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INFORMATION PROCESSING AND PTSD: A REVIEW OF THE EMPIRICAL LITERATURE

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ABSTRACT. *This article reviews a series of studies that have utilized information-processing paradigms with posttraumatic stress disorder (PTSD) populations. The review suggests that pretrauma measures of intelligence (IQ) are predictive of the development of PTSD symptoms following trauma. There is also evidence of impaired performance on standardized tests of memory (independent of IQ) in PTSD populations. PTSD populations are found to exhibit deficits in memory function that may be due to hippocampus damage secondary to excessive neuroendocrine responses to conditioned stimuli. In addition, individuals with PTSD evince an attentional bias towards trauma-related stimuli at postrecognition stages of information processing. The review also includes that there is insufficient evidence to either support, or reject, the theoretical proposition that PTSD patients are sensitive to global valence effects at the earliest stages of information processing relative to traumatized non-PTSD populations. Finally, there is some evidence to suggest that the processes associated with autobiographical memory in PTSD populations are similar to those seen in depression. The implications of these findings for the behavioral and cognitive treatment of PTSD are discussed. Directions for future research with such paradigms are also discussed in light of contemporary information processing theories of PTSD.* © *2000 Elsevier Science Ltd.*

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POSTTRAUMATIC STRESS DISORDER (PTSD) is a syndrome that is characterized by involuntary and intrusive cognitive phenomena. These involuntary cognitive phenomena include: flashbacks, nightmares, and intrusive recollections of the traumatic experience (Kilpatrick & Resnick, 1993). The disorder is also characterized by the allocation of attentional resources towards the recognition of threatening stimuli (Harvey, Bryant, & Rapee, 1996), problems with concentration, and deficits in memory function (Uddo, Vasterling, Brailey, & Sutker, 1993). Given the problems associated with memory processes and attention seen in traumatized populations, it is not surprising that information-processing theories have been proposed to explain the syndrome known as PTSD (e.g., Brewin, Dalgleish, & Joseph, 1996; Chemtob, Roitblat, Hamada, Carlson, & Twentyman, 1988; Foa, Steketee, & Rothbaum, 1989; Litz & Keane, 1989). The past two decades have also seen an increase in the number of theoretical papers that attempt to explain the emotion of anxiety from an information-processing perspective (e.g., Beck & Clark, 1997; Foa & Kozak, 1986). These theoretical accounts of anxiety have relevance to the study of PTSD, as it is currently classified as an anxiety-based disorder by the Diagnostic and Statistical Manual of Mental Disorders-4th Edition (American Psychiatric Association, 1994).

In addition to the publication of these theoretical papers about the etiology and maintenance of PTSD symptoms, there have been a large number of empirical papers that have utilized research paradigms that have their origin in experimental-cognitive-psychology. More specifically, clinical researchers have utilized auditory recognition tasks (McFarlane, Weber, & Clark, 1993; McNally et al., 1987), dichotic listening tasks (Trandel & McNally, 1987), modified Stroop paradigms (Foa, Feske, Murdock, Kozak, & McCarthy, 1991; Thrasher, Dalgleish, & Yule, 1994; Vrana, Roodman, & Beckham, 1995), autobiographical memory paradigms (McNally, Lasko, Macklin, & Pitman, 1995; McNally, Litz, Prassas, Shin, & Weathers 1994), dot-probe paradigms (Bryant & Harvey, 1997), and noise-judgment paradigms (Amir, McNally, & Wiegartz, 1996) to help elucidate the information-processing characteristics associated with PTSD and to test the main tenets of information-processing theories. These experimental paradigms hold promise for the study of information-processing mechanisms associated with anxiety disorders because they are less subject to response bias, and thus, may be more sensitive than paper and pencil self-report measures of cognitive processes (Williams, Mathews, & MacLeod, 1996). In addition to these experimental paradigms, investigators have also examined the relations between PTSD, intelligence, and basic memory functioning in studies that have utilized correlational methods (Macklin et al., 1998; McNally & Shin, 1995; Uddo et al., 1993).

