Cognitive Therapy and Research, Vol. 29, No. 4, August 2005 (© 2005), pp. 479–499
DOI: 10.1007/s10608-005-0627-5

Information Processing and Anxiety Sensitivity: Cognitive Vulnerability to Panic Reflected in Interpretation and Memory Biases

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The relationship between panic and anxiety sensitivity (AS) has been well established. Further, cognitive theories of panic have received substantial support through demonstrations of cognitive biases toward threatening information. However, past research has produced mixed findings on whether AS is itself associated with biased information processing. To explore this question, the current study examined evidence for and relationships among attention (on a modified Stroop), interpretation (using the Brief Body Sensations Interpretation Questionnaire), and schematic/memory biases (on Implicit Association Tests) in individuals with high ($N = 55$) and low ($N = 48$) AS. Results indicated interpretation and memory biases favoring threat among the high AS group, but no attentional bias. Further, the memory bias was positively related to the interpretation bias and to measures of anxiety and panic, offering the first evidence for a schema potentially related to the development of panic. Findings are discussed regarding implications for cognitive models of vulnerability.

KEY WORDS: anxiety sensitivity; interpretation; information processing bias; panic; schema.

Anxiety sensitivity reflects a tendency to experience fear or concern over the symptoms associated with anxiety, such as physical symptoms like a racing heart and subjective feelings of nervousness (Reiss & McNally, 1985). This fearful disposition appears to operate as a cognitive vulnerability factor for panic, offering critical support to models that suggest a cognitive etiology for anxiety disorders (e.g., Beck & Emery with Greenberg, 1985; Clark, 1986). The models propose that it is maladaptive beliefs, such as that anxiety symptoms are dangerous, and biased ways of processing information that lead an individual to develop and maintain pathological anxiety reactions. There is now both cross-sectional and longitudinal prospective data demonstrating that AS predicts future panic and anxiety problems (e.g., Cox, Endler, Swinson, & Norton, 1991; Schmidt, Lerew, & Jackson, 1997). For instance,

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Maller and Reiss (1992) found that high levels of AS were associated with a five times greater risk of developing an anxiety disorder than were low levels of AS. The construct of AS is believed to be trait-like, and importantly, it is thought to precede the development of panic attacks, rather than simply being a correlate of anxious states.

If AS is a cognitive risk factor for panic disorder, as suggested by accumulating evidence, then McNally (1990) and others propose that individuals high in AS should demonstrate biases in information processing that are comparable to those seen among persons with panic disorder. The logic guiding this assertion follows from expectancy theory, which predicts that AS should augment reactions to potential threat cues (Reiss, 1991; Reiss & McNally, 1985), and from suggestive evidence that biases may precede the development of panic disorder (e.g., Donnell & McNally, 1989). Finding that participants at risk for panic, such as those with high AS, show preferential threat processing lends support to cognitive explanations of the etiology for panic. To date, it is reasonably clear that AS is associated with panic, and clear that information processing biases are associated with panic disorder (e.g, Clark et al., 1997; Ehlers, Margraf, Davies, & Roth, 1988; McNally & Foa, 1987), but past research has produced mixed findings on whether high AS is associated with biased processing of threat information.

Relationships between AS and information processing typically evaluate differences among persons scoring high or low on the Anxiety Sensitivity Index (ASI; Reiss, Peterson, Gursky, & McNally, 1986). To investigate attentional biases, the modified Stroop task has been used most frequently. Lundh, Wikstrom,Westerlund, and Öst (1999) found no correlation between AS and a subliminal Stroop task that evaluated interference for panic-related words. Similarly, McNally, Hornig, Hoffman, and Han (1999) found no relationship between a supraliminal Stroop task and the ASI. In contrast, Stewart, Conrod, Gignac, and Pihl (1998) did find that high AS participants showed more Stroop interference than low AS participants to threat items. Interestingly, there was a gender difference in this study, with males preferentially attending to social threat items and females to physical threat items.

The picture is also somewhat confusing for interpretation biases. Harvey, Richards, Dziadosz, and Swindell (1993) found no strong relationship between AS and misinterpretation of ambiguous interoceptive stimuli (internal bodily cues) on the Interpretation Questionnaire (McNally & Foa, 1987), whereas McNally et al. (1999) did find a bias for external threat on the same measure (but not biases toward interoceptive threat). Finally, Richards, Austin, and Alvarenga (2001) used the Brief Body Sensations Interpretation Questionnaire (Clark et al., 1997) and found that AS predicted biases toward both interoceptive and external threat stimuli.

Findings for memory biases are also inconsistent. Lundh, Czyzykow, and Öst (1997) found that AS correlated with explicit memory for physical threat words (using a cued recall task) but not with implicit memory (based on a word stem completion task). Similarly, McCabe (1999) found no implicit bias on a word completion test, but high AS participants recalled more general threat words on a cued recall task, again demonstrating an explicit bias. However, they did not recall more anxiety words. Further, McNally et al. (1999) found no bias on a surprise free-recall test for threat words.

It is difficult to make sense of these inconsistent findings, though a number of options seem plausible, some that are theoretical and others that are methodological. One possible explanation may relate to the low reliability and sensitivity of some of the information processing methodologies used. Another possibility may relate to the samples used, which varied both in intensity of AS (i.e., what cutoff on the ASI constituted high AS), and in whether or not individuals with a previous history of panic attacks were excluded from participation. McCabe (1999) and others (e.g., McNally et al., 1999) have suggested that some panic experience may be required for expression of the information processing biases. Alternatively, some researchers have proposed that AS may reflect risk for panic while information processing biases may be correlates of the disorder (e.g., McNally et al., 1999). Although this explanation has some intuitive appeal, it leaves unanswered why so many studies have found at least some evidence of biases to preferentially process threat information among high AS samples. Another suggestion by the same research group (McNally et al., 1999) is that AS and other cognitive factors may independently present risk for panic but not covary. A related possibility is that the various cognitive biases are not activated in a unitary way, so AS may be associated with some preferential threat processes, like interpretation biases which have been found relatively more consistently, but not others, like attention biases, which have been found less frequently.

