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Interpretation of ambiguous social scenarios in social phobia and depression: Evidence from event-related brain potentials

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ABSTRACT

In the current study, event-related potentials (ERPs) and behavioral responses were measured in individuals meeting diagnostic criteria for social phobia, depression, their combination, or neither in order to examine the unique and combined effects of social phobia and depression on the interpretation of ambiguous social scenarios. ERPs revealed a lack of positive interpretation bias and some suggestion of a negative bias in the semantic expectancy N4 component across all clinical groups. Furthermore, socially phobic and comorbid individuals showed reductions in baseline attention allocation to the task, as indexed by P6 amplitude. RT and accuracy likewise revealed a lack of positive interpretation bias across disordered groups. When considered on a continuum across all samples, social phobia and depression symptoms were related to the N4 interpretation bias effect whereas P6 amplitude reduction and RT interpretation bias appeared uniquely associated with social phobia.

1. Introduction

Much of the information transmitted between individuals in social contexts is ambiguous. What does it mean when someone smiles at you when you are giving a speech? Is that a signal of positive reinforcement for a job well done or a mocking gesture underneath which a snarky chuckle resides? The interpretation of social ambiguity is particularly relevant to social anxiety because individuals with social phobia experience overwhelming anxiety in and avoidance of social situations that may result from maladaptive interpretations of ambiguous social information (Hirsch and Clark, 2004). The body of research in this area generally refers to one who tends to interpret ambiguous social information in a more negative light (e.g., that person smiling in the audience is mocking me) as having a *negative interpretation bias* whereas one who tends to interpret ambiguous social information in a positive light (e.g., that person smiling in the audience thinks I am doing a good job) as having a *positive interpretation bias*.

Given the beliefs most socially phobic individuals hold about themselves (e.g., "I am uninteresting"; Clark and Wells, 1995; Rapee and Heimberg, 1997), it seems logical to propose that individuals with social phobia must suffer from a negative interpretation bias. Indeed, studies employing self-report questionnaires generally demonstrate the presence of a negative interpretation bias in social phobia. For example, socially phobic individuals spontaneously generate more negative endings to ambiguous social scenarios (Franklin et al., 2005; Huppert et al., 2007; Stopa and Clark, 2000) and rate negative and ambiguous scenarios as being similar to each other (Amir et al., 1998; Huppert et al., 2003; Murphy et al., 2007). Such findings, however, do not speak directly to how socially phobic individuals interpret incoming social information at the time it is first encountered. The thoughts and beliefs measured by self-report questionnaires are acquired 'offline', such that they require the individual to contemplate their response to a social event in either an anticipatory or retrospective fashion.

How do socially phobic individuals immediately process and respond to real-time (online) ambiguous information (e.g., a stranger smiling during a speech)? Clark and Wells (1995) suggested that individuals with social phobia direct attention inward toward negative self-talk and -imagery during social interactions and thus fail to fully process external information. It may be then that individuals with social phobia do not make 'online' interpretations of social information when it is initially being processed because of internal focus and subsequently rely on their preexisting negative beliefs and images about themselves when they recover from and anticipate future social interactions. Since 2000, Hirsch and colleagues have tested this hypothesis in a number of studies using reaction time (RT) paradigms that presumably measure 'online' interpretation bias because they require quick

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responses to ambiguous information (see Hirsch et al., 2006 for a review). In their seminal paper, Hirsch and Mathews (2000) employed an ambiguous passage task in which socially phobic patients and controls were asked to make lexical decisions about words completing ambiguous sentences in a positive or negative manner. They found that controls were faster to respond to words that completed the ambiguous sentences in a positive manner, whereas socially phobic patients demonstrated no bias; that is, the RTs of individuals with social phobia were indistinguishable between negative and positive sentence endings. This effect in individuals with social phobia has since been termed a 'lack of positive bias'. A follow-up study by Hirsch et al. (2003) showed that when non-phobic individuals were instructed to hold negative self-images in mind while completing the ambiguous sentence task they evidenced a lack of positive bias further supporting the notion that negative self-imagery blocks positive interpretation bias. The model proposed by Clark and Wells that has been borne out by Hirsch and colleagues reconciles the seeming differences between offline and online measures of interpretation bias and suggests that both reflect the influence of negative self-imagery/talk. Thus, offline and online measures should not be thought of as reflecting different interpretation biases per se, but rather as measures reflecting the impact of negative self-imagery/talk on interpretation at different stages of information processing.

Although the studies described above offer insights into interpretation bias in social phobia, it is inherently difficult to determine the exact nature and time course of the bias because they employed measures (self-report and RT) that reflect an amalgam of cognitive processes such as stimulus detection, identification, categorization, response selection, and response execution. Given the model proposed by Clark and Wells (1995) and the nuances of interpretation bias revealed by different measures, we recently addressed this issue using event-related brain potentials (ERPs) to study interpretation bias in social phobia (Moser et al., 2008). ERPs are ideally suited for this work because they are direct measures of online neural activity characterized by excellent temporal resolution. Specifically, ERP waveforms allow for the examination of the sequence of constituent operations involved in stimulus- and response-processing on the order of milliseconds. Stimulus-related processes are reflected in stimulus-locked ERPs that occur as the operative stimulus is initially being attended to and registered in working memory. Response-related processes are reflected in response-locked ERPs that occur around the time that an action is taken toward the stimulus and typically follow the processes reflected in stimulus-locked ERPs. Therefore, ERPs provide more specific information about the mechanisms underlying interpretation bias and help to separate out processes involved in stimulus evaluation from those of response execution. ERPs may also be especially sensitive to detecting the presence of biases, as several studies have demonstrated ERP differences between negative affective (anxious and depressed) and control groups in the face of comparable behavioral performance (Fallgatter et al., 2004; Hajcak et al., 2003, 2004; Hajcak and Simons, 2002; Shestyuk et al., 2005).

In our first ERP study (Moser et al., 2008), we employed a sentence-processing task similar to that of Hirsch and Mathews (2000) in which ambiguous social scenarios were completed with either a negative or positive terminal word. We found that the P6 component of the ERP revealed a lack of positive interpretation bias in high socially phobic community volunteers. The P6 is a stimulus-locked ERP that shows its maximal amplitude at the center of the head, peaks around 600 ms, and whose amplitude is enhanced by violations of expectancy related to identification and categorization (Coulson et al., 1998a,b; Gunter et al., 1997). Specifically, when a reader's expectations are violated in sentence processing tasks, enhanced P6 is proposed to reflect the language system's check of the reader's initial analysis of the sentence (van Herten et al., 2005), as if to say "Did I read that correctly the first time? I better go back and check". Whereas low phobic individuals evidenced larger P6 amplitudes to sentence endings that completed ambiguous social scenarios in a negative fashion, the high socially phobic individuals showed equally large P6 amplitudes to negative and positive sentence endings. That is, low phobic individuals evidenced a positive interpretation bias because negative endings were seen as more unexpected/violating their expectations whereas high phobic individuals showed no bias. The lack of positive bias we reported in the P6 is consistent with Hirsch and Mathews's (2000) RT finding and Clark and Wells's (1995) theoretical model.

Although this study showed preliminary evidence that ERPs may contribute additional information to the study of interpretation bias in social phobia, it suffered from two limitations: (1) it did not have interview-based Diagnostic and Statistical Manual (DSM; American Psychiatric Association, 1994) diagnostic information on participants from either group; rather, participants were grouped based on extreme scores on a self-report questionnaire, the Social Phobia Inventory (SPIN; Connor et al., 2000), and (2) the socially phobic group also showed higher levels of self-reported depression than the low socially phobic group. Therefore, it is important to ascertain whether the findings would generalize to individuals diagnosed with social phobia. Moreover, the role of depression in the above findings is particularly important given that social phobia and depression are highly comorbid (Lépine and Lellouch, 1995; Ohayon and Schatzberg, 2010; Regier et al., 1998) and share common features, yet it is unclear whether they share similar underlying mechanisms (Brown et al., 1998; Heinrichs and Hofmann, 2001; Hirsch and Clark, 2004; Huppert, 2008; Kessler et al., 1994).