Despite the large number of empirical papers that have been published on these topics, a comprehensive review of this literature has yet to be conducted. In this paper, we summarize the empirical literature on the topic of information processing and PTSD. In the latter half of the paper, we discuss the theoretical implications of the results obtained in the empirical literature and also discuss directions for future research.

We have searched the literature as far back as 1980 (the point at which PTSD became a formal diagnostic entity) for relevant articles. A PSYCLIT review using the topic hearings of PTSD, intelligence, memory, attention, and the aforementioned experimental paradigm names was conducted. In addition, a journal by journal search was conducted for the following journals; *Journal of Abnormal Psychology, Behaviour Research and Therapy, Cognition and Emotion, Cognitive Therapy and Research, Journal of Anxiety Disorders,* and *Journal of Traumatic Stress.*

INTELLIGENCE, BASIC MEMORY FUNCTION, AND PTSD

Intelligence and PTSD

General cognitive ability (intelligence or IQ) has often been correlated with risk of psychopathology. For some disorders, higher IQ is associated with a greater risk for onset of disorder. This is true for obsessive–compulsive disorder (Rachman & Hodgson, 1980) and bipolar II disorder (Donnelly, Murphy, Goodwin, & Waldman, 1982). For other disorders, such as conduct disorder, lower IQ appears to be a risk factor (Moffit, 1993). Since most individuals who are exposed to trauma do not develop PTSD (Kulka et al., 1990), clinical researchers have searched for individual difference variables that can account for the acquisition of PTSD following trauma. Intelligence has been investigated as a possible individual difference variable to account for these findings.

Studies that have directly assessed general cognitive ability through the use of standardized measures of intelligence have found that IQ is negatively correlated with the development of PTSD symptoms. McNally and Shin (1995) found that scores on the Shipley Institute of Living Scale (Zachary, 1991) predicted a statistically significant amount of the variance in PTSD symptoms after controlling for extent of combat exposure and years of education in a sample of Vietnam veterans with varying degrees of PTSD symptoms. In the most well controlled study of the relationship between IQ and PTSD development, Macklin et al. (1998) examined the relationship between pre-trauma measures of IQ, current measures of IQ, and self-reported PTSD symptoms in a sample of Vietnam veterans. Pre-trauma IQ measures were predictive of the development of PTSD after statistically controlling for extent of combat exposure. In addition, current IQ measures were not correlated with PTSD after controlling for pre-combat IQ measures. This finding suggests that lower pre-trauma IQ is predictive of PTSD development, as opposed to an alternative hypothesis that PTSD lowers performance on current measures of IQ because of difficulties with concentration and memory function.

Vasterling, Brailey, Constans, Borges, and Sutker (1997) examined the relationship between PTSD development and IQ in a sample of Operation Desert Storm (ODS) veterans. They compared scores on the Wechsler Adult Intelligence Scale-Revised (WAISR; Wechsler, 1981) across two groups of veterans that were equivalent with respect to variables that might affect IQ. Even though this study employed a retrospective design as in the McNally and Shin (1995) study, it was unique in that it examined a group of veterans who were relatively young and free of psychiatric and medical comorbid problems. Psychiatric and medical problems that can affect performance on tasks of intellectual functioning are often present in samples of Vietnam veterans who as assessed 20–30 years post-trauma (Sutker, Uddo-Crane, & Allain, 1991). The study also employed the WAIS-R as its measure of IQ, thereby allowing for assessment of attention, verbal memory, and visuospatial memory. Despite these differences in sample selection and methodology, Vasterling et al. (1997) also found that veterans who developed PTSD had lower full-scale IQ than those who did not develop PTSD. This difference was not accounted for by differential exposure to trauma. When examining the subtests of the WAIS-R, they found that the two groups did not differ on tasks of attention or visuospatial memory. However, the groups were largely different in their performance on tasks that tap verbal memory. Given the lack of differences on attentional tasks (which are often disrupted by current distress) and the large group differences on measures of verbal memory (thought to tap into more crystallized as-

pects of IQ), the authors of that study tentatively concluded that the differences may have been reflective of cognitive deficits that existed prior to trauma exposure.