Given the disparate potential explanations for previous findings, it is unrealistic to clarify all of the mixed results in one study. However, the present study was designed to evaluate the relationship between AS, panic history, and information processing biases by addressing a number of the sampling and design limitations from previous studies and examining a variety of processing biases. First, the cognitive tasks were selected to heighten the likelihood of getting an effect based on reasonable reliability and sensitivity of the measures. Second, individuals were preselected based on ASI scores and the ASI was then again completed during the testing session. Only those individuals who met the ASI cutoffs for high or low AS status at testing were included in the final sample to maximize the reliability of the AS classification and select individuals with relatively stable beliefs about the dangerousness of anxiety symptoms. Third, individuals who reported a prior history of panic attacks were included so that the role of experience with panic in cognitive biases could be evaluated. Fourth, a variety of information processing biases were evaluated, including attention, interpretation, and schematic/memory, to determine how the biases relate to one another and whether there would be evidence for some threat-oriented processes but not others having yet developed. Specifically, this study reflects the first attempt to evaluate a proxy for schematic processing in panic or AS (though see interesting related work in trait anxiety by Egloff & Schmukle, 2002). The measures used reflect automatic associations in memory; hence they are referred to in the paper as schematic/memory biases.

The selection and design of the schematic/memory, interpretation, and attentional bias tasks was driven by theoretical models of cognitive vulnerability to panic, given that AS is a risk factor for panic. The specific cognitive model of panic derives from more general cognitive theories to explain anxiety and fear. The general model proposes that maladaptive schemata or cognitive frameworks influence information processing to make the individual more attentive to potentially threatening cues, more likely to interpret ambiguous cues as threatening, and more likely to remember cues relevant to fear (e.g., Beck, 1976; Beck & Emery with Greenberg, 1985). To evaluate these general anxiety biases, cognitive processing of various types of threat cues were examined, as well as tendencies to associate panic with one's self-concept, thereby indicating a panic self-schema analogous to negative self-schemata in depression (see Segal, 1988). To evaluate cognitive theories of panic in particular, the information processing tasks also focused on responding to interoceptive cues following Clark's (1986) suggestion that panic attacks occur because certain bodily sensations are misinterpreted as indicating a catastrophe, such as a heart attack.

In summary, the current study evaluated a series of information processing biases among individuals high and low in anxiety sensitivity based on the following hypotheses:

1. Individuals high in AS will show preferential processing of threat stimuli on measures of schematic/memory, interpretation, and attentional bias.
2. Evidence of a panic self-schema will be evident among the high AS sample, thereby establishing preliminary evidence of a schema operating as a cognitive vulnerability marker for panic, and this schema is expected to relate to the other cognitive threat biases, given its primacy in cognitive models. (Clearly, the cross-sectional design does not test cognitive vulnerability, but evidence of a panic schema among a sample high in AS provides initial support.)
3. Evaluation of whether panic experience is necessary for the expression of cognitive biases will be conducted as an exploratory aspect of the current study to address arguments (e.g., McCabe, 1999) that the absence of panic experience may explain the null findings from previous studies.

METHOD

Participants

Approximately 1,000 undergraduate psychology students completed an array of questionnaires, including the ASI, as part of a prescreening process for the psychology participant pool at the University of Virginia. Following the cut points established in McCabe (1999), participants scoring 14 or less or 23 or greater on the ASI were invited to participate in the study, matching the .5 standard deviation (*SD*) cutoff above or below ASI college student norms (Peterson & Reiss, 1992). Only those students whose ASI scores *at testing* met the established cutoffs were included in the final sample. This resulted in 103 students who participated in the experiment in partial completion of requirements for introductory psychology courses. The sample was 66% female, mean age was 18.9 years old ($SD = 1.24$, Range = 17–26), and 77% were Caucasian (6% African American, 12% Asian, 2% Hispanic, and 3% indicated "other" for ethnicity). The sample included 48 Low AS (Mean = 8.93, $SD = 3.55$, 60% female), and 55 High AS (Mean = 30.68, $SD = 5.90$, 70% female). A chi-square test indicated the groups did not differ by gender ($\chi^2 = 1.17, p > .10$), and an independent samples *t*-test indicated no significant age difference between the High and Low AS groups ($t_{96} = .11$, $p > .10$, *Cohen's* $d = .02$). The ASI test-retest reliability from preselection to the testing session for the final sample was $r = .75, p < .001$.

Materials

Measures of Mood and Anxiety Symptoms

Anxiety Sensitivity Index (ASI; Reiss et al., 1986). This 16-item questionnaire measures fear about or concern over the symptoms associated with anxiety (e.g., "It scares me when my heart beats rapidly"). The instrument has adequate psychometric properties (Telch, Shermis, & Lucas, 1989), and is typically evaluated as a unitary, higher-order factor (Reiss & McNally, 1985), though a three-factor solution has also received support (Physical Concerns, Mental Incapacitation, and Social Concerns subscales; Zinbarg, Mohlman, & Hong, 1997).

Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996). The BDI-II is a 21-item self-report inventory that measures severity of symptoms associated with depression.

General Measures of Panic Symptoms and Avoidance

Fear Questionnaire—Agoraphobia Subscale (Marks & Mathews, 1979). This 5-item subscale measures participants' level of phobic avoidance toward common situations, such as crowded shops.

Panic Disorder Severity Scale (PDSS; Shear et al., 1997). This 7-item scale has good inter-rater reliability, and provides a composite severity score of frequency, distress, and impairment associated with panic attacks (PA). Although this measure was designed as a clinician-administered instrument, several prior studies have had participants complete it as a self-report measure (e.g., Otto, Pollack, Penava, & Zucker 1999; Penava, Otto, Maki, & Pollack, 1998). The instrument was modified slightly for this study by adding a description of PA to the instructions so that it could be completed in a self-report format and so that only participants who endorsed a history of PA would complete the subsequent severity items.[3]

Measures of Information Processing

Schematic/Memory Processing: Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998). The IAT shows promise for assessing the memory-based cognitive structures referred to in schema theories. The IAT measures automatic associations in memory (automatic in the sense that evaluations occur outside conscious control, and at times, outside conscious awareness), thus appearing to share many of the qualities ascribed to fear and anxiety schemata. The IAT has adequate psychometric properties (Greenwald & Nosek, 2001), and like many tasks used by social cognition researchers (Fazio, 2001), the IAT is

[3]This modification permitted evaluation of cognitive biases as a vulnerability to PA across all participants, but results should be interpreted in light of this novel application of the measure.

a reaction time task that purportedly reflects strength of association between concepts in memory. The computerized version of the IAT requires items to be classified while two category labels are paired on either side of the screen. (See http://implicit.harvard.edu/implicit/ for more information and a sample test.) Specifically, the task involves comparing the time taken to classify stimuli when paired categories match a person's automatic associations versus the time taken when paired categories contradict automatic associations.

The task has a number of features that make it particularly suitable for anxiety research. First, this methodology minimizes the influence of self-presentational concerns and conscious control (Greenwald et al., 1998). Second, the IAT uses a within-subject design, so the influence of mood state is controlled because the anxiety-evoking stimuli are present in all conditions being compared, permitting a relatively clean evaluation of cognitive processing. To apply this technique to the area of AS and panic, response times to classify stimuli when category pairs match the hypothesized anxiety network or schema are compared with response times for classifying stimuli when category pairs contradict the hypothesized schema for persons with high AS. Because the IAT is a relative task, equivalent comparison categories are required. In the first IAT task, which evaluated a panic-relevant self-concept (referred to as "IAT Panicked > Me"), the category "Calm" was used as a comparison to the category "Panicked" because it reflects the opposing emotional response. These categories were compared while being paired with descriptor categories to reflect the self versus others. Specifically, the categories "Panicked" and "Me" were paired at the top left of the computer screen while "Calm" and "Not me" were simultaneously paired at the top right. Participants were told to classify any stimuli that belonged to either the "Panicked" or "Me" categories on the left, and any stimuli that belonged to either the "Calm" or "Not me" categories on the right. The dependent variable was speed of classification across a series of trials. Following this category pairing condition, the labels were switched and the same categorization task was completed while pairing "Panicked" with "Not me" (and "Calm" with "Me"). Thus, for each IAT task, two sets of category pairs were presented simultaneously.

The second IAT task (referred to as "IAT Bodily Changes > Alarming") focused on evaluating the prediction of catastrophic misinterpretation of bodily sensations. Here, the target categories "Bodily Changes" versus "Weather Changes" were paired with the descriptors "Uncomfortable" versus "Alarming." "Weather changes" was selected as the comparison category because negative stimuli could be used for both the bodily and weather categories, reducing the confound of valence differences between the categories. Unfortunately, this design made for a difficult test because it required participants to hold different automatic associations toward the idea of bodily changes being alarming rather than just being uncomfortable; a complex concept for what has been termed the "dumb unconscious" (Greenwald, 1992). It is expected that when categories are paired to match a person's automatic associations, they will be able to classify the stimuli more quickly. Thus, IAT effects are determined by contrasting average response time in one category pairing with average response time in the other. The expectation in the current study was that the High AS group would more readily associate feeling panicked with the self, and evaluate bodily changes as being alarming than would the Low AS group.

Four items were selected for each category. See Appendix for IAT category labels and stimuli. In each IAT task, there were two critical trial blocks: one block of trials where the target and descriptor categories reflected negative panic-relevant associations and one block in which the categories reflected non-panic associations. Each critical block consisted of 72 classification trials, and was preceded by a 40-trial practice block. Following the revised scoring algorithm (Greenwald, Nosek, & Banaji, 2003), the average of the practice and critical trial data were used for analyses. Participants first completed an unrelated practice IAT task to familiarize them with the procedure and then completed the two IAT tasks in random order. In addition, the ordering of the panic-consistent versus inconsistent blocks was counterbalanced, and the order of stimuli presentation within blocks was random. Participants were instructed to respond as quickly and as accurately as possible, and were provided error feedback throughout the task so they could correct any misclassifications before moving on to the next trial.

