

The right hemisphere's contribution to emotional word processing in currently depressed, remitted depressed, and never-depressed individuals

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Abstract

To examine how unipolar depression influences hemispheric processing of emotional stimuli, words with clear affective content were assessed by depressed, remitted depressed, and never depressed participants. Semantic stimuli were selected for both their valence (positive vs. negative) and for their ability to engender affective arousal (high vs. low). After completing a structured clinical interview to determine depression experience, participants were asked to make valence judgements for laterally presented emotional words. Study results suggest that the right hemisphere (RH) is particularly sensitive to the affective semantic content of emotional stimuli, furthermore, two interesting higher order interactions were observed in the RH. First, in a replication of recent findings by Atchley et al. [2003. Hemispheric asymmetry in the processing of emotional content in word meanings: The effect of current and past depression. *Brain and Language*, 84, 105–119], individuals who have experienced depression (both currently depressed and remitted depressed groups) show an advantage when processing negatively valent words, while the never depressed individuals show an advantage for positive words. Also in the RH, affective arousal interacted with stimulus valence (but not diagnostic group), such that all participants exhibited an advantage when categorizing highly arousing negative information, while for positive words the low arousing stimuli were identified more accurately. These results are discussed in the context of models of depressive cognition and in regards to general models of hemispheric specialization for emotion processing.

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1. Introduction

In the last few decades, research concerning the laterality of emotion processing has grown immensely (please see Borod, Bloom, & Haywood, 1998; Murphy, Nimmo-Smith, & Lawrence, 2003; Springer & Deutsch, 1998 for reviews). Currently, there are three primary theories regarding the neuropsychology of perceptive and expressive emotion. The oldest of these is the *right hemisphere (RH) dominance hypothesis*. According to this theory, the RH is responsible for processing all emotional information, positive and negative, perceptive and expressive. For example, there is evidence of RH dominance in the comprehension of emotional content in facial expressions and in the processing of prosody, into national and affective information conveyed during speech (Bobes, Martin, Olivares, & Valdez-Sosa, 2000; Bower, Bauer, Coslett, & Heilman, 1993; Ross & Mesulam, 1979; Wymer, Lindman, & Booksh, 2002). This RH dominance for emotion processing is illustrated in Safer and Leventhal's (1977) classic study, in which participants were asked to make a valence judgement for monaurally presented verbal passages differing in affective tone. When stimuli were presented to the left ear (RH) participants used the prosodic tone to rate the passage, while those listening on the right ear (or left hemisphere, LH) used the semantic content to make their judgements—thereby confirming a LH dominance for initial lexical processing and a RH dominance for processing emotional prosody.

A second influential theory is the *valence hypothesis*, which states that the prefrontal cortex of each cerebral hemisphere is specialized for the processing of emotion depending upon the valence content of the stimulus (Davidson, 1984, 2003; Tucker, 1981). Based on results from both electrophysiological and functional imaging studies, it has been argued that the left hemisphere is specialized for more positive emotions that illicit approach or appetitive behaviors. In contrast, the right prefrontal cortex is specialized for processing more negative emotions that lead to defensive or withdraw behaviors (Davidson 1995; Davidson, 2003; Davidson & Irwin, 1999; Davidson & Tomarken, 1989). For example, Canli, Desmond, Zhao, Glover, and Gabrieli (1998) collected fMRI data while subjects rated how emotional pictures made them feel. They found that the LH was more active when participants were responding to positive pictures, while the RH was more active for the negative ones. Similarly, while employing words and non-words as stimuli in a divided visual field (DVF) study, Ali and Cimino (1997) had participants rate as quickly as possible whether or not each trial was a word in a “go/no go” task. When recognition memory for the words was tested, the positive words presented to the right visual field (RVF) were recalled more accurately than negative words, while the opposite pattern was found in the left visual field (LVF).

In a synthesis of the RH dominance and valence theories, a third theory of hemispheric lateralization for emotion, sometimes referred to as the *circumplex model of emotion*, postulates that the posterior RH is responsible for all perception of emotion, regardless of valence, while the anterior frontal regions are differentially mediated in accordance with the valence model for the experience of emotion (Adolphs, Damasio, Tranel, & Damasio, 1996; Heller, 1993; Heller & Nitschke, 1998). Researchers in this domain have emphasized the application of models to understand more stable patterns of emotion processing, such as variance seen across people with different personality styles (such as extraversion or impulsivity) and across different patient populations (such as individuals with anxiety or depression).