There is considerable overlap in cognitive theories of social phobia and depression, especially as both are proposed to involve biased processing of social signals (Abramson et al., 1989; Clark and Beck, 1991; Coyne, 1976; Hirsch and Clark, 2004; Joiner, 2000; McCann and Lalonde, 1993; Rapee and Heimberg, 1997). Depression (Butler and Mathews, 1983; Nunn et al., 1997) and social phobia (see above review) are both associated with a negative interpretation bias in studies using self-report measures. This negative interpretation bias in depression is indeed applied to social situations (Anderson and Arnoult, 1985; Bruch and Belkin, 2001). Furthermore, comorbid depression seems to exacerbate the tendency for socially phobic patients to believe that negative social events will result in a variety of negative consequences (Wilson and Rapee, 2005). Some have therefore concluded that social phobia and depression share a common interpretation bias (e.g., Mathews and MacLeod, 2005).

On the other hand, studies of online interpretation bias in depression do not yield a consistent picture. Lawson and MacLeod (1999), for example, failed to show an interpretation bias in depression using an ambiguous sentence-priming RT task. Recently, however, Dearing and Gotlib (2009) found an interpretation bias in young females at risk for developing depression using a RT paradigm similar to that of Hirsch and Mathews (2000). Although the authors interpreted their findings as evidence for a negative bias in the at-risk females, in fact, the group difference was due to faster RTs to positive endings in the control group and not to differences between the positive and negative endings in the at-risk group. Hirsch and Mathews interpreted the same pattern of findings in their study of social phobia as evidence for a lack of positive bias. Last, because it has been argued that reaction time is more variable and thus less reliable in depressed populations for reasons such as psychomotor retardation, Lawson et al. (2002) used the startle eyeblink response to study interpretation bias in depression. Findings from their study revealed a negative interpretation bias in individuals scoring high on self-reported depression symptoms.

The current study builds on our preliminary findings and addresses the two limitations mentioned above by examining ERP correlates of interpretation bias in individuals diagnosed with social phobia, depression, social phobia and depression, and healthy controls. Although we showed sensitivity of the P6 to interpretation bias in our previous study, there are other stimulus-locked ERPs that are sensitive to violations of expectancy in sentence processing tasks, most notably the N4. The N4 is maximal at central scalp locations and peaks around 400 ms. Like the P6, the N4 shows larger amplitude (in this case, more negativity) to violations of expectancy. Both the P6 and the N4 are modulated by a range of expectancy violations, including semantic violations, and index effortful re-analysis of sentence meaning (for a review see Coulson et al., 1998a). The N4 is specifically proposed to reflect the ease with which a word is integrated into its surrounding contextual meaning (Chwilla et al., 1995; van Herten et al., 2005). Thus, more serious semantic violations tend to be necessary preconditions for elicitation of an enhanced N4. Most importantly for the current study, however, is the fact that the P6 and N4 have also shown modulation by emotional or social-emotional expectancy (Barthalow et al., 2001; Cacioppo et al., 1996; Osterhout et al., 1997; Zayas et al., 2009). Based on the previous literature, we were surprised to not find modulation of the N4 in our first study and therefore evaluate it again here.

Although it seems clear from studies of offline (i.e., self-report) interpretation bias that social phobia and depression show a common negative bias, it is less clear what to expect from online measures of interpretation bias. As noted earlier, both social phobia and depression have been associated with a lack of positive bias in two reaction time studies (Hirsch and Mathews, 2000; Dearing and Gotlib, 2009), but only depression has been associated with a negative bias in a startle eyeblink study (Lawson et al., 2002). What does seem clear, however, is that healthy controls consistently show a positive bias in online measures (Hirsch and Mathews, 2000; Hirsch et al., 2003; Moser et al., 2008). Therefore, our strongest prediction was that the healthy control group would evidence a positive interpretation bias – i.e., smaller N4 and P6 responses (greater expectancy) to positive sentence endings than negative ones/larger N4 and P6 responses (lower expectancy) to negative sentence endings than positive ones. Given that social phobia has been associated with a lack of positive bias in RT and ERPs (Hirsch and Mathews, 2000; Moser et al., 2008), we predicted that the social phobia group would demonstrate a lack of positive bias – i.e., no difference in N4 and P6 amplitudes to positive and negative sentence endings. Because studies on interpretation bias in depressed individuals yielded inconsistent findings we predicted that the two groups with depression (depressed and socially phobic and depressed) would evidence either a lack of positive bias (equal expectancy for positive and negative), or the presence of a negative bias (greater expectancy for negative endings) that would be indicated by smaller N4 and P6 responses to negative sentence endings compared to positive ones/larger N4 and P6 responses to positive sentence endings compared to negative ones.

2. Methods

2.1. Participants

Sixty-seven participants were recruited from the University of Pennsylvania and surrounding communities via advertisements, and through referrals from outpatient clinics in the University of Pennsylvania's Department of Psychiatry including the Center for the treatment and Study of Anxiety (CTSA), an expert clinic in anxiety disorders where the current experiments were conducted. Native English speakers of all ethnic origins between the ages of 18 and 36 years were considered. Participants were invited to perform several experiments of thoughts and emotions, one of which was the ERP task described in the current paper.

All participants were evaluated by phone and in person at the CTSA by the first author or research assistants. All prospective participants were initially screened by phone using the Social Phobia Inventory (SPIN; Connor et al., 2000), the Quick Inventory of Depression Symptomatology – Clinician Rating (QIDS-C; Rush et al., 2003) and a brief interview to determine preliminary eligibility. The SPIN is a psychometrically sound self-report measure of social phobia comprised of 17 items rated on a Likert scale ranging from 0 (not at all) to 4 (extremely). The QIDS-C is 16-item interview for depression that covers the nine DSM-IV symptom criterion domains. Each item is rated on a 0–3 scale.

After initial phone screen, eligible participants recruited from the community ($n=59$) were interviewed face-to-face by the first author at the CTSA using the MINI International Neuropsychiatric Interview (MINI; Sheehan et al., 1998) whereas patients referred by psychiatric clinics ($n=8$) were diagnosed by either MINI or Structured Clinical Interview for DSM-IV (SCID; First et al., 1996) and confirmed by chart review by the first author. The MINI is a brief, structured clinical interview that assesses for the primary DSM-IV axis I diagnoses, including the anxiety disorders, mood disorders, substance use disorders, and schizophrenia. The MINI is a widely used clinical interview and demonstrates sound psychometric properties. Four types of participants were included in the current study based on diagnostic interview: (1) individuals meeting criteria for current Social Phobia (SP; $n=18$), (2) individuals meeting criteria for current Major Depressive Disorder or Dysthymia (MDD/DYS; $n=10$), (3) individuals meeting criteria for current Social Phobia and a Depressive Disorder (SP + MDD/DYS; $n=19$), and (4) individuals not meeting criteria for any current DSM-IV axis I disorder (CTRL; $n=20$). Exclusion criteria for all participants included active substance dependence, psychosis, history of schizophrenia or organic brain syndrome, mental retardation or other pervasive developmental disorder, bipolar disorder, active suicidal or homicidal ideation, and computer illiteracy. Four subjects (one from the SP group, two from the SP + MDD/DSY group, and one from the CTRL group) were not included in analyses: three subjects had less than 50% usable trials and one subject's data were irretrievable due to equipment malfunction. Thus, the final sample comprised 63 individuals.

The four groups did not differ with regard to age, sex, or ethnicity ($ps>.38$; see Table 1). Table 2 displays the self-report data across the four groups. All one-way ANOVAs were significant ($Fs>26.24$, $ps<.001$). As expected, the social phobia groups (SP, SP + MDD/DYS) scored significantly higher than the other two groups (MDD/DYS, CTRL) on all social phobia measures. Likewise, the depressed groups (MDD/DYS, SP + MDD/DYS) scored significantly higher than the other two groups (SP, CTRL) on all depression measures. Last, the SP group also scored higher than the control group on all measures of depression, and the MDD/DYS scored higher than the control group on all measures of social phobia. Written informed consent was obtained from all participants, and the experiment was approved by the research ethics committee of the University of Pennsylvania. All participants were paid $20.00 per hour for their participation.