Interpretation Bias: Brief Body Sensations Interpretation Questionnaire (BBSIQ; Clark et al., 1997). The BBSIQ is a 14-item version of the Body Sensations Interpretation Questionnaire, which is modified from McNally and Foa's (1987) Interpretation Questionnaire. In the present study, very minor wording modifications were made to make the measure more prototypic of American rather than British English. Participants are presented with ambiguous events, and then asked to rank order three alternative explanations for why this event might have occurred. One option is always negative, whereas the other responses are either neutral and/or positive. Half of the items refer to events consistent with the theoretical prediction of a catastrophic misinterpretation of bodily sensations (referred to as "Panic" items), and the "External Threat" items reflect other general and social threat events. An example of a panic item is, "You notice that your heart is beating quickly and pounding," and the three alternatives are, "because you have been physically active," "because there is something wrong with your heart," or "because you are feeling excited." After ranking these options, participants rate the extent they believe each of the explanations on a 0–8 Likert scale. Clark et al. (1997) found the measure had satisfactory internal consistency, and effectively discriminated between individuals with panic and other anxiety problems.

Attentional Bias: Emotional Stroop Test (Modified From the Stroop Task; Stroop, 1935). The most commonly used paradigm to assess attentional bias in emotional disorders is the modified or emotional Stroop test (Williams, Mathews, & MacLeod, 1996). It is a reaction time task that measures latency to name a word attribute, such as ink color, for threat-relevant versus neutral or other emotion words, based on the assumption that threat words will be named more slowly because of interference caused by their semantic content. The difference in response time is interpreted as evidence of attentional bias (though this has been disputed; see Dalgleish & Watts, 1990; Williams, Watts, MacLeod, & Mathews, 1997).

The word stimuli for the present study include one AS-relevant category (panic/physical threat words), and three control categories (social threat, positive, and neutral words), similar to previous studies evaluating Stroop effects in panic disorder (McNally, Riemann, & Kim, 1990; McNally, Riemann, Louro, Lukach, & Kim, 1992). The Stroop blocks were administered in random order to control for possible order effects, and semantically-related neutral words (all household items) were used to control for potential priming effects. Procedures were modeled after those described in Holle, Neely, and Heimberg (1997) using a blocked presentation. Following an initial check for color blindness, participants completed a brief practice task (naming the ink of 12 instrument words randomly presented in one of four colors). The four critical blocks of word categories were then presented with each block consisting of 48-trials (so each word was presented four times, and each ink color was used with equal frequency). The ink colors (red, green, blue, yellow) were used in random order. Error feedback was given in the form of a red exclamation mark on the screen and the incorrect color name would need to be corrected before the program would proceed to the next trial. The percentage of correct responses and the average response time in milliseconds was presented at the end of each block. Participants were instructed to respond as quickly and as accurately as possible by pressing one of four keys that were clearly marked with either an R for red, G for green, B for blue, or Y for yellow. They were told to ignore the meaning of the word and to just try to press the correct color key. Participants had little difficulty with this response format as indicated by a 97% correct response rate across the critical blocks.

Procedure

Following informed consent, participants completed the three cognitive bias measures and a series of questionnaires. Order of the information processing tasks (IATs, Stroop, BBSIQ) and the questionnaires was counterbalanced, order of the questionnaires was randomized, and order of the IAT blocks (i.e., panicked as me/not me, and bodily changes as alarming/uncomfortable) was randomized. Finally, participants were fully debriefed.

RESULTS

Anxiety Sensitivity and Panic Symptoms

As expected, the ASI was positively related to panic symptoms on the PDSS ($r = .59$, $p < .001$) and avoidance on the FQ-agoraphobia ($r = .46$, $p < .001$); only those participants who endorsed having a PA completed the PDSS, whereas the full sample was able to report on avoidance behaviors. Not surprisingly, the Low AS group reported significantly less experience with panic ($\chi^2 = 9.76$, $p = .003$) than the High AS group (17% versus 45%, respectively reported having had a PA).[4]

[4]Although this study did not include a formal evaluation of panic disorder, there is every indication that it was primarily a nonclinical sample of persons with infrequent PA. Fully 88% of the sample who reported a history of panic indicated a "mild" panic frequency on the PDSS (indicating only panic-like sensations or limited symptom attacks or less than one full PA a week).

Evidence of Information Processing Biases

Schematic Processing: Automatic Associations in Memory

The IAT data were scored according to the new scoring algorithm developed by Greenwald et al. (2003), because this approach improves the psychometric properties of the tool. Using this approach, no participants' IAT data needed to be eliminated (based on either high error rates and/or unusually fast or slow response times). Positive IAT effects reflect relatively faster response times for panic-relevant automatic associations. As expected, the High AS group responded more quickly to self-evaluations with panic (IAT Panicked > Me: $t_{101} = 3.62, p < .001, d = .72$) than did the Low AS group, providing preliminary support for a panic schema. Note in Fig. 1 that the absolute value of the IAT *d* measures (less than zero) reflects more automatic associations with calm for both groups, which is not surprising given that these participants are high in AS, a vulnerability for panic disorder, but do not necessarily have PA.

The IAT task measuring catastrophic misinterpretation of bodily sensations did not indicate AS group differences ($t_{101} = .84$, $p > .10$, $d = .17$). These results are somewhat hard to interpret as the task itself may have been complicated for participants because of the unusual category classifications. Supporting this possibility, the response latencies for the IAT blocks in this task were slower than the latencies for the IAT Panicked > Me task. Thus, given the methodological concerns about the IAT Bodily Changes > Alarming task, only the IAT Panicked > Me task will be used in subsequent analyses.