1.1. Affective arousal: another dimension of emotional semantics

Research designed to examine differential neuroanatomical contributions to emotion processing has not only examined how the brain accomplishes the task of emotional categorization or emotional valence perception, but also the role of affective arousal. Within this line of inquiry, a distinction is made between two emotion processing systems—one sensitive to emotional valence (as discussed above), and the second sensitive to the degree of psychological and/or physiological arousal generated by the incoming affective stimulus. One of the most influential conceptualizations in this theoretical domain is referred to as the *motivated attention hypothesis* (i.e. Lang, Bradley, & Cuthbert, 1990, 1997; Schupp et al., 2004). The general idea is that incoming stimuli are more likely to capture attention if the stimulus generates a high level of emotional arousal, regardless of the specific emotional valence.

This influence of arousal, which might confer an adaptive advantage, is thought to happen very early (possibly before the specific valence of the stimulus is detected). Keil and colleagues (2003) and others (Junghofer, Bradley, Elbert, & Lang, 2001) have provided electrophysiological evidence for this early influence of emotional arousal/stimulus significance on sensory processes. A sensory gain effect (such as discussed by Hillyard & Anllo-Vento, 1998) is seen in electrophysiological visual cortex responses both in event-related potential (ERP) components such as the magnitude of the N100 (Kiel et al., 2001), and in the amplitude and phase of steady-state visual evoked potentials (Kiel et al., 2003) generated by emotional pictures. There have also been a number of studies that have reported arousal effects that appear later in the time course of emotion processing. In the late 1990s a number of ERP studies demonstrated a late positive component, referred to by some as the emotion effect, which starts about 300 ms post-stimulus and has an amplitude dependent on the level of arousal associated with the eliciting stimulus (Cuthbert, Schupp, & Cacioppo, 1998; Diedrich, Naumann, Maier, & Becker, 1997; Palomba, Angrilli, & Mini, 1997; Ito, Larsen, Smith, & Cacioppo, 1998).

Returning to our earlier discussion of how emotional information is differentially processed in the cerebral hemispheres, one might ask if there are hemispheric differences in the mediation of arousal related processes. The most common neuroanatomical dichotomy posited in the affective arousal literature is one in which the amygdala plays a central role in judging the arousal level of a incoming stimulus while the prefrontal cortex is more involved in valence detection and the selection of a response pattern (either approach or withdrawal) for salient incoming emotional stimuli (for a recent review of these neuroanatomical issues, see Davidson, 2003). Less work has focused on potential hemispheric differences in arousal processing, but this is not to say that there is no evidence of hemispheric differences. Van Strien and Marpurgo (1992), using threatening and non-threatening prime words followed by unilateral, tachistoscopic presentation of a three-letter target, found a LVF/RH performance enhancement for threatening primes and the opposite for non-threatening primes, suggesting a greater RH involvement during the processing of more arousing information. Likewise, in the Keil et al. (2003) study, changes in steady-state visual evoked potentials were most pronounced over the right occipital and temporal regions. Therefore, it is very much possible that hemispheric differences in arousal processing might emerge.

1.2. Depression and hemispheric lateralization

In addition to considering the influence of specialized hemispheric systems on the real-time perception and expression of emotional stimuli, researchers have also applied these

hemispheric models of emotion to further understand long-term emotional experience and emotional style (for example, see Davidson, 1998; Heller, Schmidtke, Nitschke, Koven, & Miller, 2002). It has been extensively argued that the experience of major depression is characterized by a distinctive pattern of acute lateralized brain activity, with a pronounced reduction of activity in the left versus right prefrontal cortex (Davidson, 1992, 1998, 2003; Davidson, Mednick, Moss, Saron, & Schaffer, 1987), and a probable impairment of function in the right posterior cortex (Banich, Stolar, Heller, & Goldman, 1992; Heller, 1993; Heller & Nitschke, 1997; Henriques & Davidson, 1997). This characterization is based in part on neurological patient data, such as a sample of 160 lesion patients examined by Gainotti (1972), who found catastrophic or anxious-depressive reactions more frequently among patients with damage to the left frontal cortex and euphoric/indifference reactions among patients with right frontal damage. A large number of corroborative studies have also employed resting electroencephalographic (EEG) measures as a way of examining both prefrontal cortex asymmetries and asymmetries in right posterior brain activity (see Davidson, 2003 for a review).