2.2. Self-report measures

In addition to the screening measures administered over the phone and the in-person MINI, participants completed a number of self-reports at experimental sessions to establish symptom severity for social phobia and depression. For self-assessment of social phobia, participants completed the Liebowitz Social Anxiety Scale-self report (LSAS; Liebowitz, 1987) and the Social Interaction Anxiety Scale (SIAS; Mattick and Clarke, 1998). The LSAS is a 24-item measure of social phobia, which asks individuals to rate their fear and anxiety on a 0–4 (none to extreme) scale in response to a number of different social scenarios. It is commonly used in research on social phobia, and has been shown to have good psychometric properties (Baker et al., 2002; Fresco et al., 2001). ROC analyses of the LSAS suggest cut scores of >30 for specific social phobia, and >60 for generalized social phobia (Mennin et al., 2002). Based on these cut scores, Table 2 illustrates that the social phobia groups in the current study would be classified in the generalized social phobia range on the LSAS. The SIAS is a commonly used measure of social phobia, which evaluates the severity of social phobia in interpersonal situations. It has 16 items, and is scored on a 0–4 scale. It has been shown to have good psychometric properties in multiple samples (Mattick and Clarke, 1998; Safren et al., 1998; Ries et al., 1998).

For self-assessment of depression, participants completed the Beck Depression Inventory-II (Beck et al., 1996) and the Depression, Anxiety, and Stress Scales – 21 item version (DASS; Lovibond and Lovibond, 1995). The BDI-II is one of the most widely used measures of depression in the world. It is comprised 21-items revised from the first version of the BDI in line with DSM-IV diagnostic criteria, with higher scores indicating more severe symptoms. The BDI-II demonstrates excellent psychometric properties in numerous different clinical (e.g., Steer et al., 1997) and non-clinical (e.g., Storch et al., 2004) samples. The DASS is comprised of three subscales developed to evaluate anxiety, depression, and stress, as described by the tripartite model of affect (Watson et al., 1995). Its psychometric properties have been shown to be good in clinical (Antony et al., 1998; Brown et al., 1997) and nonclinical (Lovibond and Lovibond, 1995; Crawford and Henry, 2003) populations. The depression subscale of the DASS was the focus of analysis in the current study.

2.3. Task and stimuli

The grammar decision task consisted of 140 sentence stems, and accompanying sentence-terminal words, created by the CTSA research team. The sentences

Table 1
Demographic information for the four groups.

Variable	SP (n = 17)	MDD/DYS (n = 10)	SP + MDD/DYS (n = 17)	CTRL (n = 19)
Female (%)	12 (70.59)	9 (90.00)	10 (58.82)	14 (73.68)
Age, mean (SD) (years)	25.18 (5.31)	26.60 (5.66)	24.06 (5.60)	24.05 (3.05)
White (%)	14 (82.35)	7 (70.00)	13 (76.47)	13 (68.42)

All between groups $ps > .38$.

were circulated to experts in social phobia who provided feedback, and then revised according to the experts' comments. All sentence stems were ambiguous until the final word. Of the 140 sentences, 80 described experiences within social situations (e.g., "As you give a speech, you see a person in the crowd smiling, which means that your speech is . . .") and were resolved by either a negative (e.g., "stupid") or positive (e.g., "funny") terminal word; 40 sentences described experiences within non-social contexts (e.g., "You've just started reading a new book that you bought and you find it to be . . .") and were also resolved by either a negative (e.g., "boring") or positive (e.g., "interesting") terminal word; and 20 sentences were social in nature but emphasized neutral aspects of social situations (e.g., "While walking with a friend through the park, you decide to stop and rest on a . . .") and were always terminated with a neutral word (e.g., "bench"). The 80 sentences were piloted and administered to a separate group prior to this experiment, and endings were selected on the basis of those that differentiated high and low socially phobic individuals (Huppert et al., 2007). Non-social sentences were included as fillers, and neutral sentences were included to establish a baseline of responding to the sentence stimuli. Finally, five additional sentences were generated for use as practice trials. The sentence stems were recorded into wav files by a male English-native speaker. The terminal words were visual text displays. Half of the sentences of each type were completed with a grammatical terminal word whereas the other half was completed with a non-grammatical terminal word. An example of a non-grammatical sentence and accompanying terminal word is "You've just started reading a new book that you bought and you find it to be . . . bore".

The grammar decision task was administered on a Pentium II class computer, using Presentation software (Neurobehavioral Systems, Inc.) to control the presentation and timing of all stimuli. All sentence stems were presented at a constant volume to all subjects. The sentence-terminal word was displayed in white against a black background, and occupied approximately 5° of visual angle on an 18″ monitor. The experiment began with the five practice trials. Participants were instructed to listen to the beginning of a sentence, and to watch for the sentence-terminal word on the computer screen. Subjects were then instructed to determine whether the sentence-terminal word was grammatical or non-grammatical by pressing the left or right mouse button. This task ensured that subjects had to pay close attention to the context of the sentences to appropriately categorize the endings. The actual experiment consisted of the 140 sentences described above. A white fixation cross was always present at the center of the computer screen to help subjects keep their focus. Each trial began with the sentence stem played over the speakers. Five hundred milliseconds after the offset of the sentence stem the sentence-terminal word was presented until the subject responded. The following trial began at a random interval between 500 and 1250 ms after the subject's response. Subjects were instructed to respond as quickly and as accurately as possible.

2.4. Procedure

The current report describes an ERP experiment administered with several other tasks in a larger experimental psychopathology study aimed at investigating information processing biases in social phobia. Upon first arrival at the CTSA all participants read and signed consent to participate in the study. Participants then completed the LSAS, SIAS, DASS-21 as part of a battery of questionnaires. The ERP interpretation paradigm described above was then administered. Approximately 1 week later, participants returned to the CTSA and completed another information processing task and the BDI-II.

2.5. Psychophysiological recording and data reduction

The electroencephalogram (EEG) was recorded from the frontal (Fz), frontocentral (FCz), central (Cz), and parietal (Pz) recording sites using an ECI electrocap. In addition, tin disk electrodes were placed on the left and right mastoids (M1 and M2, respectively). During the recording, all activity was referenced to Cz. The electro-oculogram (EOG) generated from blinks and vertical eye-movements was also recorded using Med-Associates miniature electrodes placed approximately 1 cm above and below the subject's right eye. The right earlobe served as a ground site. All electrode impedances were below 10 kΩ. Fz, FCz, Pz, M1, M2, and EOG were recorded by a Grass Model 8-10 D polygraph with Grass Model 8A5 preamplifiers (bandpass = 1–35 Hz). All bioelectric signals were digitized on a laboratory microcomputer using VPM software (Cook, 1999). The EEG was sampled at 200 Hz. Data collection began 500 ms prior to visual presentation of the sentence-terminal words and continued for 1500 ms.

Off-line, the EEG for each trial was corrected for vertical EOG and artifacts using the method developed by Gratton et al. (1983; Miller et al., 1988) and then re-referenced to the average activity of the mastoid electrodes. Trials were rejected and not counted in subsequent analysis if there was 25 ms of invariant analog data on any channel or A/D values on any channel that equaled the converters minimum or maximum values. In addition, trials were rejected for incorrect responses as well as if the reaction time to the sentence-terminal words fell outside of a 200–2000 ms window. Single trial EEG data were lowpass filtered at 20 Hz with a 51-weight FIR digital filter as per Cook and Miller (1992). Finally, the EEG for each trial was time-locked to the onset of the sentence-terminal word and averaged across trial types for each electrode site. To quantify the stimulus-locked ERP, a baseline equal to the average activity in a 100 ms window prior to stimulus onset was used. The N4 was measured at Cz, where it was maximal, as the average activity in the 400–500 ms time window and the P6 was measured at Cz, where it, too, was maximal, as the average activity in the 500–700 ms time window.

