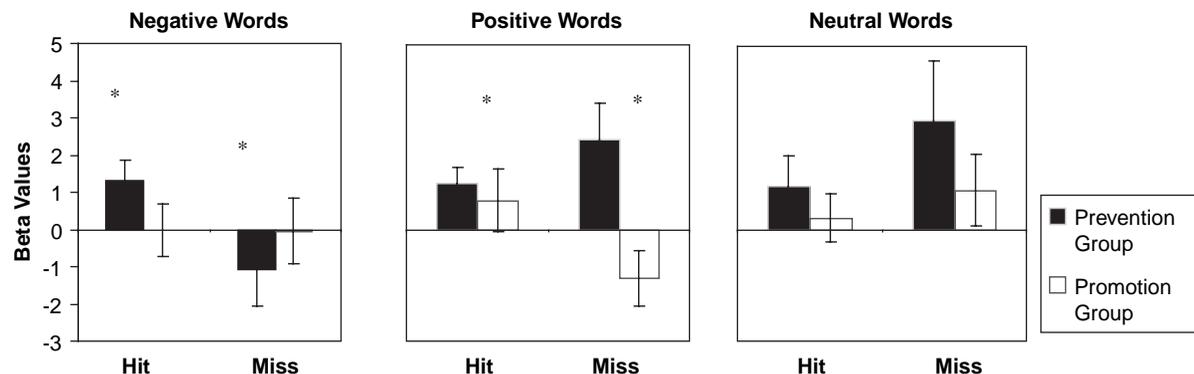

Figure 2. Beta values extracted from right parahippocampus (BA 20; MNI co-ordinates: 32, −20, −20) for hits and misses by word valence and RF group. Planned contrasts confirmed a focus-consistent memory effect for hits versus misses within each valence: H >M for negative words in the prevention group (*$p <.05$), but H >M for positive words in the promotion group (*$p <.05$).
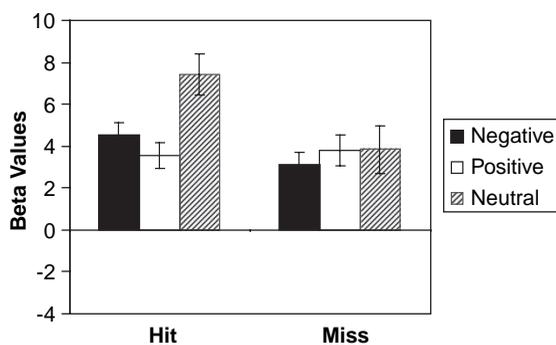
Figure 3. Beta values extracted from a region of left middle/ inferior frontal gyrus (BA 9; MNI co-ordinates: $-40, 8, 32$) for hits and misses. Planned contrasts of hits versus misses for each valence showed that H > M for neutral items only ($p <$ .001).

2006; S. C. Johnson et al., 2005; Ochsner et al., 2005; Wagner, Shannon, Kahn, & Buckner, 2005), this dissociation may reflect a manipulation-induced effect on the type of episodic memories activated during the evaluative task. Although the good–bad judgments did not explicitly involve episodic or self-referential processing, the evaluative nature of the task likely induced activation of prior knowledge and memories. Thus, the RF manipulation may have led to activation of information consistent with RF, similar to schema activation. Stimuli consistent with the activated information may then have been more easily processed. In addition, focus-consistent stimuli may have been more likely to induce personal memories. For example, someone in a promotion focus may have been more likely to recall a memory in response to the word *graduate* than the word *penalty*. This account predicts that the observed dissociation in PCC sensitivity might not be observed if the encoding task were modified to involve non-evaluative word judgments (e.g., length), which are less likely to invoke episodic memories or self-referential processing.