Many have argued that the study of depression-specific cognitive processes, especially as they occur in the context of brain activity, should be informed by attention to the manner in which such processes vary across the two cerebral hemispheres (see, for example, Heller & Nitschke, 1997). Among the cardinal diagnostic features of major depressive disorder are persistent thoughts reflecting themes of personal worthlessness, guilt, and death (American Psychiatric Association, 1994). In fact, a burgeoning literature documents the tendency of depressed individuals to engage in a variety of negativistic cognitive processes, ranging from self-reported appraisals of personal unlovability and failure (Beck, 1976; Blatt & Zuroff, 1992; Robins & Luten, 1991) to preferential allocation of attention to negatively valent verbal and nonverbal stimuli and mnemonic biases for negatively toned material stimuli (reviewed in Gotlib & Neubauer, 2000). The influential cognitive model of depression (Beck, 1976, 1987) has posited an important role of such maladaptive (i.e., negativistic) cognitive phenomena in the etiology and maintenance of unipolar depression, and this theory has catalyzed the development of an efficacious short-term cognitive-behavioral psychotherapeutic intervention for depression (Chambless & Ollendick, 2001; Craighead, Craighead, & Ilardi, 1997).

Recently our research group (Atchley, Ilardi, & Enloe, 2003; Enloe, Ilardi, Atchley, Cromwell, & Sewell, 2001) has used the DVF paradigm as a means of both detecting depression-related differences in hemispheric cognitive function and as a way of looking at the long-term impact of depression on hemispheric processing of emotion. An important challenge to Beck's cognitive model of depressive cognition is reflected in the repeated observation that depressive cognitive patterns appear to "remit" concurrent with the remission of the depressive syndrome itself (e.g., Barnett & Gotlib, 1988). That is, the self-reported thoughts of recovered depressed individuals (even patients treated exclusively with pharmacotherapy) are generally indistinguishable from those of never-depressed controls (reviewed in Ilardi & Craighead, 1999), especially in the absence of dysphoric mood. Simply put, depressive cognition—at least as assessed by commonly employed self-report measures such as the Dysfunctional Attitudes Scale (Weissman & Beck, 1978)—tends to be a trait or symptom of a current depressive episode, and depressive cognition is not a persistent trait or general characteristic of all individuals who have experienced depression. Further, self-report measures of cognition do not consistently yield robust prediction of vulnerability to future episodes of depression (e.g., Ilardi, Craighead, &

Evans, 1997). Therefore, one of our general research goals has been to apply information learned from the study of hemispheric differences in emotion processing in order to readdress this question of whether depressive cognition is only observable while a patient is currently experiencing depression or if depressive cognitive biases are a more persistent symptom.

An additional benefit we anticipate from the continued study of lateralized emotion processing in depressed individuals is the potential extension of our general psycholinguistic understanding of individual differences in lateralized cognitive processes. Atchley and colleagues (Atchley, Keeney, & Burgess, 1999; Atchley, Story, & Buchanan, 2001) have shown that the application of DVF techniques to the study of special populations may both inform us regarding the underlying cognitive processing which lead to gross behavioral differences, and also extend psycholinguistic models of normative cognition. For example, this research should be informative regarding the manner in which the right and left hemispheres differ in semantic processing as a function of long-term affective experience.

Motivated by the issues described, we conducted a study of DVF valence priming effects among depressed, previously depressed, and never depressed individuals (Atchley et al., 2003). Valence priming refers to the ability of word of a distinct emotional valence (HONEST) to facilitate the subsequent processing of a word that is of the same emotional valence (PRETTY). In priming experiments such as this one, related valence trials (HONEST–PRETTY) are compared with unrelated trials (HONEST–UGLY). If the related trials are significantly faster than the unrelated trials, this is taken to indicate that valence is speeding semantic access for the subsequent target word. The design of the experiment was a 3 (diagnostic group: depressed, remitted, and never-depressed) \times 2 (target valence: positive and negative) \times 2 (visual field of target presentation: LVF and RVF) \times 2 (prime-target relatedness: HONEST–PRETTY vs. HONEST–UGLY) mixed factorial design. There was observed a differential pattern of valence priming across diagnostic groups as a function of visual field and valence, with significant between-group differences occurring only in the LVF/ RH. On LVF trials, depressed and remitted depressed individuals showed significantly greater priming (related trial advantage) for negative prime-target pairs (STUPID–UGLY; depressed: 60 ms, remitted depressed: 77 ms), as compared to positive pairs (HONEST–PRETTY; depressed: –66 ms, remitted depressed: –88 ms). Negative priming indicates that related trials (HONEST–PRETTY) are actually slower than unrelated trials (HONEST–UGLY). In contrast, the never-depressed group experienced a greater priming effect for positive pairs (131 ms) than for negative pairs (28 ms).