Interpretation Bias: BBSIQ

Based on the scoring of the BBSIQ in Clark et al. (1997), four threat-relevant dependent variables are derived from the scale: panic ranking, panic rating, external

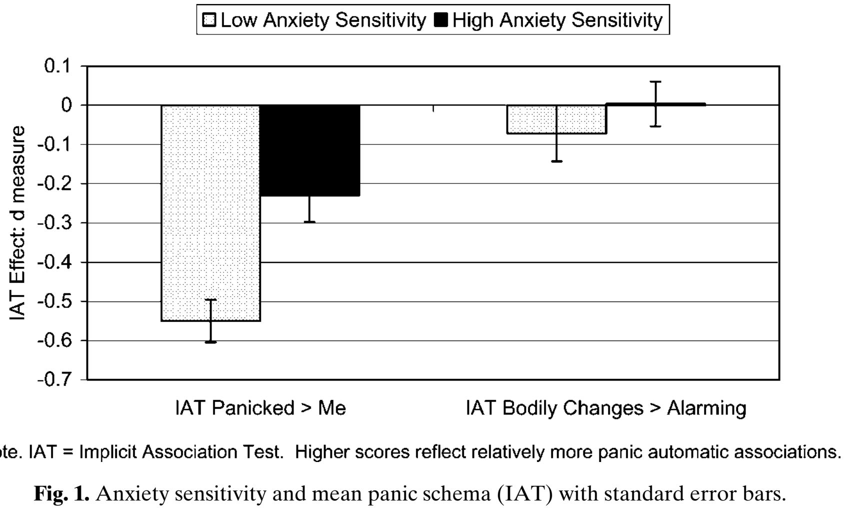
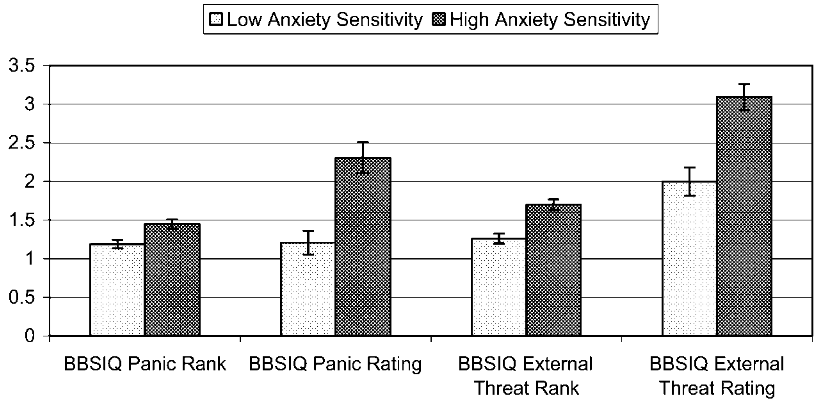


Fig. 1. Anxiety sensitivity and mean panic schema (IAT) with standard error bars.



Note. BBSIQ = Brief Body Sensations Interpretation Questionnaire (range for rank data = 1-3, range for rating data = 0-8).

Fig. 2. Anxiety sensitivity and mean interpretation biases with standard error bars.

threat ranking, external threat rating. As expected, the High AS group both ranked and rated the threat interpretations more highly than the Low AS group[5] for all indices (panic ranking: $t_{78} = 3.06, p = .003, d = .72$; panic rating: $t_{78} = 3.98, p < .001, d = .95$; external threat ranking: $t_{78} = 4.44$, $p < .001$, $d = 1.04$; external threat rating: $t_{78} = 4.36$, $p < .001$, $d = 1.00$). Interestingly, follow-up analyses with the High AS group indicated that the external threat rankings and ratings were higher than the panic-specific ones (ranking: $t_{47} = 3.86$, $p < .001$, $d = 1.13$; rating: $t_{47} = 5.27$, $p < .001$, $d = 1.54$), suggesting that the interpretation bias is more threat-general than panic-specific. See Fig. 2.

Attention Bias: Stroop

To control for individual differences in overall color-naming speed, the Stroop effect was calculated by subtracting the average latency for color-naming positive words from the average latency for color-naming panic/physical threat-relevant words. This same difference score was obtained for the neutral and social threat word categories (subtracted from the panic words). Results were similar for all three difference scores, with no evidence for group differences between the High and Low AS groups in interference effects (all $p > .10$). Given the congruent results for each of the Stroop difference scores, in the interest of space, the panic-positive word effect will be used to represent the attentional bias findings in any subsequent analyses.

Interestingly, this lack of group differences may be explained in part by a main effect of slower reaction times to panic words for all participants. A repeated measures ANOVA indicated a significant difference in response latency among the Stroop word categories: panic, neutral, positive, and social threat ($F_{3,85} = 2.92$,

[5]Due to an administrative error, not all participants completed the BBSIQ & Stroop task, which is why the degrees of freedom vary across information processing tasks.

$p = .04, f = .32$), and follow-up comparisons indicated significantly slower reaction times for panic words than for positive words ($t_{87} = 2.43, p = .02, d = .52$). This interference for all participants (rather than as a function of AS) may be due to the priming of the panic concept that would have occurred for all subjects in the study in advance of completing the Stroop task.

Gender Differences in Information Processing Biases

Multivariate ANOVAs were run for the three categories of information processing biases, looking at between-subjects AS group × gender interactions. The multivariate tests for each bias category resulted in nonsignificant gender × AS interactions, and there were no significant univariate interactions or gender effects for the IATs or Stroop difference scores (all $p > .10$). There was a significant gender × AS interaction for the BBSIQ *panic rating* ($F_{1,76} = 5.07, p = .03, f = .25$). Follow-up tests indicated no AS group differences among males, but among females, the High AS group reported significantly more negative ratings than did the Low AS group (external threat rating: $t_{54} = 4.76, p < .001, d = 1.35$; panic rating: $t_{54} = 3.90$, $p < .001, d = 1.13$). Thus, overall, there was little evidence for gender differences, and those that were found were incongruent with Stewart et al.'s (1998) findings.