Social and neutral sentences that were completed with grammatical endings were the focus of analyses. Thus, a maximum of 20 social sentences completed with a negative ending, 20 social sentences completed with a positive ending (social negative and positive terminal words did not differ with respect to length or part of speech; Moser et al., 2008), and 10 neutral sentences completed with a neutral ending were available for statistical tests. After artifact rejection and data reduction procedures, an average of 18.46 (92%) positive ending trials, 17.87 (89%) negative ending trials, and 8.68 (87%) neutral ending trials were available for statistical analysis. There were statistically more positive than negative ending trials available for analysis ($F(1, 59) = 7.04$, $p = .01$). However, there were no effects of group on available positive and negative ending trials ($Fs(3, 59) < 2.50$, $ps > .06$). There were also no differences between groups on available neutral ending trials ($F(3, 59) < 1$, $p = .74$). Because individual subject RT were not normally distributed, median RTs were used for each subject (see Ratcliff, 1993) and then averaged together to create mean RT for negative, positive, and neutral endings for each group.

2.6. Data analysis strategy

Behavioral and ERP measures were statistically evaluated using SPSS General Linear Model software (Version 18.0). Partial eta squared (η^2_p) and Cohen's d values are reported as estimates of effect size. Analysis of behavioral and ERP measures proceeded as follows: (1) one-way analysis of variances (ANOVAs) with factor Group (SP vs. MDD/DYS vs. SP + MDD/DSY vs. CTRL) were conducted on behavioral and ERP responses to neutral sentence endings to evaluate baseline responding to the task;

Table 2
Mean (standard deviation) self-report data for the four groups.

Variable	SP (n = 17)	MDD/DYS (n = 10)	SP + MDD/DYS (n = 17)	CTRL (n = 19)
SPIN	36.71^a (7.23)	19.50^b (11.68)	36.65^a (12.61)	4.68^c (3.16)
QIDS	4.88^a (3.33)	12.80^b (1.75)	12.94^b (3.25)	.84^c (1.07)
LSAS	72.53^a (20.31)	51.10^b (18.49)	77.88^a (24.04)	16.84^c (11.16)
SIAS	48.59^a (7.78)	32.00^b (15.77)	49.94^a (13.35)	11.68^c (6.70)
BDI-II	11.43^a (8.71)	26.46^b (12.16)	25.69^b (9.77)	2.26^c (3.40)
DASS-D	16.00^a (10.37)	25.20^b (11.44)	26.12^b (8.56)	2.95^c (4.02)

Note. SPIN = Social Phobia Inventory; QIDS = Quick Inventory for Depression Symptoms; LSAS = Liebowitz Social Anxiety Scale; SIAS = Social Interaction Anxiety Scale; BDI-II = Beck Depression Inventory – 2nd version; DASS-D = Depression-Anxiety-Stress Scales – Depression subscale. Means with different superscripts across rows differ significantly at $p < .01$.

(2) 4 (Group: SP vs. MDD/DYS vs. SP + MDD/DSY vs. CTRL) × 2 (Sentence Ending: negative vs. positive) ANOVAs were conducted on behavioral and ERP responses to examine the primary hypotheses of interest concerning interpretation bias; and (3) if the critical Group × Sentence Ending interaction was significant, we followed up the ANOVAs with paired-samples *t*-tests of the difference between responses to negative and positive sentence endings within each group and with between-subjects *t*-tests of the differences between groups on responses to negative and positive endings. Neutral sentence endings were treated separately and not included in the 4 × 2 ANOVAs because they were constructed separately from the social sentences in both format – in that neutral sentences endings emphasized neutral aspects of social scenarios – and number (10 vs. 20). For similar methods please see Moser et al. (2008).[1]

3. Results

3.1. Behavioral measures

Table 3 contains the accuracy and RT data for neutral, positive, and negative sentence endings in the four groups.

3.1.1. Neutral endings

The one-way ANOVA conducted on neutral sentence accuracy showed no effect for Group F (3, 59) < 1. Likewise, the one-way ANOVA conducted on neutral RT showed no effect for Group, F (3, 59) < 1. Thus, accuracy and reaction time did not reveal any differences between groups with respect to baseline responses to the task.

3.1.2. Negative vs. positive endings

The 4 (Group) × 2 (Sentence Ending: negative vs. positive) ANOVA conducted on accuracy revealed a significant main effect for Sentence Ending, F (1, 59) = 28.01, $p < .001$, $\eta^2_p = .32$, indicating higher accuracy on positive than negative sentence ending trials. The main effect of Group was also significant, F (3, 59) = 3.99, $p = .01$, $\eta^2_p = .17$, indicating higher accuracy in the SP and MDD/DYS groups overall (see Table 3). These two main effects were qualified by a Group × Sentence Ending interaction, F (3, 59) = 2.69, $p = .05$, $\eta^2_p = .12$. The CTRL group showed the largest accuracy advantage for positive sentence endings (M positive − negative difference = 5.79%, SD = 4.79; t (18) = 5.27, $p < .001$, d = 1.24). The SP + MDD/DYS group showed the next largest advantage (M positive − negative difference = 5.00%, SD = 6.37; t (16) = 3.23, $p < .01$, d = .80). The SP group showed a much smaller advantage (M positive − negative difference = 2.35%, SD = 4.00; t (16) = 2.43, p = .03, d = .59), and the MDD/DYS group showed no accuracy advantage for positive endings (M positive − negative difference = 1.00%, SD = 5.16; t (9) = .61, p = .56, d = .20).

Direct comparison of positive sentence ending accuracy between groups failed to show an effect for Group, F (3, 59) = 1.17, p = .33, $\eta^2_p = .06$. However, direct comparison of negative sentence ending accuracy between groups yielded a significant effect of Group, F (3, 59) = 5.07, $p < .01$, $\eta^2_p = .21$. SP and MDD/DYS individuals showed significantly greater negative sentence ending accuracy than SP + MDD/DYS and CTRL subjects ($ps < .03$), but did not differ from each other (p = .99). CTRL and SP + MDD/DYS subjects likewise did not differ from each other with respect to negative sentence ending accuracy (p = .71).

The 4 (Group) × 2 (Sentence Ending: negative vs. positive) ANOVA conducted on RT showed no significant effect for Sentence Ending, F (1, 59) = 1.50, p = .23, $\eta^2_p = .03$ or Group F (3, 59) = 1.30, p = .28, $\eta^2_p = .06$. The Group × Sentence Ending interaction approached significance, F (3, 59) = 2.56, p = .06, $\eta^2_p = .12$, however. Consistent with our predictions, CTRL subjects evidenced faster RTs to positive compared to negative endings (t (18) = 2.21, p = .04, d = .56; i.e., evidence for a positive bias). Moreover, the social phobia groups (SP and SP + MDD/DY) failed to demonstrate a significant RT bias ($ps > .14$). Although the MDD/DYS participants also failed to demonstrate a significant RT bias, they demonstrated a moderate effect for faster RT to positive sentence endings (t (9) = 1.86, p = .10, d = .70). Directly comparing positive sentence ending RT between groups did not yield a significant main effect of Group, F (3, 59) = 2.05, p = .12, $\eta^2_p = .10$. Likewise, direct comparison of negative sentence ending RT across groups failed to show an effect for Group, F (3, 59) < 1.

Thus, accuracy revealed evidence for a positive bias in the CTRL group – that is, superior accuracy for positive sentence endings – and a reduced positive bias–that is, a smaller accuracy advantage for positive sentence endings – in the disordered groups, most notably the SP and MDD/DYS groups. Accuracy data also revealed the tendency toward a negative bias for SP and MDD/DYS subjects compared to SP + MDD/DYS and CTRL groups. Reaction time likewise revealed evidence for a positive bias in the CTRL group and a lack of positive bias across all disordered groups.

3.2. ERP measures

Table 4 contains the ERP data for neutral, positive, and negative sentence endings in the four groups.

3.2.1. Neutral endings

The one-way ANOVA conducted on the N4 elicited by neutral sentence endings showed no significant effect of Group, F (3, 59) = 1.97, p = .13, $\eta^2_p = .09$.