Valence × focus interactions were also observed in other brain areas. For example, the precuneus was more active for focus-consistent stimuli when those stimuli were negative. The area of precuneus we observed encompasses a relatively posterior subdivision, as defined by Cavanna and Trimble (2006). These authors suggest that this area is involved in episodic retrieval, thus activity observed here may reflect episodic retrieval during the task. What needs to be accounted for is the restriction of activity to the Prevention > Promotion contrast. As reported

by Liotti, Mayberg, Brannan, McGinnis, Jerabek, and Fox (2000) precuneus activation is associated with negative mood in healthy adults. Therefore, the prevention group was perhaps more likely to experience negative emotions in response to the negative words, consistent with the expected influence of focus on sensitivity to negative stimuli. (The possible involvement of mood in these findings is addressed in more detail below.)

Interestingly, there was evidence that OFC was active in response to negative stimuli in both groups (ventral ACC extending into OFC for the prevention group, and OFC for the promotion group). These findings are consistent with other studies reporting OFC involvement in the processing of negative stimuli (Phan, Wager, Taylor, & Liberzon, 2002; Rule, Shimamura, & Knight, 2002; Schäfer, Schienle, & Vaitl, 2005), and suggest that OFC may be less sensitive to differences in regulatory focus compared to other regions. This is a speculation that deserves further investigation.

Emotional memory

In a region of the parahippocampus, memory related activity (hits > misses) was greater for focus-consistent stimuli (see Figure 2). This supports our hypothesis that differential sensitivity to focus-consistent stimuli should affect processing in memory-related areas such as the parahippocampus (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998). That is, variations in RF lead to variations in brain activation that are predictive of memory for certain types of stimuli (negatively valenced for prevention, positively valenced for promotion). The similar interactions observed in the PCC and the parahippocampus suggests that RF influences the nature of self-relevant information available during encoding, which in turn affects memory-related processing of the task words. In other words, activating past memories influences future ones. Indeed, it has been shown that the posterior cingulate and parahippocampus are anatomically interconnected (Parvizi, Van Hoesen, Buckwalter, & Damasio, 2006), supporting the functional relations we have observed.

Activity in the lateral frontal cortex was also related to subsequent memory. A region of middle/inferior frontal gyrus showed the greatest activity for neutral words later remembered (see Figure 3). This is consistent with other research implicating this area in memory-related proces-

sing (e.g., Habeck et al., 2005; Johnson, Raye, Mitchell, Greene, Cunningham, & Sanislow, 2005; Wager & Smith, 2003). For example, Johnson et al. (2005; Experiment 2) found that a frontal region very near that reported here (3D distance approximately 9 mm) was involved in refreshing (thinking about) just-activated information. Such findings suggest that the pattern in Figure 3 is related to greater processing of neutral compared to emotional words during evaluative judgments, in turn leading to improved memory for neutral words.

Greater amygdala activity was associated with hits than misses for the promotion group but not the prevention group. Interestingly, in the promotion group greater amygdala activity was associated with recognition of both emotional and neutral words. This seems in contrast to other reports suggesting that the amygdala is generally only involved in emotion-mediated memory (Cahill et al., 1996; Hamann et al., 1999; LaBar & Phelps, 1998). One explanation is that promotion participants experienced some arousal in response to both the emotional and neutral words. Whereas the impact of the positive and negative words likely results from their emotional nature, the impact of the neutral words may have resulted from the difficulty in evaluating them as either good or bad. In any event, the differential patterns in parahippocampus and amygdala suggest the functional relationship between these two areas with respect to emotional memory is complex.

Behavioral findings

Similar RTs between groups during the evaluative task suggest that this task was equally challenging for both groups. This makes it unlikely that any between-group differences in brain activity resulted from differences in task difficulty. Memory was better overall in the prevention group compared to the promotion group. Other researchers have also found that a prevention focus is associated with improved task performance. For example Farb et al. (2006a) found that trait levels of prevention focus predicted improved discriminability in a signal detection task compared to trait levels of promotion focus. As well, Forster, Higgins, and Bianco (2003) found that a prevention focus (whether chronic or acute) was associated with slower but more accurate performance in drawing and proofreading tasks com-

pared to a promotion focus. This tendency is thought to result from a greater motivation to avoid incorrect responses, compared to a promotion focus. Although we observed a memory advantage consistent with the findings of Forster et al. (2003), we did not observe group differences in RTs, possibly due to differences in task instructions in the two studies. Forster et al. asked participants to be both fast and accurate, whereas we did not provide explicit instructions in terms of speed or accuracy.