Is Panic History Necessary to Explain the Relationship Between Anxiety Sensitivity & Cognitive Biases?

To explore the possibility that interpretation and schematic biases were found in the High AS group because individuals with a history of PA were included in the sample, independent sample *t*-tests for the four BBSIQ interpretation indicators and the IAT Panicked > Me were rerun comparing the High and Low AS groups while excluding any participants who had reported a previous PA. All of the information processing bias differences remained significant even when only including the sample who was panic-free, suggesting panic experience alone does not account for cognitive biases in AS (BBSIQ panic ranking: $t_{49} = 3.69, p = .001, d = 1.01$; BBSIQ panic rating: $t_{49} = 3.01, p < .004, d = .84$; BBSIQ external threat ranking: $t_{49} = 4.12$, $p < .001, d = 1.14$; BBSIQ external threat rating: $t_{49} = 3.05, p = .004, d = .86$; IAT Panicked > Me: $t_{68} = 2.69, p = .009, d = .64$).

Relationships Between Anxiety and Mood Symptoms and Information Processing Biases

As expected, the IAT Panicked > Me, was significantly positively related to three of the four measures of the BBSIQ interpretation bias (panic rating: $r = .25$, $p = .03$; external threat ranking: $r = .24$, $p = .03$; external threat rating: $r = .26$, $p = .02$). Not surprisingly, given that the Stroop did not capture an AS bias, the Stroop was not significantly related to any indices of the IAT or BBSIQ measures (all $p > .10$). As evident from Table I, the ASI and its subscales showed positive, significant relationships with the interpretation and schematic/memory information processing biases. The relationships between the panic and avoidance symptom

Table I. Relationships Between Anxiety Sensitivity, Panic Symptoms, and Information Processing Biases

Information processing bias:	ASI Total	ASI Physical concerns	ASI Mental incapacitation	ASI Social concerns	FQ Agoraphobia	Panic Disorder Severity Scale	Beck Depression Inventory-II
Interpretation BBSIQ Panic/Physical threat rank	.459**	.496**	.360**	.204	.122	.304	.356**
Interpretation BBSIQ Panic/Physical threat rating	.487**	.505**	.419**	.190	.166	.114	.327**
Interpretation BBSIQ External threat rank	.564**	.543**	.457**	.354**	.327**	.408*	.519**
Interpretation BBSIQ External threat rating	.504**	.450**	.435**	.359**	.281*	.179	.321**
Schema/Automatic association IAT Panicked > Me	.335**	.273**	.368**	.244*	.174	.244	.314**
Attention Stroop Panic-positive words	.129	.163	.062	.044	.149	.221	.031

Note. ASI = Anxiety Sensitivity Index, FQ = Fear Questionnaire—Agoraphobia subscale, BBSIQ = Brief Body Sensations Interpretation Questionnaire, IAT = Implicit Association Test.
*Significant at the 0.05 level. **Significant at the 0.01 level.

measures and the information processing biases varied (range in $r = .11–.41$). Surprisingly, the BDI-II showed consistent, positive relationships with the BBSIQ and the IAT, perhaps suggesting that the biases are associated with negative affect more broadly, and not exclusively with AS. These correlations should be interpreted with caution because the original sample was preselected to have a bimodal distribution on the ASI, likely exaggerating the observed relationships.

DISCUSSION

The current study investigated information processing biases in schematic/memory processes, interpretation, and attention among individuals high and low in anxiety sensitivity to evaluate predictions from cognitive models of anxiety and panic so that biases in the processing of threat stimuli would be evident even before the onset of panic disorder. Results indicated that people who believe their anxiety symptoms are in some way dangerous (i.e., who are high in AS) tend to interpret ambiguous situations in a catastrophic manner, and they associate themselves with panic at an automatic level, reflecting a memory process analogous to a panic self-schema. Further the schematic/memory bias was related to the interpretation bias as well as to anxiety, panic, and mood symptoms, and these cognitive biases remained even among high AS participants who reported no prior experience with panic.

Implications Regarding Cognitive Vulnerability for Panic

These findings provide compelling evidence that AS is associated with a range of cognitive biases (though not an attentional bias), and have interesting implications for models of cognitive vulnerability. The role of psychological variables, like AS, playing a role in the onset of panic is predicated on information processing views of panic. These views suggest that even before the first attack, beliefs about threatening outcomes associated with physical sensations will likely be present (Rapee, 1996). This contrasts with views that panic may not require any psychological predisposing factors, such as biological perspectives that suggest panic results from a central, faulty suffocation monitor (e.g., Klein, 1993).

The present study provides support for the information processing view, and is consistent with theories positing that biased thought processes may play a role in the onset of panic (rather than just being a consequence), given that the group differences in cognitive biases between the High and Low AS groups remained significant even when excluding participants who reported an experience of prior panic. However, it leaves open the intriguing question of where these expectations of disastrous outcomes come from, and how the relationship between AS and information processing biases develop (i.e., is there a causal link, whereby automatic danger interpretations lead to explicit beliefs about the harmfulness of anxiety symptoms or vice versa, or is the relationship spuriously explained by a third variable?). According to schema theories (e.g., Young, 1999), the mechanism that guides the catastrophic beliefs is a panic schema, like the automatic associations in memory reflected in the current study, but this does not answer the larger question of how the panic schema initially develops to preferentially process threat cues. It seems likely that an integrated model of panic is necessary that takes into account the multitude of predisposing biological, familial, social, personality, cognitive, and conditioning factors (e.g., see Barlow's, 1988, emotion theory, though this model does not posit necessary cognitive vulnerabilities).