The depressive processing advantage for negative words was observed in this study only in the right cerebral hemisphere (i.e., only for items presented to the LVF); moreover, it was only in the RH that there was observed a processing advantage among never-depressed controls for positive words. These findings can be seen as consistent with two of the models discussed above, either the dominant RH theory (Borod et al., 1998; Springer & Deutsch, 1998) or the circumplex model, which argues that the RH plays a more significant role during the interpretation of incoming emotional stimuli (Adolphs et al., 1996; Heller, 1993; Heller et al., 2002). We interpret these results as consistent with the thesis that it is predominantly in the RH that the negativistic bias that characterizes depression has its impact on the organization of an individual's semantic network. In fact, we hypothesize that the RH, by virtue of its heightened access to the emotional-linked facets of

communication, has a semantic network that incorporates emotion-linked elements as salient features—a semantic network organized to some extent on the basis of the emotional context within which ongoing linguistic interactions occur. Thus, we find that even fully remitted depressed individuals continue to experience a negative semantic processing bias in the RH. This finding is especially significant in light of the fact that clinical researchers have consistently failed to observe evidence of a stable, trait-like negativistic information processing bias among previously depressed individuals (Barnett & Gotlib, 1988; Ilardi & Craighead, 1999). If replicated, our results would suggest that the detection of some cognitive phenomena of clinical interest may be contingent upon the use of a methodology—e.g., the DVF paradigm—that accounts for cerebral lateralization effects in the processing of relevant information.

1.3. *Examining hemispheric processing of valence and arousal in depression*

The studies discussed above represent a portion of the research that has looked at neuroanatomical contributions to emotional valence detection in patient samples. However, little previous research on hemispheric contributions to depressive cognition has specifically examined the differential influence of emotional valence versus emotional arousal. In the work in our lab (Atchley et al., 2003), for example, emotional stimuli were chosen to reflect words of two valence categories (positive and negative), but the level of arousal generated by these stimuli was not controlled for. This is potentially problematic in light of the possibility that emotional valence and affective arousal may be confounded, i.e., because words of negative emotional valence tend (on average) to be more arousing than words with positive emotional valence (Bradley & Lang 1994, 1999; Lang et al., 1997). With this potential confound in mind, it is difficult to say conclusively that our earlier results were solely due to the valence of the stimulus. Our results may have been due to some combined influence of valence and arousal.

Our understanding of the distinction between emotional valence and arousal has been significantly influenced by the work of Bradley, Lang and colleagues who have collected extensive normative data for a wide range of stimuli including words (Bradley & Lang, 1999), pictures, and acoustic emotional stimuli. Further information about these large normative studies can be obtained at the website for the *NIMH Center for the Study of Emotion and Attention* (www.phhp.ufl.edu/csea). The stimuli used in the current research were specifically taken from the set of norms called the Affective Norms for English Words (ANEW) (Bradley & Lang, 1999). The ANEW provides researchers with normative data for three different emotion-related, semantic dimensions (valence, arousal, and dominance or control) based on participants responses using a technique developed by Lang referred to as the Self-Assessment Manikin (Lang, 1980). The selection of these three dimensions is originally motivated by factor analytic, semantic deferential research of Osgood and colleagues (Osgood, Suci, & Tanenbaum, 1957). We would argue that at least the distinction between the dimensions of valence and arousal continues to be supported by research in both the cognitive and cognitive neuroscience domains, as discussed above in the section titled affective arousal.

Thus, the current study represents an opportunity to replicate, both conceptually and methodologically, our previous research regarding the long-term impact of emotional experience and depression on hemispheric differences in the categorization of affective

semantic information. Moreover, in the current research, we use emotion related words that vary in both valence and arousal dimensions as a way of looking at the relative influence of both aspects of emotional stimuli. We had two possible outcomes in mind when we began this research. First, we expected to observe simple replications of our previous findings, with the RH being the primary locus of results, and with the depressed and remitted depressed participants showing an advantage in the RH for processing negative emotional words and the never depressed, control participants showing an advantage for positive words. Alternatively, we thought we might see a higher-order interaction involving not only the variables of diagnostic group (currently depressed, remitted depressed, and never depressed), valence, and visual field, but also involving the variable arousal. Specifically, we expected to find that the pattern described above might be most pronounced for highly arousing emotional words due to the increased attention allocated to these more salient stimuli (Cuthbert et al., 1998; Lang et al., 1990; Lang et al., 1997).

2. Method

2.1. Participants

Participants were selected from a sample of 650 introductory psychology students. Each student was given course credit for participating in a brief screening measure for depression. The screen consisted of: (1) the Beck depression inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961); and (2) a short questionnaire based on diagnostic criteria for major depressive disorder specified in the Diagnostic and Statistical Manual for Mental Disorders, 4th edition (DSM-IV) (American Psychiatric Press, 1994). After initial screening, participants were selected for further participation in a diagnostic interview based on their self-reported depressive symptomatology.