We did not observe an overall advantage in memory for emotional words compared to neutral words. This is most likely due to the extended processing required for the neutral words during the evaluative judgment task, leading to comparatively improved memory for those words. This finding suggests that superior memory for emotional versus neutral words is influenced by the orienting task, similar to the picture versus word superiority effect (see Durso & Johnson, 1980).

The relatively short study–test delay we used may have also contributed to the observed pattern of results. Differences in recognition of emotional and neutral information tend to appear after fairly long delays (e.g., ≥1 week using pictorial stimuli; Cahill, Prins, Weber, & McGaugh, 1994; Hamann et al., 1999). The increased effect of emotion after substantial delays is thought to reflect the effect of emotional arousal on consolidation processes that occur over time (Roozendaal, 2003; Sapolsky, 2003). Thus, increasing the delay (e.g., to 24 hours) in our paradigm may reduce the difference in memory between neutral and emotional items, or lead to an emotional item advantage, in spite of the greater processing given to the neutral items. We are currently pursuing the impact of regulatory focus on memory after longer study–test delays.

Additional considerations

One alternative explanation for the patterns of brain activity and behavioral findings that we observed is that the focus manipulation (essay) induced a particular mood state, leading to mood-congruent processing (happy mood for promotion focus, negative mood for prevention focus). However, other research shows that mood does not mediate the influence of regulatory focus (state or trait) on cognitive processing (Higgins, Idson, Freitas, Spiegel, & Molden, 2003; Higgins &

Tykocinski, 1992). Furthermore, subsequent data we collected suggests that mood is not a sufficient explanation for these results. In this study (Touryan, unpublished data), mood measures (sad, anxious, angry, happy) were taken immediately before and after participants wrote the focus-induction essay. With 28 participants (Promotion group: $N = 15$; Prevention group: $N = 13$) changes in sad, anxious, and happy scores were not significantly different from zero ($p > .10$ for all comparisons), nor were changes significantly different between groups ($p > .10$ for all comparisons). Anger increased slightly, 0.82 pt increase (± 1.4 SEM) on a 9-pt scale, $p < .01$, but this increase did not differ between groups ($p > .10$). This is not to say that mood did not play some role in our findings. Previously reported results suggest potentially complex relationships among moods, inter-participant variations (such as variations in regulatory focus), and brain activity (Canli, Amin, Haas, Omura, & Constable, 2004).

Finally, we should note that the relatively small number of participants in each group may have kept us from identifying additional regions of interest (e.g., amygdala activity related to both focus conditions, see Cunningham et al., 2005)—other regions that might be expected to show RF-related activity and predict subsequent memory.

CONCLUSIONS

We found evidence that manipulations in regulatory focus influence brain activity in response to verbal information during an evaluative task. The posterior cingulate and the parahippocampus are two areas where we observed a dissociation between word valence and focus group, with greater activity for focus-consistent stimuli. Other areas, such as the amygdala, also showed differences in activity dependent on focus group. These findings highlight the importance of dynamic motivational factors in understanding neural function—in particular the intersection of emotion and cognition. At a behavioral level, our findings suggest that regulatory focus influences what episodic details are preferentially elaborated during on-going experience, possibly by relating such details to self-referential information or episodic memories. This, in turn, influences memory. Social interactions are likely a frequent trigger for changes in focus, and thus information about others and our relationships with them might be framed by a regulatory

window subsequently affecting what we remember about a given interaction. In short, how we perceive, remember, and possibly act towards others in the future may be modulated by social interactions that affect our regulatory focus.

REFERENCES

Bradley, M. M., & Lang, P. J. (1999). *Affective norms for English words (ANEW): Instruction manual and affective ratings*. University of Florida: The Center for Research in Psychophysiology.