In addition to utilizing between-group comparisons based on diagnostic status (i.e., presence or absence of PTSD diagnosis), some of these studies have also examined within-group correlations between measures of IQ and continuous measures of PTSD symptoms. These analyses have revealed moderate–negative correlations between these constructs (McNally & Shin, 1995; Vasterling et al., 1997).

Other studies have indirectly examined the association between PTSD and IQ through a variety of means. Kulka et al. (1990) found that lower levels of educational achievement were predictive of the level of PTSD symptoms in Vietnam veterans exposed to combat. This report did not assess IQ directly; however, IQ is a strong predictor of educational achievement (Herrnstein & Murray, 1994). Thus, the Kulka et al. (1990) data provided indirect evidence of a relation between IQ and the development of PTSD. The correlation between educational achievement and the development of PTSD in Vietnam veterans has been replicated by Green, Grace, Lindy, Gleser, and Leonard (1990). In addition, Watson, Davenport, Anderson, Mendez, and Gearhart (1998) examined the relations between academic performance in both primary and secondary schools and PTSD symptoms among Vietnam War veterans. They found a negative correlation between secondary-school performance (pretrauma) and the presence of PTSD symptoms related to wartime experiences.

Studies that have examined the relationship between military enlistment aptitude tests (e.g., Arithmetic Reasoning subtest of the Armed Forces Qualification Test-AFQT) have found that pre combat-exposure aptitude test scores are negatively correlated with PTSD symptoms (Maier, 1993). Pitman, Orr, Lowenhagen, Macklin, and Altman (1991) found that veterans' scores on the arithmetic subtest of the AFQT were negatively correlated with the development of PTSD following exposure to wartime atrocities. In addition, the Center for Disease Control Vietnam Experiences Study (1988) found that overall scores on the AFQT were predictive of psychological outcome at discharge from the military. These studies also provide indirect evidence of a relationship between IQ and the development of PTSD because the tests used are highly correlated with scores on standardized measures of IQ (Herrnstein & Murray, 1994).

In total, literature that has examined the relationship between IQ and PTSD development reveals two things. First, pretrauma IQ is predictive of PTSD diagnostic status following exposure to trauma (e.g., Macklin et al., 1998; Pitman et al., 1991). This relationship is robust even after controlling for other well established predictors of PTSD such as combat exposure (Macklin et al., 1998). Secondly, there is a negative linear relationship between scores on measures of IQ and measures of PTSD-symptom severity–frequency. The magnitude of this negative correlation tends to be about .35 (McNally & Shin, 1995; Vasterling et al., 1997). We located one report that suggested that these findings might replicate across cultures. Gil, Calev, Greenberg, Kugelmass, and Lerer (1990) found that PTSD patients exposed to a variety of civilian traumas in Jerusalem were of lower intelligence than matched controls, as assessed by the WAIS-R (Wechsler, 1981).

These findings have potential clinical relevance. General cognitive ability appears to be an important individual difference variable that may be predictive of who develops PTSD subsequent to trauma. Since many individuals meet symptomatic criteria for PTSD shortly after trauma and will show remission without intervention (Rothbaum, Foa, Riggs, Murdock, & Walsh, 1992), it is important to establish predictors of

chronic PTSD in order to identify those in need of early intervention; IQ appears to be one such predictor.

The relation between IQ and PTSD may operate through one of several different mechanisms. First, it has been hypothesized that IQ may influence subjective appraisal of threat when confronted with a trauma such that those with lower IQ tend to overestimate the threat value of traumatic situations (Macklin et al., 1998). This interpretation has intuitive appeal since data from longitudinal studies indicate that subjective threat appraisal predicts the development of PTSD diagnostic status and is positively correlated with the severity and frequency of PTSD symptoms (Blanchard et al., 1995; Ehlers, Mayou, & Bryant, 1998).