Right-handed individuals speaking English as a first language were contacted and asked to complete a clinical diagnostic interview. All interviews were conducted by a doctoral level clinical psychologist or advanced graduate student in clinical psychology. The interview consisted of portions of the major depression, mania, and dysthymia sections of the Mood Disorders module of the Structured Clinical Interview for DSM-IV Axis I Disorders, Clinician Version (SCID; First, Spitzer, Gibbon, & Williams, 1997). The SCID has become the “gold standard” in clinical research settings for the diagnostic classification of relevant symptomatology due mainly to its high level of inter-rater reliability and use (Hong & Ilardi, *in press*). Also the SCID is more valid and preferable to the BDI alone. We used the SCID in addition to the BDI in order to ensure that we correctly categorized participants as either currently depressed, remitted dressed, or never depressed.

Based on the diagnostic interview we selected the present sample of 42 undergraduate students who were all right-handed, native English speakers, with normal or corrected-to-normal vision. Of the total sample, 14 were diagnosed as currently suffering from depression (six males and eight females), 14 were characterized as having previously suffered from a clinically significant period of depression (four males and 10 females), and the final 14 participants fell into the category of never depressed, control participants (four males and eight females).

2.2. Stimuli

Each participant was presented with three blocks of trials. The practice block consisted of 30 words. If a participant showed poor accuracy during their first exposure to the practice block, then this block was repeated until they obtained an average of 75% of the trials correct. Each of the two experimental blocks contained 52 trials. Blocks 1 and 2 contained the same stimuli but presented the words to a different visual field. In other words, if the stimulus KILLER went to the LVF in Block 1, it was then presented to the RVF in Block 2. This methodological approach helps control for individual differences in the magnitude of possible visual field effects. Trials were pseudo-randomized such that no more than three consecutive trials appeared in the same visual field. The distance from the center of fixation to the inner edge of the words was 4.21 degrees of visual angle. The total angle subtended by the lateralized stimuli was 11.79. Words were presented in black on a white background. Word length ranged from four to nine characters, and varied semantically according to valence (positive vs. negative) and arousal (high vs. low) based on previous norming research (Affective Norms for English Words: Bradley & Lang, 1999). To avoid problems that may result from individual differences in the interpretation of our emotion-related stimuli, we avoided the selection of words that fell in the middle of the norming list for each of our two semantic variables (valence and arousal). For example, we did not use a simple median split and categorize to top half of the ANEW word list (those with a rating above 5 on a 9 point scale) as positive. Instead, we selected our words from the top and bottom thirds of the ANEW word list so that we would be presenting words that would be more unambiguously characterized as clearly positive or negative by our participants. Words were also selected so that they would have statistically similar production frequency across all categories (Kucera & Francis, 1967) and were statistically similar in word length. Finally, words were selected so that arousal and valence values were statistically similar within each factor (for example, negative and positive words in the high arousal category had the same average arousal level). Examples of these four affective/semantic conditions are provided in Table 1. The order of stimulus presentation was randomized within each block and the ordering of blocks was counterbalanced to protect against order effects.

2.3. Design

The experiment was a 3 (diagnostic category: currently depressed, remitted depressed, and never depressed) \times 2 (valence: positive and negative) \times 2 (arousal: high and low) \times 2 (visual field of stimulus presentation: right and left) mixed factorial design. Diagnostic category was the only between participant factor.

Table 1
Examples of Affective/Semantic Conditions

	Low arousing	High arousing
Negative valence	bored false timid grime messy fat	killer violent enraged assault demon terrified
Positive valence	bunny warmth polite pillow carefree relaxed	erotic adventure sexy romantic thrill miracle

Just to aid clarification, we would note that in comparing our previous research design (Atchley et al., 2003) to the current study's design, in the current study we are no longer examining valence priming (comparing valence judgements on related vs. unrelated word pairs). Instead we are looking only at participant accuracy on valence judgements for each laterally presented word. This change in design was motivated by our earlier findings, which suggest that valence judgement patterns and priming patterns were equally sensitive to our experimental variables. Thus, reducing our research design by one independent variable (relatedness) helps to make interpretation of the data easier and increases statistical power.

2.4. Apparatus and procedure

An IBM-compatible, Pentium-class computer with a Dell monitor and the *E-prime* (E-studio) program were used for stimulus presentation. Participants viewed the screen from a chin-rest, a vital part of any DVF task, as it aids in maintaining vigilance to the fixation target and minimizes overall head movement.