Although these results are consistent with cognitive vulnerability explanations for panic, they do not speak to temporal questions because of the cross-sectional design. It will be important for future prospective studies to determine whether it is those individuals with high AS *and* information processing biases who are most vulnerable to developing panic disorder. It is likely that no single cognitive factor will account for the occurrence of all panic (McNally, 1990). For instance, Rachman, Lopatka, and Levitt (1988) noted that 27% of their clinical sample did not report any fearful cognitions that accompanied their panic attacks, suggesting that explicit cognitions are unlikely to account for the onset of all panic. This points to an important potential causal role for processing biases. Mathews and MacLeod (2002) found that experimental induction of attentional and interpretive biases influenced the processing of subsequent, novel threat information. Thus, it seems likely that information processing biases have a bidirectional relationship with anxiety, both causing vulnerability to anxiety and being exaggerated by experience with anxiety and panic, reinforcing the learning of danger associations.

Significance of Finding Interpretation and Schematic/Memory, but Not Attentional, Biases

The current study found strong evidence of cognitive biases in the High AS group, but it was not consistent across all of the information processing tasks evaluated. Specifically, the study raises questions about why evidence for interpretation and schematic/memory biases was found, but not for attentional bias. The limitations associated with the modified Stroop (MacLeod, Mathews, & Tata, 1986) may partly explain the findings; however, some previous researchers (Stewart et al., 1998) have found AS to be associated with Stroop effects. One difference between Stewart's study and the present investigation is that they used a very high AS sample (Mean = 37.9 on the ASI). Nevertheless, this difference is unlikely to explain the discrepant results across studies because reanalysis of the Stroop effects in the current study looking only at the subset of the sample who scored 1 *SD* above or below the ASI norm for college students (matching Stewart et al.'s cutoff) still indicated no AS group differences. A second difference in the Stroop procedures across studies was the use of semantically related words in the neutral category in the present study versus unrelated words in Stewart's study. The lack of semantic relatedness could reduce priming effects (Holle et al., 1997) and hence lead to less interference in naming the ink color for neutral words. Consequently, reaction times for threat words in Stewart's study may have been relatively slower because of semantic priming (rather than because of the threat bias it was intended to reflect). In addition, word presentation was randomized in Stewart et al., whereas it was in a blocked format in the present study. It is not clear if McNally et al. (1999) used a blocked format, but they also found no relationship between the Stroop and the ASI.

Perhaps a more likely explanation is that both McNally and colleagues and our study required participants to complete other tasks related to anxiety in advance of completing the Stroop, which may have primed the panic concept and thus slowed responding to threat words for all participants regardless of AS status. (Supporting this idea, there was a main effect of slower reaction times for panic words in the present study.) In contrast, the procedures section in Stewart et al. (1998) suggests that the Stroop was the first part of that experiment. Thus, it may be that the Stroop is particularly vulnerable to priming effects, compromising its use as a measure of attentional bias in studies that involve a variety of experimental procedures related to anxiety and threat. Given these various methodological issues, and the robust evidence for attention biases in panic disorder (e.g., Beck, Stanley, Averill, Baldwin, & Deagle, 1992; Ehlers et al., 1988), it seems plausible that limitations of the Stroop design may explain the null effects.

Evidence for Automatic and Strategic Processing in Threat Biases

McNally (1995) has suggested that supraliminal Stroop tasks, like the one used in the current study, demonstrate involuntary processing, the hallmark of automaticity in anxiety. In the Stroop, anxious respondents are aware of the stimuli, yet are still unable to counteract the interference effects from the threat stimuli, illustrating the uncontrollable nature of threat processing in anxiety problems. This raises a number of questions about the balance of automatic and strategic biases that are associated with AS and cognitive vulnerability to panic. In an interesting review on the nature of automaticity and the anxiety disorders, McNally (1995) evaluates how clinical research in anxiety problems corresponds to the prototype of automatic processing, which Shiffrin and Schneider (1977) define in three parts. In their view, automatic processing is capacity-free (i.e., requiring no cognitive resources or effort), involuntary (i.e., obligatory and difficult to control), and unconscious (i.e., requiring no conscious awareness). McNally suggests that when researchers cite evidence for automatic biases in pathological anxiety, the findings most fundamentally demonstrate involuntary processing.

The information processing tasks used in the present study reflect a range of automatic and strategic processes, suggesting that threat biases associated with AS are not limited to one or the other. The IAT, used here to reflect schematic processing or automatic associations in memory, is automatic in the sense that it is difficult to control responding on the task, but it is not necessary that individuals be unaware what the task is measuring. Notwithstanding, it appears very difficult to fake responding on the task. In one of the only other demonstrations of implicit anxiety associations, Egloff and Schmukle (2002) developed an IAT to capture automatic anxious self-concept associations in a normal sample, and showed that individuals given instructions to make a good impression were able to manipulate their responding on an explicit measure of anxiety, but not on the IAT.

On the other hand, the BBSIQ, used to reflect interpretation biases in the present study, reflects a very different blend of automatic and strategic processing. The measure is more direct than the IAT, asking participants to report which interpretation for an ambiguous scenario is most probable, so one could presumably choose benign interpretations in order to appear nonanxious. Thus, the measure is probably more vulnerable to demand effects than the IAT is, but it is not clear that participants are aware of the impact of their interpretation choices. For instance, Mathews and Mackintosh (2000) reported that participants who read a series of scenarios with either positive or negative outcomes (in order to experimentally induce interpretation biases) reported no awareness that these induced biases were influencing their later interpretations, despite clear evidence that this was the case.