The P6, however, showed a significant effect of Group, F (3, 59) = 4.78, p = .01, $\eta^2_p = .20$ (see Fig. 1). Neutral sentence endings elicited the largest P6 in the CTRL (M = 5.40 μV) and MDD/DSY groups (M = 4.14 μV), whose amplitudes were not different from each other (p = .41). The SP group demonstrated some impairment in baseline resource allocation as indicated by an intermediate neutral sentence P6 amplitude (M = 2.73 μV) that was significantly reduced compared to the CTRL group (t (34) = 2.38, p = .02, d = .79) but similar in magnitude to the MDD/DYS group ($t < 1$). The SP + MDD/DYS group, on the other hand, evidenced pronounced impairment in baseline resource allocation as indicated by significant reduction in neutral sentence-elicited P6 amplitude (M = .65 μV) compared to the CTRL (t (34) = 3.44, p = .002, d = 1.15) group and marginal reduction compared to the MDD/DYS (t (25) = 1.97, p = .06, d = .79) The SP + MDD/DYS group neutral sentence P6 amplitude did not differ from the SP group's, however (t (32) = 1.54, p = .14, d = .53). Thus, P6 amplitude elicited by neutral sentence endings suggested reduced baseline resource allocation to the task in the two socially phobic groups, which was most evident in the SP + MDD/DYS group.

3.2.2. Negative vs. positive endings

The 4 (Group) × 2 (Sentence Ending: negative vs. positive) ANOVA conducted on the N4 time window showed no main effects of Sentence Ending or Group ($ps > .10$). The Sentence Ending × Group interaction, however, for N4 amplitude was significant, F (3, 59) = 3.09, p = .03, $\eta^2_p = .14$[2] (see Fig. 2). Consistent with hypotheses, the within-group difference between the negative and positive sentence ending N4s approached significance in the CTRL group (M = −1.40; t (18) = 1.77, p = .09, d = .41), indicating enhanced N4 amplitude for negative endings – i.e., a positive bias. As predicted, the CTRL group was the only group to demonstrate evidence

[1] Subtracting neutral sentence ending responses from the negative and positive ending responses resulted in identical results for all measures as those presented in Section 3.

[2] This effect remained significant when controlling for accuracy effects, F (3, 58) = 3.25, p = .03, $\eta^2_p = .14$.

Table 3
Mean (standard deviation) of accuracy (% correct) and median RT data (ms) for the four groups.

Sentence ending	SP (n = 17)		MDD/DYS (n = 10)		SP + MDD/DYS (n = 17)		CTRL (n = 19)	
	Accuracy	RT	Accuracy	RT	Accuracy	RT	Accuracy	RT
Neutral	89.41 (4.29)	780 (175)	88.00 (4.22)	728 (191)	89.41 (2.43)	754 (164)	88.95 (3.15)	731 (168)
Positive	98.82 (2.19)	930 (200)	97.50 (2.64)	788 (163)	96.47 (6.06)	912 (197)	96.58 (4.10)	823 (152)
Negative	96.47 (2.94)	891 (183)	96.50 (4.74)	832 (200)	91.47 (7.45)	928 (156)	90.79 (5.34)	861 (188)

Table 4
Mean (standard deviation) ERP data for the four groups.

Component	Sentence ending	SP (n = 17)	MDD/DYS (n = 10)	SP + MDD/DYS (n = 17)	CTRL (n = 19)
N4 (μV)	Neutral	2.81 (4.60)	4.66 (7.23)	1.77 (5.64)	5.71 (4.13)
	Positive	2.23 (3.49)	3.15 (4.25)	1.76 (5.13)	5.51 (2.95)
	Negative	3.77 (4.35)	4.43 (4.36)	3.32 (3.38)	4.11 (3.34)
P6 (μV)	Neutral	2.73 (3.10)	4.14 (4.07)	.65 (4.63)	5.40 (3.63)
	Positive	3.18 (5.22)	4.49 (3.29)	3.27 (3.90)	5.07 (3.26)
	Negative	5.15 (3.29)	5.07 (3.07)	3.34 (2.70)	4.49 (3.02)

for a positive bias. All disordered groups, on the other hand, demonstrated greater negativity for positive endings (i.e., evidence for a negative bias; SP difference M = 1.53; MDD/DYS difference M = 1.28; SP + MDD/DYS difference M = 1.56). Although effect sizes for all groups were similar in magnitude, only the SP + MDD/DYS group's within-group difference between negative and positive ending N4 s approached significance (SP t (16) = 1.64, p = .12, d = .41; MDD/DYS t (9) = 1.67, p = 13, d = .53; SP + MDD/DYS t (16) = 1.82, p = .09, d = .50).

Direct comparison of the positive sentence ending N4 between groups revealed an effect for Group, $F(3, 59) = 3.21$, $p = .03$, $\eta^2_p = .14$. SP and SP + MDD/DYS groups showed larger negativity compared to the CTRL group ($ps < .02$), and did not differ from each other with respect to positive ending negativity ($p = .73$). The MDD/DYS group showed positive ending N4 amplitude that fell between the other disordered groups and the CTRL group ($ps > .13$; see Table 4). Direct comparison of the negative sentence ending N4 between groups, however, failed to reveal an effect for Group, $F(3, 59) < 1$. Analysis of the P6 showed no significant effects ($ps > .28$).

In sum, the comparison of ERPs elicited by positive and negative sentence endings showed evidence for a positive bias in the CTRL group and lack of positive bias across the disordered groups. There was also some evidence that the comorbid group was characterized by a tendency toward a negative bias. Direct comparison of sentence ending N4s across groups likewise indicated that the disordered groups lacked the positive expectancy bias characterizing the control group.

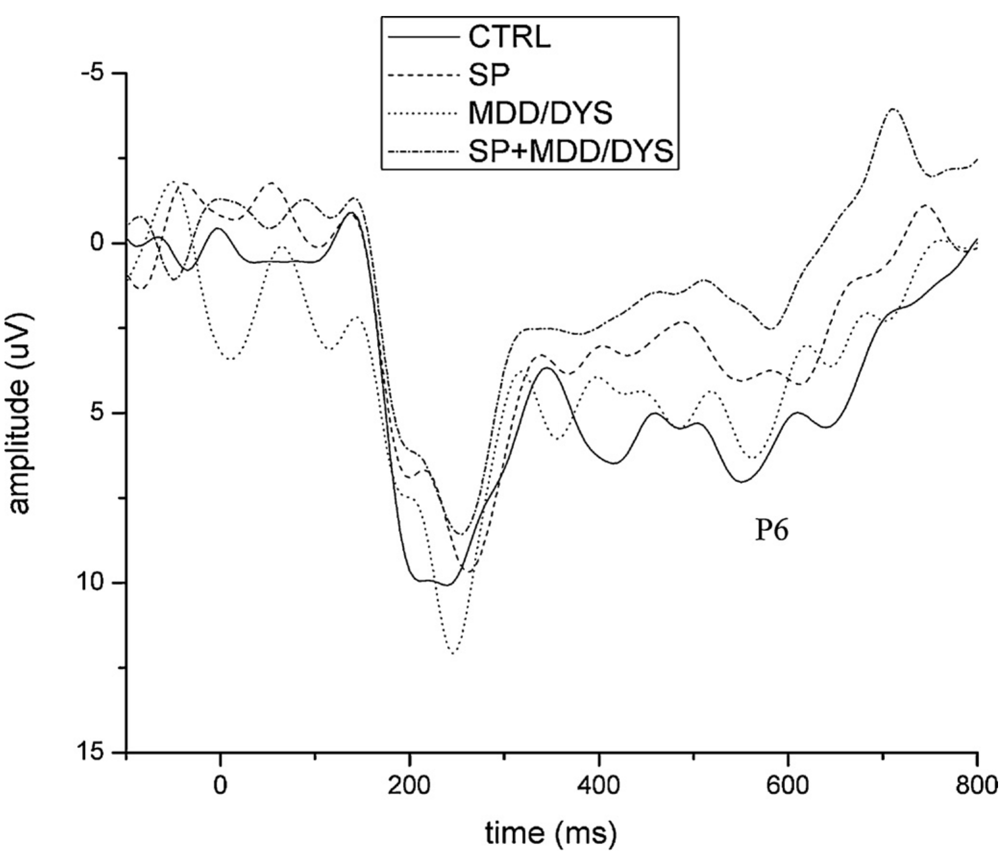

Fig. 1. Event related brain potentials (ERPs) at Cz time-locked to the onset of neutral sentence endings across the four groups. ERPs submitted to statistical analyses are labeled.