Secondly, it has been hypothesized that individuals with higher IQ have better cognitive ability to cope with the emotional impact of traumatic experiences (Schnurr, Rosenberg, & Friedman, 1993). This latter model is more consistent with a diathesis-stress explanation for PTSD acquisition, with low-cognitive ability (which leads to poor coping ability) being the diathesis. In fact, the problem-focused coping strategies that have been associated with positive outcome following trauma require verbal-mediation strategies that should be related to IQ (Sutker, Davis, Uddo, & Ditta, 1995; Wolfe, Keane, Kaloupek, Mora, & Wine, 1993).

Finally, individuals with lower IQ tend to have poorer access to mental health resources (Herrnstein & Murray, 1994). Therefore, yet another possible explanation of these findings is that the inflated rates of PTSD among those with low IQ might be due to poor access to behavioral health care. Those who do not have access to such care would not be able to receive early intervention and may be more likely to develop chronic PTSD relative to those who receive early intervention.

The relation between IQ and PTSD is relatively well established in war veteran populations. As noted, this finding is of both theoretical and clinical relevance. This literature would be strengthened however, if the relation was studied more often in non-wartime trauma survivors. In addition, the majority of the papers cited studied veteran populations who were many years post-trauma. Longitudinal studies with acute PTSD populations across a variety of trauma types are needed in order to more fully understand the relationship between IQ and PTSD. We revisit these points in the discussion section of the paper.

Basic Memory Function and PTSD

Basic science researchers have demonstrated that both short-term and long-term stress responses can affect memory function (Quervain, Roozendaal, & McGaugh, 1998). In short, the release of high levels of glucocorticoids during times of actual threat or through repeated exposure to conditioned-fear stimuli can lead to damage in the hippocampus (McEwen, Gould, & Sakai, 1992; Sapolsky, Uno, Rebert, & Finch, 1990; Wooley, Gould, & McEwen, 1990). Decreased hippocampal volume has been demonstrated to produce lasting deficits in short-term memory (see Bremner, Krystal, Southwick, & Charney, 1995). Given that PTSD patients show strong physiological responses to conditioned stimuli (see Blanchard & Buckley, 1999), the finding that similar responses can impair memory function in animals may help to shed light on the etiology of some of the cognitive deficits reported by trauma patients (e.g., problems with short-term memory and difficulties with concentration). We have already noted that IQ differentiates those groups of individuals who develop PTSD from those who do not. Studies that have examined specific memory deficits that may be a conse-

quence of PTSD have often matched comparison groups on measures of full scale IQ in order to control for pre-trauma cognitive differences.

Bremner et al. (1993) found evidence of short-term memory deficits among Vietnam veterans with PTSD relative to veterans without PTSD. Twenty-six Vietnam veterans with PTSD were compared to 15 non-PTSD comparison subjects matched on variables that might affect performance on standardized measures of memory. Despite being equivalent on measures of full scale IQ, the PTSD groups showed deficits in immediate recall and delayed recall on the Wechsler Memory Scale (WMS) (Wechsler, 1987) relative to the comparison group. The PTSD group also showed deficits on total recall, long-term storage, and long-term retrieval of information on the Selective Reminding Test (Hannay & Levin, 1985). This pattern of findings was similar for both verbal and visual memory components of the test. Comparable effects have been found in an independent laboratory. Uddo et al. (1993) found evidence of attentional and both visual and verbal memory deficits on a variety of attentional and memory indices in a group of 16 Vietnam veterans suffering from PTSD relative to a control group of 15 National Guard members.