Instructions were presented to the participant both verbally and visually (on the computer screen). Participants were instructed to attend to a fixation cross in the middle of the screen (appeared for 500 ms). They were informed that a word would appear on either side of the screen, after which they were to make a valence judgement as quickly and accurately as possible. Subjects made these judgements with their right hand, pressing “1” for negative and “2” for positive on the number pad. Each stimulus was presented for 185 ms, followed by a series of number signs as an object mask in each visual field. After the response, feedback was given in the center of the screen (“correct” in blue ink or “incorrect” in red ink). A “no response detected” message appeared in red if no response was detected after 2500 ms. The experiment required approximately 20–30 min to complete. The participants were debriefed following completion of the final experimental block.

3. Results

An analysis of variance (ANOVA) was conducted for the primary dependent variable, response accuracy. For all planned and post hoc analyses to be discussed a $p < .05$ was used as the critical value. Reaction time data were not analyzed, inasmuch as overall accuracy across all participant groups was too low (averaging 69% across all three participant groups). It is not atypical for overall accuracy to be low in DVF research in part because of three characteristics of the research method: the short target presentation duration used to eliminate the possibility that the subject will foveate the target; lateralized target presentation; and attention capture which makes it difficult to suppress programmed saccades in response to the lateralized target onset. The most common method for dealing with the high error rates generally obtained in DVF research is to remove the data of participants who fail to reach a specified accuracy criterion. However, for the current research, because we were recruiting participants that are relatively rare in a college-aged sample, we instead chose to include the data from all our participants who met diagnostic criteria and only analyze accuracy data and not reaction time data, which would be more susceptible to the influence of outliers.

A significant main effect of visual field ($F(1, 39) = 50.10, p < .001$) was observed. Words presented to the RVF/LH were more accurately judged (74%) than were words presented to the LVF/RH (65%). There was no main effect for any of the other three independent variables (F 's < 2). The null result for diagnostic group replicates our previous findings (Atchley et al., 2003) in that we again found that our depressed sample (70%) responded with an overall accuracy level that is comparable to our never depressed, control sample (72%). There were also two, two-way interactions that reached statistical significance. We found a valence \times arousal interaction ($F(1, 39) = 5.63, p < .05$) and a significant interaction between diagnostic group and valence ($F(2, 39) = 4.90, p < .05$). Both of these 2-way interactions obtained were also influenced by the independent variable of visual field, resulting in two significant three-way interactions.

First, there was a three-way interaction between valence, diagnostic group, and visual field, ($F(2, 39) = 3.64, p < .05$), depicted in Fig. 1 and Table 2. Examination of this three-way interaction reveals no significant differences between conditions found for the RVF/LH trials. Planned comparisons indicate that this three-way interaction is carried by a complex pattern of results observed in the LVF/RH trials. Specifically, we found that both the currently depressed and the remitted depressed participants were significantly more accurate in judging the valence of negative words (depressed = 67%, remitted = 65%) as opposed to positive words (depressed = 60%, remitted = 57%). In contrast, participants who had never experienced depression showed the opposite pattern, and were significantly more accurate in judging positive words (76%) than negative words (64%). Given the issues under investigation in the current study, it is important to note that the above three-way interaction was not further mitigated by a four-way interaction involving arousal

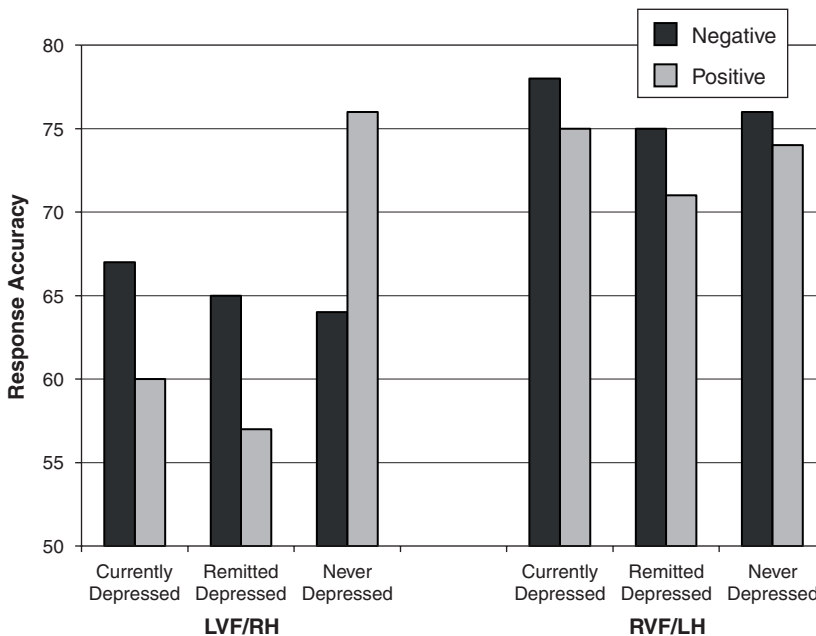


Fig. 1. Mean accuracy as a function of visual field of stimulus presentation, valence of stimulus, and diagnostic group.