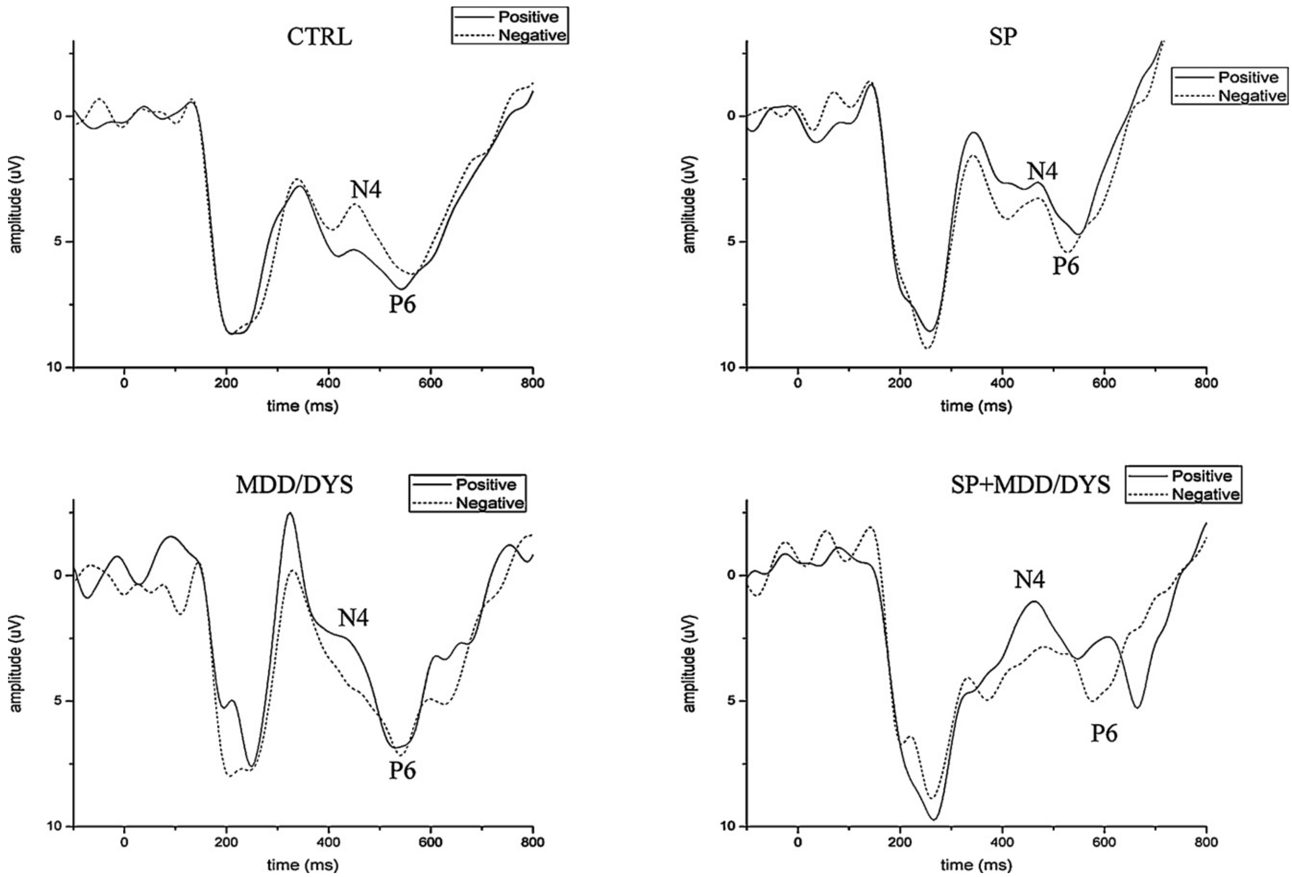

Fig. 2. Event related brain potentials (ERPs) at Cz time-locked to the onset of positive and negative sentence endings across the four groups. ERPs submitted to statistical analyses are labeled.

3.3. Secondary analyses

3.3.1. Analysis strategy

All of our clinical groups scored higher than the control group on measures of social phobia *and* depression. Thus, our ANOVA results are still somewhat inconclusive regarding the unique contributions of social phobia and depression to interpretation bias. We therefore conducted separate regression analyses using each of the interpretation bias measures that showed significant group effects – i.e., negative vs. positive accuracy, negative vs. positive RT, neutral sentence P6, and negative vs. positive N4- as dependent measures and composite measures of social phobia and depression as predictors across all participants. For accuracy, RT and N4, bias scores were created by subtracting responses elicited by positive endings from responses elicited by negative endings. We also examined negative sentence ending accuracy and positive ending N4 separately, as these measures showed significant group differences in the analyses described above. Scores on each self-report measure were transformed to Z scores and then averaged across the two measures of social phobia administered at experiment (LSAS and SIAS) to create a social phobia composite and averaged across the two measures of depression administered at experiment (BDI-II and DASS-D) to create a depression composite. The SPIN was excluded from the social phobia composite and the QIDS from the depression composite, as these measures were utilized as screening tools and thus showed less variability. The social phobia and depression composites were positively correlated with one another, $r(63) = .69$, $p < .001$. Two regressions were conducted for each interpretation bias measure: (1) to assess the unique effect of social phobia after controlling for the effects of depression, the depression composite was entered into the regression first, followed by the social phobia composite; (2) to assess the unique effect of depression after controlling for the effects of social phobia, the social phobia composite was entered first, followed by the depression composite. Finally, as our primary interest is the nature of social anxiety and depression, we used the bias scores as independent variables to predict social anxiety and depression in separate regressions. Collinearity diagnostics indicated that none of the models suffered from multicollinearity problems (VIFs < 1.93; Tolerances > .52).

3.3.2. Negative minus positive accuracy and RT bias scores

None of the regressions predicting the accuracy bias score were significant ($ps > .06$). For the negative minus positive RT bias score, depression was not a significant predictor when entered first, change in $F\ (1,\ 61) = 1.26$, $p = .27$, $\beta = .14$. However, social phobia was a significant predictor even after controlling for the effect of depression, change in $R^2 = .06$, change in $F\ (1,\ 60) = 4.12$, $p < .05$, $\beta = .35$, suggesting that increases in social phobia symptoms related to increases in the negative minus positive RT score – i.e., decreases in a positive interpretation bias/increases in a negative interpretation bias. The same analysis with social phobia scores entered first showed that social phobia was a significant predictor by itself, change in $R^2 = .08$, change in $F(1, 61) = 5.21$, $p = .03$, $\beta = .28$. Findings from these analyses therefore suggest that social phobia symptoms are uniquely associated with the RT interpretation bias, as measured by the difference between negative and positive ending RT.

3.3.3. Neutral sentence P6 amplitude

For the neutral sentence ending P6, depression was a significant predictor when entered first, change in $R^2 = .12$, change in $F(1, 61) = 8.19$, $p = .01$, $\beta = -.35$, suggesting that increases in depression severity were related to decreases in P6 amplitude. Social phobia was also a significant predictor even after controlling for the effect of depression, change in $R^2 = .06$, change in $F(1, 60) = 4.38$, $p < .05$, $\beta = -.34$, suggesting that increases in social phobia symptoms were related to decreases in P6 amplitude. When entered first, social phobia was a significant predictor of neutral sentence ending P6, change in $R^2 = .18$, change in $F(1, 61) = 12.69$, $p < .01$, $\beta = -.42$. Conversely, depression failed to significantly predict neutral sentence P6 after controlling for the effect of social phobia, change in $R^2 = .01$, change in $F(1, 60) < 1$, $\beta = -.11$. These findings suggest, then, that social phobia symptoms are also uniquely associated with decreased baseline resource allocation.