Brett, M. (2002). *The MNI brain and the Talairach atlas* [computer application and manual]. Available from http://www.mrc-cbu.cam.ac.uk/Imaging/Common/mnispace.shtml

Brewer, J. B., Zhao, Z., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. E. (1998). Making memories: Brain activity that predicts how well visual experience will be remembered. *Science*, *281*(5380), 1185–1187.

Brown, R., & Kulik, J. (1977). Flashbulb memories. *Cognition*, *5*(1), 73–99.

Cahill, L., Haier, R. J., Fallon, J., Alkire, M. T., Tang, C., Keator, D., et al. (1996). Amygdala activity at encoding correlated with long-term, free recall of emotional information. *Proceedings of the National Academy of Sciences of the USA*, *93*(15), 8016–8021.

Cahill, L., Prins, B., Weber, M., & McGaugh, J. L. (1994). Beta-adrenergic activation and memory for emotional events. *Nature*, *371*(6499), 702–704.

Canli, T., Amin, Z., Haas, B., Omura, K., & Constable, R. T. (2004). A double dissociation between mood states and personality traits in the anterior cingulate. *Behavioral Neuroscience*, *118*(5), 897–904.

Canli, T., Sivers, H., Whitfield, S. L., Gotlib, I. H., & Gabrieli, J. D. E. (2002). Amygdala response to happy faces as a function of extraversion. *Science*, *296*(5576), 2191.

Canli, T., Zhao, Z., Brewer, J., Gabrieli, J. D. E., & Cahill, L. (2000). Event-related activation in the human amygdala associates with later memory for individual emotional experience. *The Journal of Neuroscience*, *20*(19):RC99, 1–5.

Cavanna, A. E., & Trimble, M. R. (2006). The precuneus: A review of its functional anatomy and behavioural correlates. *Brain*, *129*(3), 564–583.

Cunningham, W. A., Raye, C. L., & Johnson, M. K. (2005). Neural correlates of evaluation associated with promotion and prevention regulatory focus. *Cognitive, Affective, & Behavioral Neuroscience*, *5*(2), 202–211.

Davidson, R. J. (1998). Affective style and affective disorders: Perspectives from affective neuroscience. *Cognition and Emotion*, *12*(3), 307–330.

Davidson, R. J. (2001). Toward a biology of personality and emotion. In A. R. Damasio, et al. (Eds.), *Unity of knowledge: The convergence of natural and*

human science (pp. 191–207). New York: New York Academy of Sciences.

Doerksen, S. R., & Shimamura, A. P. (2001). Source memory enhancement for emotional words. *Emotion*, 1(1), 5–11.

Durso, F. T., & Johnson, M. K. (1980). The effects of orienting tasks on recognition, recall, and modality confusion of pictures and words. *Journal of Verbal Learning and Verbal Behavior, 19*, 416–429.

Farb, N., Cunningham, W. A., & Anderson, A. K. (2006a). *Regulatory fit and action readiness: A reinterpretation of the role of regulatory focus in motivation.* Manuscript in preparation, University of Toronto, Ontario, Canada.

Farb, N., Nezlek, J. B., & Cunningham, W. A. (2006b). *Regulatory focus and mental health: The effects of attention to plan content versus outcome.* Manuscript in preparation, University of Toronto, Ontario, Canada.

Forster, J., Higgins, E. T., & Bianco, A. T. (2003). Speed/accuracy decisions in task performance: Built-in trade-off or separate strategic concerns? *Organizational Behavior and Human Decision Processes, 90*(1), 148–164.

Fraley, R. C., Garner, J. P., & Shaver, P. R. (2000). Adult attachment and the defensive regulation of attention and memory: Examining the role of preemptive and postemptive defensive processes. *Journal of Personality and Social Psychology, 79*(5), 816–826.

Francis, W. N., & Kucera, H. (1982). *Frequency analysis of English usage: Lexicon and grammar.* Boston: Houghton Mifflin.

Freitas, A. L., & Higgins, E. T. (2002). Enjoying goal-directed action: The role of regulatory fit. *Psychological Science, 13*(1), 1–6.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology, 85*(2), 348–362.