Table 2

Accuracy means for all three diagnostic conditions comparing across valence and visual field of target presentation

	Negative valence	Positive valence
<i>Currently depressed</i>		
LVF/RH	67% (18)	60% (18)
RVF/LH	78% (15)	75% (16)
<i>Remitted depressed</i>		
LVF/RH	65% (15)	57% (17)
RVF/LH	75% (15)	71% (13)
<i>Never depressed</i>		
LVF/RH	64% (18)	76% (14)
RVF/LH	77% (14)	74% (14)

Standard deviations provided in parentheses.

($F < 1$). Moreover, the three-way interaction of arousal, diagnostic group, visual field did not reach significance ($F < 1$).

However, a significant 3-way interaction between arousal, valence, and visual field was observed ($F(1, 39) = 8.17, p < .01$). This significant interaction is illustrated in Fig. 2. Newmans–Kuels post hoc analysis of this three-way interaction again reveals that none of the analyses for data in the RVF/LH trials obtained significance. In contrast, in the RH there exists a cross-over interaction between arousal and valence. For negative words, participants were more accurate in their valence judgements if the stimulus was a highly arousing word (69%) than if the stimulus was low-arousing (62%). For positive words the opposite pattern emerged, such that low-arousing positive words (67%) were judged more accurately than high-arousing positive words (62%).

4. Discussion

Consistent with our previous research (Atchley et al., 2003), we found that the most interesting and pronounced influence of emotion-related variables on semantic judgements occurred when stimuli were presented to the LVF (or right cerebral hemisphere). This pattern of results—i.e., showing a distinct difference in RH processing of affective semantic content—may be viewed as evidence in support of either a right hemisphere dominance theory of emotion or the circumplex model. Also, consistent with study hypotheses, experience with clinical depression appeared to exert a significant and sustained influence on the manner in which people judge the affective content of words. In this study and in our previous research (Atchley et al., 2003), currently and previously depressed individuals showed an advantage in processing negatively valent words. In contrast, those who had *not* experienced sustained clinical depression evidenced a processing advantage for positive semantic information. Moreover, this sustained, or trait-like, difference in valence processing was observed only when emotion-related words were presented to the right cerebral hemisphere (via the left visual hemifield). As discussed in the Introduction, a growing literature documents the cortical and sub-cortical hemispheric lateralization of emotion comprehension and expression, and there exists specific evidence

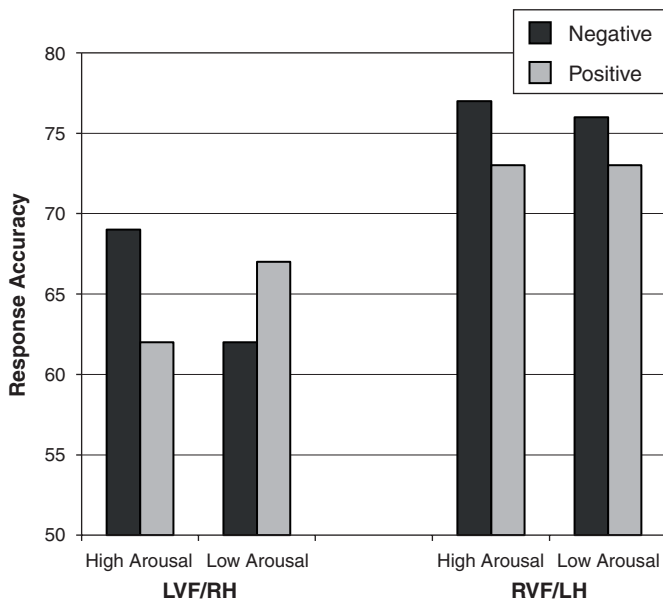


Fig. 2. Mean accuracy as a function of visual field of stimulus presentation, valence of stimulus, and affective arousal level of stimulus.