3.3.4. Negative minus positive N4 bias score

For the negative minus positive N4 bias score, depression was a significant predictor when entered first, change in $R^2 = .11$, change in $F(1, 61) = 7.72$, $p = .01$, $\beta = .34$, suggesting that increases in depression symptoms were related to increases in negativity on positive ending trials – i.e., evidence for decreases in positive interpretation bias/increases in negative interpretation bias. Social phobia was not a significant predictor after controlling for depression, change in $R^2 = .01$, change in $F(1, 60) < 1$, $\beta = .16$. Similarly, social phobia was a significant predictor when entered first, change in $R^2 = .10$, change in $F(1, 61) = 6.81$, $p = .01$, $\beta = .32$, suggesting that increases in social phobia symptoms were related to increases in negativity on positive ending trials. Depression was not a significant predictor after controlling for social phobia, change in $R^2 = .03$, change in $F(1, 60) = 1.81$, $p = .19$, $\beta = .22$. Despite the fact that neither social phobia nor depression were unique predictors of N4 bias score, the overall model with both measures entered simultaneously was significant, change in $R^2 = .13$, change in $F(2, 60) = 4.35$, $p = .02$, indicating that what the two measures share contributes to significant variance in N4 bias score. No significant effects emerged when we analyzed positive N4 s separately ($ps > .14$). Therefore, results suggest that social phobia and depression symptoms or a common component between them (e.g., negative affect) are associated with N4 interpretation bias, as indexed by the difference between negative and positive ending N4 amplitude.

3.4. Prediction of social anxiety and depression symptoms from bias measures

Predicting social anxiety symptoms across the whole sample using the four measures of bias – accuracy differences, RT difference, P6 to neutral endings, and N4 difference – produced a significant effect, change in $R^2 = .30$, change in $F(4, 58) = 6.12$, $p < .001$. With all four measures in the model, P6 to neutral endings and RT difference remained significant predictors ($\beta s = -.36$ and .26, respectively, $ps < .05$). N4 difference was a marginal predictor, $\beta = .20$, $p = .09$, and accuracy difference was nonsignificant, $\beta = .10$, $p = .39$.[3] The four measures of bias continued to significantly predict social anxiety even after controlling for depression symptoms, change in $R^2 = .08$, change in $F(4, 57) = 2.63$, $p = .04$. Depression was a significant predictor, $\beta = .56$, $p < .001$, as were the P6 to neutral endings, $\beta = -.22$, $p = .03$, and the RT difference, $\beta = .19$, $p = .04$. Neither the N4 difference nor the accuracy difference remained significant predictors, $\beta s < .06$, $ps > .54$.[4]

Predicting depression symptoms across the whole sample using the four measures of bias – accuracy differences, RT difference, P6 to neutral endings, and N4 difference – produced a significant effect, change in $R^2 = .20$, change in $F(4, 58) = 3.55$, $p = .01$.[5] With all four measures in the model, P6 to neutral endings and N4 difference remained significant predictors ($\beta s = -.26$ and .26, respectively, $ps < .05$). Neither RT difference nor accuracy difference were significant, $\beta s < .13$, $ps > .30$. The four measures of bias did not significantly predict depression after controlling for social anxiety symptoms in the first block, change in $R^2 = .02$, change in $F(4, 57) < 1$.

4. Discussion

The aims of the current study were to build on our previous findings showing ERP evidence for a lack of positive bias in socially phobic community volunteers (Moser et al., 2008) by including: (1) clinically diagnosed groups to extend our initial work to clinical cases, and (2) groups varying in severity of both social phobia and depression in order to investigate their relative contributions. The primary finding of the present study was that the stimulus-locked N4 revealed a lack of positive bias across individuals diagnosed with social phobia, depression and comorbid social phobia and depression as compared to a control group that evidenced a positive interpretation bias. There was also evidence that the disordered groups, and, in particular, the comorbid socially phobic and depressed group, were characterized by the presence of a negative bias.

The lack of positive bias present in the social phobia groups is consistent with the lack of positive bias in our previous work (Moser et al., 2008), Hirsch and Mathews's (2000) RT finding, and Clark and Wells's (1995) theoretical model. The lack of positive bias shown in the MDD/DYS group is consistent with a RT study in girls at risk for developing depression (Dearing and Gotlib, 2009). The clinical groups also showed some evidence for a negative interpretation bias, with the SP + MDD/DYS group showing a relatively more reliable effect. This result suggests that the combination of social phobia and depression may increase the likelihood of imposing negative interpretations on ambiguous social scenarios at an early stage of semantic processing, as indexed by the N4. This result dovetails with Wilson and Rapee's (2005) self-report findings in which patients with social phobia and comorbid depression evidenced the strongest negative interpretation bias. Like Wilson and Rapee, we also found that our pathological groups scored higher than the control group on measures of both social phobia and depression, thus making it difficult to ascertain whether the lack of positive bias/presence of a negative bias was attributable to social phobia, depression, or both. Regression analyses across all samples, treating social phobia and depression symptoms and ERP bias scores as continuous variables, showed that the N4 bias effect was associated with both social phobia and depression symptom severity, but was not uniquely associated with either. These results are consistent with the view that social phobia and depression share a common interpretation bias (Mathews and MacLeod, 2005).

It is important to point out that by analyzing the ERP interpretation bias scores (i.e., negative – positive), the distinction between a lack of positive bias and the presence of a negative bias was somewhat blurred. However, we feel this should not confuse the nature

[3] Replacing the accuracy difference with negative ending accuracy and the N4 difference with the positive ending N4 produced a nearly identical effect, change in $R^2 = .32$, change in $F(4, 58) = 6.91$, $p < .001$. With all four measures in the model, P6 to neutral endings and RT difference remained significant predictors ($\beta s = -.32$ and .27, respectively, $ps < .05$). Positive ending N4 was a marginal predictor, $\beta = -.24$, $p = .06$, and negative ending accuracy was nonsignificant, $\beta = .15$, $p = .18$.

[4] Replacing the accuracy difference with negative ending accuracy and the N4 difference with the positive ending N4 produced a nearly identical effect, change in $R^2 = .12$, change in $F(4, 57) = 4.27$, $p < .01$. Depression was a significant predictor, $\beta = .56$, $p < .001$, as was the RT difference, $\beta = .19$, $p = .03$. Positive ending N4 was a marginal predictor, $\beta = -.18$, $p = .07$. Neither the neutral ending P6 nor accuracy difference remained significant predictors, $\beta s < .16$, $ps > .12$.

[5] Replacing the accuracy difference with negative ending accuracy and the N4 difference with the positive ending N4 failed to produce a significant effect, change in $R^2 = .14$, change in $F(4, 58) = 2.35$, $p > .06$.

of interpretation bias in social phobia and depression. Rather, our results conform to the notion that unaffected individuals interpret ambiguous information in a positive light, and that increases in anxiety and depression symptoms lead to an 'erosion' of the positive bias and ultimate evolution of a negative bias (Hirsch et al., 2006; Huppert et al., 2007; Mathews and Mackintosh, 1998; Mathews and MacLeod, 2005). Thus, online interpretation bias can be thought of as representing a continuum on which individuals can fall toward one end (e.g., negative) or the other (e.g., positive) and anywhere in between depending on the strength of focus on internal negative self-imagery that likely increases with more severe symptoms. It is critical to also note, however, that direct comparison of N4 responses to the sentence endings across groups revealed larger N4s to positive sentence endings in the disordered groups, consistent with a lack of positive expectancy bias. There were no group differences in N4 responses to the negative sentence endings, further suggesting a specific deficit in expecting positive resolutions to ambiguous scenarios in socially anxious and depressed individuals.