Habeck, C., Rakitin, B. C., Moeller, J., Scarmeas, N., Zarahn, E., Brown, T., et al. (2005). An event-related fMRI study of the neural networks underlying the encoding, maintenance, and retrieval phase in a delayed-match-to-sample task. *Brain Research. Cognitive Brain Research, 23*(2–3), 207–220.

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences, 5*(9), 394–400.

Hamann, S., & Canli, T. (2004). Individual differences in emotion processing. *Current Opinion in Neurobiology, 14*(2), 233–238.

Hamann, S., Herman, R. A., Nolan, C. L., & Wallen, K. (2004). Men and women differ in amygdala response to visual sexual stimuli. *Nature Neuroscience, 7*(4), 411–416.

Hamann, S. B., Ely, T. D., Grafton, S. T., & Kilts, C. D. (1999). Amygdala activity related to enhanced memory for pleasant and aversive stimuli. *Nature Neuroscience, 2*(3), 289–293.

Higgins, E. T. (1997). Beyond pleasure and pain. *American Psychologist, 52*(12), 1280–1300.

Higgins, E. T. (1998). Promotion and prevention: Regulatory focus as a motivational principle. *Advances in Experimental Social Psychology, 46*, 1–46.

Higgins, E. T., Idson, L. C., Freitas, A. L., Spiegel, S., & Molden, D. C. (2003). Transfer of value from fit. *Journal of Personality and Social Psychology, 84*(6), 1140–1153.

Higgins, E. T., Shah, J., & Friedman, R. (1997). Emotional responses to goal attainment: Strength of regulatory focus as moderator. *Journal of Personality and Social Psychology, 72*(3), 515–525.

Higgins, E. T., & Tykocinski, O. (1992). Self-discrepancies and biographical memory: Personality and cognition at the level of psychological situation. *Personality and Social Psychology Bulletin, 18*(5), 527–535.

Johnson, M. K., Raye, C. L., Mitchell, K. J., Greene, E. J., Cunningham, W. A., & Sanislow, C. A. (2005). Using fMRI to investigate a component process of reflection: Prefrontal correlates of refreshing a just-activated representation. *Cognitive, Affective, & Behavioral Neuroscience, 5*(3), 339–361.

Johnson, M. K., Raye, C. L., Mitchell, K. J., Touryan, S. R., Greene, E. J., & Nolen-Hoeksema, S. (2006). Dissociating medial frontal and posterior cingulate activity during self-reflection. *Social Cognitive and Affective Neuroscience, 1*, 56–64.

Johnson, M. K., Mitchell, K. J., Raye, C. L., McGuire, J. T., & Sanislow, C. A. (in press). Mental rubbernecking to negative information depends on task context. *Psychonomic Bulletin & Review.*

Johnson, S. C., Schmitz, T. W., Kawahara-Baccus, T. N., Rowley, H. A., Alexander, A. L., Lee, J., et al. (2005). The cerebral response during subjective choice with and without self-reference. *Journal of Cognitive Neuroscience, 17*(12), 1897–1906.

LaBar, K. S., & Phelps, E. A. (1998). Arousal-mediated memory consolidation: Role of the medial temporal lobe in humans. *Psychological Science, 9*(6), 490–493.

Lancaster, J. L., Woldorff, M. G., Parsons, L. M., Liotti, M., Freitas, C. S., Rainey, L., et al. (2000). Automated Talairach Atlas labels for functional brain mapping. *Human Brain Mapping, 10*, 120–131.

Leen-Feldner, E. W., Zvolensky, M. J., Feldner, M. T., & Lejuez, C. W. (2004). Behavioral inhibition: Relation to negative emotion regulation and reactivity. *Personality and Individual Differences, 36*(6), 1235–1247.

Levine, B., Turner, G. R., Tisserand, D., Hevenor, S. J., Graham, S. J., & McIntosh, A. R. (2004). The functional neuroanatomy of episodic and semantic autobiographical remembering: A prospective functional MRI study. *Journal of Cognitive Neuroscience, 16*(9), 1633–1646.