The evidence from the current study suggests that both automatic and strategic processing can be vulnerable to threat biases even among a high-risk sample (those with high AS) who do not yet have clinical panic. This is consistent with Clark's (1988) model of panic, "In patients who experience recurrent attacks, catastrophic misinterpretations may be so fast and automatic that patients may not always be aware of the interpretive process" (p. 76). It will be interesting to see how biased automatic and strategic processes differentially predict anxious states and behavior. Preliminary evidence to speak to this question follows from Egloff and Schmukle (2002)'s finding that their IAT predicted several behavioral indicators of anxiety on a stressful speech task, such as speech dysfluencies and eye blinks, and findings from Teachman and Woody (2003) that an IAT evaluating spider fear predicted avoidance of a live spider.

Limitations

The study has a number of design limitations that warrant mention. Perhaps most notably, the cross-sectional nature of the design restricts any conclusive interpretation of the data as evidence of cognitive vulnerability. Further, the design is quasi-experimental in that participants were not randomly assigned to AS groups, so it is possible that another variable could explain the observed AS group differences. For example, depression symptoms were positively related to the cognitive biases, raising questions about whether the differences in cognitive processing between groups may reflect differences in negative affect more generally, rather than being specific to AS. Finding that negative affect could explain the threat biases would have implications for models that view AS as a particular risk factor for panic. Interestingly, there is emerging evidence that AS may be a risk factor for concerns other than panic, such as health anxiety and hypochondriasis (see Cox, Borger, & Enns, 1999), which raises the intriguing possibility that these other factors could have activated the information processing biases.[6] Unfortunately, health concerns were not assessed in this study, but this is an interesting question for future research. Finally, the absence of a structured interview to evaluate panic means that the self-reported PA need to be interpreted with caution, and it is not clear how many participants would have met DSM criteria for panic disorder (though this limitation seems less serious given that the AS group differences in cognitive biases held even when excluding individuals who might have panic).

Clinical Implications and Conclusion

The current findings have potential implications for recognizing individuals vulnerable to panic based on both their explicit beliefs about the dangerousness of

[6]Thank you to an anonymous reviewer for this suggestion.

anxiety symptoms and their information processing biases. This possibility is particularly promising given recent evidence that these processes may be more malleable than originally believed, and further, that shifting threat biases can have positive implications for both subsequent information processing and mood. The work by Mathews and Mackintosh (2000) demonstrating the experimental induction of interpretation biases, and Mathews and MacLeod's (2002) induction of attentional biases are intriguing examples of how these biases can be used as independent variables to manipulate anxious responding. Similarly, attentional training is already being used successfully to facilitate more objective danger appraisals in anxiety treatment (Wells & Papageorgiou, 1998), and it seems likely that improved understanding of information processing in anxiety will provide us with other novel ways to intervene early with vulnerable individuals and enhance current treatment strategies.

The complex findings from previous investigations of cognitive biases and AS cannot be resolved in a single study, and numerous questions remain about how directly information processing biases constitute vulnerability to panic and anxiety. However, the current results provide clear support for information processing views of panic and suggest that AS is associated with threat interpretations, both in external situations and specific to catastrophic misinterpretations of bodily sensations as predicted by cognitive models (Clark, 1986). In addition, the study provides the first evidence of a panic self-schema and evidence that both automatic and strategic processes can become biased toward threat even in a nonclinical sample. Further, the finding that these biases are associated with AS among individuals who do not yet report any experience with panic suggests that cognitive biases are not simply a by-product or epiphenomenon of the anxious state. With the advent of more sensitive paradigms, we can now look forward to greater insight into longstanding questions about the causal relationship between cognitive biases and emotional dysregulation, and evaluation of whether preferential processing of threat information is in fact critical to the development of anxiety and panic.

APPENDIX

Stroop Word List

Panic/physical threat	Social threat	Positive	Neutral (household)
Collapse	Inept	Applause	Lounge
Tremble	Worthless	Superb	Cushion
Emergency	Hated	Achievement	Furnished
Attack	Humiliated	Excellent	Ornament
Illness	Inferior	Terrific	Shower
Ambulance	Unsuccessful	Delight	Staircase
Tingling	Stupid	Comfort	Lamp
Death	Hopeless	Merry	Mantelpiece
Faint	Ridicule	Confident	Shelves
Choking	Foolish	Enthusiasm	Vase
Sweat	Lonely	Celebration	Chimney
Dizzy	Unfriendly	Praise	Upstairs

IMPLICIT ASSOCIATION TEST WORD LIST

IAT Task 1: Panicked vs. Calm paired with Me vs. Not me

Category label	Stimuli
Panicked	Panicked Scared Anxious Frightened
Calm	Calm Relaxed Serene Tranquil
Me	Me Self I My
Not me	Not me Other Them They

IAT Task 2: Bodily Changes vs. Weather Changes paired with Uncomfortable vs. Alarming

Category label	Stimuli
Bodily changes	Heart rate Pulse Sweat Dizzy
Weather changes	Humid Rain Thunder Hail
Uncomfortable	Uncomfortable Unpleasant Bothersome Annoying
Alarming	Alarming Scary Terrifying Dangerous

ACKNOWLEDGMENTS

The authors are thankful for the research assistance provided by Shannan Smith-Janik, Jessica Ellis, Betsy Hernandez, Nicole Heimann, Sarah Creech, Zach Patberg, and other members of the Cognition and Psychopathology lab at the University of Virginia.

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