Contrary to our previous study (Moser et al., 2008) we did not find evidence for interpretation bias in the P6 here, rather interpretation bias was reflected in the N4. Importantly, however, the pattern of results is similar between the two studies–that is, the pathological groups from both studies showed decreased positive bias/increased negative bias compared to control groups in ERPs associated with expectancy violations. Why then did interpretation biases manifest in the P6 in our previous study and the N4 in the current study? An initial point is that the N4 and P6 have been shown to be sensitive to similar violations of expectancy in semantic and syntactic processing tasks (for a review see Coulson et al., 1998a). Research further suggests that N4 effects seem to emerge when expectancy violations are particularly strong (van Herten et al., 2005). Relevant to the current study, N4 enhancements have been reported for personally relevant or meaningful expectancy violations, such as partner rejection (Zayas et al., 2009) and emotional life events (Chung et al., 1996) that activate effortful analysis of the meaning (semantics) of the event. It is possible that using more impaired individuals (i.e., patients) *and* ensuring that controls did not meet criteria for any psychological condition, expectancy violations in the current study were more salient to the different groups. Support for this explanation comes from Kotz and Paulmann's (2007) finding that expectancy violation effects emerge earlier, in the N400, as emotional relevance increases. On this point, subjects in the current study completed a battery of self-report measures prior to performing the sentence processing task – which was not the case in our previous study (Moser et al., 2008) – that may have primed them for their respective emotional states – non-anxious/depressed in the case of the controls and anxious/depressed in the disordered groups – thus making expectancy violations particularly salient to each group and emerge in the earlier N4. Nonetheless, the ERP effects from the current study (i.e., the N400) and our previous one (i.e., the P6) reveal interpretation biases consistent with extant theoretical models of anxiety and depression (Clark and Wells, 1995; Mathews and Mackintosh, 1998; Mathews and MacLeod, 2005).

The fact that pathological groups in the current study also demonstrated reduced baseline resource allocation to the task, as measured by the P6 elicited by neutral sentences, further supports our interpretation that the current patient samples were more impaired than our previous analog sample. The non-patient socially phobic individuals in our previous study did not evidence this reduction in resource allocation (Moser et al., 2008). In the current study, the SP and SP + MDD/DYS groups showed reduced P6 amplitude to neutral sentences. The SP + MDD/DYS group had the smallest P6, suggesting that the combination of social phobia and depression contributed to the greatest reductions in available task resources. Regression analyses across all samples suggested that these reductions in P6 amplitude were more associated with social phobia than with depression, although caution should be taken with any suggestion of specificity of findings, as social phobia and depression symptoms were highly correlated with one another across the entire sample ($r = .69$). Such findings underscore the difficulty in differentiating highly comorbid disorders using covariate analyses (cf. Miller and Chapman, 2001).

As previously described, models of social phobia implicate self-focused attention and resulting reduced attention allocation to external stimuli as maintaining factors of the pathology (Clark and Wells, 1995; Rapee and Heimberg, 1997). Socially phobic individuals are posited to direct attention inward toward distracting negative self-imagery when in potentially threatening environments or when experiencing distress (Hirsch et al., 2006). It is possible, then, that decreased P6 amplitude to neutral sentence endings in the socially phobic groups found here reflects their distraction by negative self-imagery, which in turn reduced attention allocation to the task. Hirsch et al. (2006) and Clark and Wells (1995) suggest that attention to negative self-imagery blocks on-line interpretations in socially phobic individuals and may also increase the likelihood that congruent information (i.e., negative) is given higher priority. Ultimately, it is possible that reduced task effort allows the interpretation bias to manifest more fully – that is, if one is extremely engaged in the grammatical decision task, it is possible that the affective content will be less influential, whereas decreased task engagement may provide fertile ground for the emotional content to override task goals, thus creating more opportunity to evidence the bias. Future studies could directly manipulate cognitive load and/or negative self-imagery to further substantiate these conclusions (cf. Hirsch et al., 2003).

We also found stronger evidence for a RT, and accuracy, bias effect in the present study than in our previous one (Moser et al., 2008) further supporting the notion that, indeed, the emotional information was more salient in the present samples. Like the N4 findings, the RT and accuracy results revealed a lack of positive bias across all three disordered groups. This finding fits well with Hirsch and Mathews's (2000) RT findings in socially phobic patients and Dearing and Gotlib's (2009) RT findings in teenage girls at risk for depression. The control group in the present study showed clear evidence for a positive interpretation bias, with faster RT and superior accuracy to ambiguous scenarios completed with a positive ending. The RT finding is perhaps the most robust in the interpretation bias literature, supported by three studies: the present study and two conducted by Hirsch and colleagues (Hirsch and Mathews, 2000; Hirsch et al., 2003). In contrast, the MDD/DYS, SP, and SP + MDD/DYS groups showed no strong evidence for preferential responding to the sentence endings in RT. Consistent with the ANOVA findings, regression analysis across the entire sample demonstrated that increases in social phobia symptoms were related to decreases in positive/increases in negative interpretation bias. Moreover, this relationship appeared independent of depression severity. Again, in so far as increases in social phobia symptoms relate to decreases in positive interpretation bias/increases in negative interpretation bias, the model proposed by Mathews and Mackintosh (1998) suggesting that increases in anxiety begin by 'eroding' the positive bias characterizing low anxious individual and at higher levels ultimately result in the emergence of a negative bias fits the current findings. On the other hand, the present results suggest little relationship between RT interpretation bias and depression, a finding that is consistent with previous reports of depression's muddying effects on response times in such tasks (Lawson et al., 2002).

In general, results from regression analyses were very similar to, if not stronger than, the ANOVA models, consistent with others who found more power in regression models in ERP studies of anxiety (e.g., Li et al., 2007). In addition to treating the bias measures as dependent variables, we used regression analysis to predict social anxiety and depression symptoms from bias measures, as our primary interests lie with better understanding the nature of anxiety, depression, and their overlap. The bias measures accounted for a significant amount of variance in social anxiety and depression, with estimates ranging from 20% to 30%. The overall pattern of effects mirrored that suggested by the analyses of the bias measures separately. Using social anxiety and depression as dependent measures, however, emphasizes the significant role these biases in information processing play in explaining variance in symptoms. This sort of analysis is important for moving toward a biological basis of classifying mental disorders in accordance with the National Institute of Mental Health's Research Domain Criteria (RDoC) initiative (e.g., Sanislow et al., 2010).

Regression analyses were initially indicated by the fact that all disordered groups scored higher than the control group on both social phobia and depression measures. Because of the comorbidity and overlap in symptoms of social phobia and depression (Brown et al., 2001), differentiation will always be complicated. In light of research suggesting a higher-order structure to mood and anxiety disorders – i.e., the internalizing/neuroticism superordinate factor (Krueger, 1999) – and the importance of dimensional perspectives (Brown and Barlow, 2005), future studies may benefit from taking a more dimensional approach to the study of interpretation and other cognitive biases in anxiety and depression and may find more precise ways to parse differences between the two. Moreover, it was rather difficult to identify 'pure depressives' when recruiting for this study as can be seen by our small sample size in the MDD/DYS group. Given the MDD/DYS group's high scores on social phobia symptoms (see Table 2), such a clean group of depressives may hardly exist. Nonetheless, our MDD/DYS group was quite small and future investigations should gather larger samples to further evaluate the role of interpretation bias in depression.

In sum, the current study demonstrated the sensitivity of ERPs and RT to interpretation bias in individuals diagnosed with clinically significant social phobia, depression, and their combination. ERP results revealed a lack of positive interpretation bias in all disordered groups, as indexed by the N4 expectancy violation effect, with some suggestion of a negative interpretation bias in the comorbid group. Socially phobic and comorbid socially phobic and depressed individuals furthermore showed reductions in baseline attention allocation to the task, as indexed by P6 amplitude elicited by neutral sentence endings. Reaction time and accuracy results similarly revealed a lack of positive bias across disordered groups. Findings from regression analyses were consistent with and generally stronger than ANOVA results. Difficulties remain with regard to differentiating highly comorbid conditions and therefore future studies of information processing biases may want to more seriously consider dimensional and higher-order factor models of negative affective psychopathology using large samples. These findings build on previous research in which social phobia and depression were examined without regard to the other. Finally, the current results further underscore the importance of combined measurement of ERPs and behavior in identifying cognition–emotion processing biases in anxiety and depression.

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