Lim, S. L., & Kim, J. H. (2005). Cognitive processing of emotional information in depression, panic, and somatoform disorder. *Journal of Abnormal Psychology, 114*(1), 50–61.

Liotti, M., Mayberg, H. S., Brannan, S. K., McGinnis, S., Jerabek, P., & Fox, P. T. (2000). Differential limbic–cortical correlates of sadness and anxiety in healthy subjects: Implications for affective disorders. *Biological Psychiatry, 48*(1), 30–42.

Maio, G. R., & Esses, V. M. (2001). The need for affect: Individual differences in the motivation to approach or avoid emotions. *Journal of Personality*, *69*(4), 583–615.

Markus, H., & Wurf, E. (1987). The dynamic self-concept: A social psychological perspective. *Annual Review of Psychology*, *38*, 299–337.

Ochsner, K. N., Beer, J. S., Robertson, E. R., Cooper, J. C., Gabrieli, J. D., Kihlstrom, J. F., et al. (2005). The neural correlates of direct and reflected self-knowledge. *NeuroImage*, *28*(4), 797–814.

Parvizi, J., Van Hoesen, G. W., Buckwalter, J., & Damasio, A. R. (2006). Neural connections of the posteromedial cortex in the macaque. *Proceedings of the National Academy of Sciences of the USA*, *103*(5), 1563–1568.

Phan, K. L., Wager, T., Taylor, S. F., & Liberzon, I. (2002). Functional neuroanatomy of emotion: A meta-analysis of emotion activation studies in PET and fMRI. *NeuroImage*, *16*(2), 331–348.

Phelps, E. A., & LeDoux, J. E. (2005). Contributions of the amygdala to emotion processing: From animal models to human behavior. *Neuron*, *48*(2), 175–187.

Reisberg, D., & Hertel, P. (Eds.). (2004). *Memory and emotion*. New York: Oxford University Press.

Roozendaal, B. (2003). Systems mediating acute glucocorticoid effects on memory consolidation and retrieval. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *27*(8), 1213–1223.

Rule, R. R., Shimamura, A. P., & Knight, R. T. (2002). Orbitofrontal cortex and dynamic filtering of emotional stimuli. *Cognitive, Affective, & Behavioral Neuroscience*, *2*(3), 264–270.

Sapolsky, R. M. (2003). Stress and plasticity in the limbic system. *Neurochemical Research*, *28*(11), 1735–1742.

Schäfer, A., Schienle, A., & Vaitl, D. (2005). Stimulus type and design influence hemodynamic responses towards visual disgust and fear elicitors. *International Journal of Psychophysiology*, *57*(1), 53–59.

Shah, J., & Higgins, E. T. (2001). Regulatory concerns and appraisal efficiency: The general impact of promotion and prevention. *Journal of Personality and Social Psychology*, *80*(5), 693–705.

Strange, B. A., Hurlemann, R., & Dolan, R. J. (2003). An emotion-induced retrograde amnesia in humans is amygdala- and beta-adrenergic-dependent. *Proceedings of the National Academy of Sciences of the USA*, *100*(23), 13626–13631.

Talairach, J., & Tournoux, P. (1988). *Co-planar stereotaxic atlas of the human brain. 3-dimensional proportional system: An approach to cerebral imaging.* New York: Thieme Medical Publishers.

Van der Werf, Y. D., Witter, M. P., Uylings, H. B. M., & Jolles, J. (2000). Neuropsychology of infarctions in the thalamus: A review. *Neuropsychologia*, *38*(5), 613–627.

Wager, T. D., & Smith, E. E. (2003). Neuroimaging studies of working memory: A meta-analysis. *Cognitive, Affective, & Behavioral Neuroscience*, *3*(4), 255–274.

Wagner, A. D., Shannon, B. J., Kahn, I., & Buckner, R. L. (2005). Parietal lobe contributions to episodic memory retrieval. *Trends in Cognitive Sciences*, *9*(9), 445–453.