that unipolar depression is characterized by distinct patterns of lateralization (e.g., decreased activity of the left frontal cortex). Data from our lab, utilizing DVF stimulus presentation to isolate hemispheric function, suggests the existence of a negativistic processing bias for emotionally toned verbal information (i.e., facilitated processing of negative information and attenuated processing of positively toned material) only in the RH among both depressed and previously depressed individuals. It could be hypothesized that the remitted individuals, by virtue of the influence of one or more previous periods of prolonged depression, are continuing to process emotion-related information presented to the RH much like presently depressed individuals. Thus we replicate our earlier research (Atchley et al., 2003) and continue to suggest that the detection of evidence of persistent depressive cognitive bias beyond the depressive episode may be contingent upon the use of a DVF paradigm, which allows for the specific examination of RH contributions to linguistic and emotion processes.

The current research was also designed to determine if the experience of depressive cognitive bias influences only the analysis of emotional valence in verbal material or if, alternatively, experience with depression affects the analysis of affective arousal in such material as well. Our results suggest that *only* the analysis of valence is influenced by long-term emotional experience. We base this inference on the absence of observed interactions that involved both depressive experience (i.e. diagnostic group) and arousal. The locus of influence for emotional experience seems to be in the instantiation of characteristics regarding a word's valence (relative positive or negative message) into an individual's semantic network, possibly via long-term individual variability in emotional communication patterns. This proposed mechanism would be consistent with the previously observed tendency of depressed individuals to engage in a variety of negativistic verbal processes,

ranging from negative self-appraisals (Beck, 1976; Blatt & Zuroff, 1992; Robins & Luten, 1991) to enhanced salience for negative verbal emotion-related stimuli (reviewed in Gotlib & Neubauer, 2000). Our results suggest that the arousal dimension of emotional semantics is not preferentially influenced by emotional experience. This suggests that emotional valence and affective arousal are largely orthogonal dimensions of emotion, at least insofar as emotional experience influences the correspondent semantic representation for these two aspects of emotional word meaning. In other words, the way that negative words are semantically decoded seems to be in part influenced by the experience of depression, while the degree of arousal generated by a word does not seem to be preferentially influenced by the experiences associated with this mood disorder.

On the other hand, in looking at the more general representation of arousal and valence as reflected by semantic judgements of valence across all study diagnostic groups, we found that arousal and valence were meaningfully interrelated. Specifically, for all participants in our study, valence judgements were more accurate for negative stimuli that were highly arousing and for positive stimuli that were low-arousing. This finding, which suggests that emotional valence and arousal are not completely independent dimensions, is consistent with recent research by Robinson and colleagues (Robinson, Storbeck, Meier, & Kirkeby, 2004), who observed a cross-over interaction between arousal and valence, with negative/high arousing and positive/low arousing stimuli (both verbal and nonverbal) being the easiest to process. The current study adds to these findings, in that we used lateralized presentation of stimuli, while they used central presentation. And, of course, the hemisphere of presentation influenced our results, such that the interaction of arousal and valence was only reliable when stimuli were presented to the RH.

Interpreting this three-way interaction between visual field of stimulus presentation, arousal, and valence is necessarily a post hoc endeavor, inasmuch as this aspect of our results was unexpected. However, we consider the analysis of Robinson, Storbeck, Meier, and Kirkeby (2004) illuminating in this regard. Specifically, Robinson and colleagues make a clear argument that negative/high arousing stimuli are processed in a way that is quite distinct from other kinds of emotional stimuli. Based on a broader literature including psychophysiological measures of the startle response (for example, Lange, Davis, & Ohman, 2000) and the stress responses in infants (for example, Harman & Fox, 1997), Robinson argues that during early assessment, highly arousing stimuli are judged as indicating threat or danger. In other words, a stimulus that generates a high level of affective arousal quickly triggers neurologically based alarm systems designed to prepare the animal to respond rapidly to threat in the environment. This argument seems to us to have strong face validity, and it is consistent with existing research on the role of affective arousal in directing attention (e.g., Cuthbert et al., 1998; Lang et al., 1990, 1997).

In keeping with this line of interpretation, it is possible that participants in the current study made a preliminary valence judgement based in large part on the degree of arousal generated by the emotional word stimuli, i.e., *with the assumption that high arousal equals negative valence*. Stimuli that were inconsistent with this assumption (i.e., low-arousing negative trials and high-arousing positive trials) were thus judged less accurately overall. In this fashion, then, affective arousal can exert an important influence on valence assessment. However, this early influence of arousal was only observed in LVF/RH trials. Our finding regarding the lateralization of this arousal effect would, therefore, need to be taken into consideration by future researchers interested in the interaction between arousal and valence detection systems.

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