Bremner, Randall, Scott, Capelli, et al. (1995) also found evidence of impairment in short-term verbal memory among adult survivors of childhood abuse. Utilizing WMS (Wechsler, 1987), the authors compared two samples of individuals who were matched on variables that might affect performance on tests of memory. The only difference between the groups was exposure to childhood trauma. The authors replicated the effect of deficits in verbal memory that they have found in the wartime veteran population, but failed to find differences in visual memory. The magnitude of the verbal memory deficits were positively correlated with the severity of the stress exposure as a child.

Yehuda et al. (1995) found evidence of very specific memory deficits in Vietnam Veterans suffering from PTSD. They compared 20 PTSD veterans to 12 matched controls, on performance on the California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1987). There were no differences between the groups on measures of attention and initial encoding of information. However, the two groups differed substantially on percentage recall of stimuli after both short and long time periods. The PTSD group showed impaired ability to accurately recall what they had been presented during the testing period. Vasterling, Brailey, Constans, and Sutker (1998) also found deficits in short-term memory in ODS veterans diagnosed with PTSD relative to a matched group of ODS veterans without PTSD. In contrast, to Yehuda et al.'s findings, Vasterling et al. (1998) also found evidence of deficits on tasks that assess attentional processes.

Gil et al. (1990) found evidence that these findings may replicate across cultures. They compared the performance of Israeli PTSD patients to a psychiatric control group and a normal control group on standardized tests of memory. The two patient groups showed impaired performance on measures of verbal memory, visual memory, and long-term memory relative to the nonpsychiatric control group. However, the two patient groups did not differ from each other, suggesting that distress from psychopathology may account for the effects, rather than something specific to PTSD.

A series of studies conducted by Sutker and colleagues demonstrated that former prisoners of war (POWs) show marked deficits in memory functioning. The association between being a POW and developing PTSD is quite high (Sutker, Allain, & Winstead, 1992). However, determining the nature of memory dysfunction in such samples is difficult given the severe physical problems that were associated with being a

POW. Prisoners of war were often the victims of severe physical torture and malnutrition. A sizable number of captives lost up to 35% of their body weight (Sutker, Vasterling, Brailey, & Allain, 1995). Such biological insult can impair cognitive functioning (Sutker, Allain, Johnson, & Butters, 1992). Therefore, although this series of studies has demonstrated an impressive number of replications showing deficits of cognitive functioning (Sutker, Allain, & Winstead, 1992; Sutker, Galina, West, & Allain, 1990; Sutker, Winstead, Galina, & Allain, 1991), disentangling the effects of PTSD from biological insult is difficult. A more recent report from this group indicates that PTSD and biological insult may independently contribute to the processes of memory, attention, and executive functioning (Sutker, Vasterling, et al., 1995). However, those results must be interpreted cautiously given the aforementioned issues associated with utilizing POW samples.

In summary, there is substantial evidence that PTSD patients show deficits in memory for trauma-neutral information. The effect has been replicated across trauma types and laboratories. What is not clear is the stage of processing at which these memory deficits occur. Some studies find deficits in verbal memory in the absence of deficits on tasks of attention (e.g., Yehuda et al., 1995). Findings such as these suggest that the problems with memory may be at the retrieval stage of processing. Golier et al. (1997) recently found evidence to support this interpretation. They examined performance on a task of sustained attention in combat-related PTSD and found no impairment in sustained attention, as measured by the Continuous Performance Test-Identical Pairs Version relative to a matched group of non-PTSD subjects. This finding would also suggest that the deficits may be a function of problems at the retrieval stage of memory function rather than the encoding stage. This is consistent with the previously cited memory studies that have utilized both attentional and memorial tasks and found primarily verbal memory deficits in the absence of attentional disturbance (e.g., Vasterling et al., 1997). However, other studies have found evidence of both impaired attention and short-term memory (Vasterling et al., 1998). The inconsistency in results may be due to methodological issues. This point will be revisited in the discussion section of the paper.

The mechanisms by which these deficits occur may be explained by reference to the basic science literature. Deficits in retrieval for previously learned information has been associated with damage to the hippocampus in animal studies (Sapolsky et al., 1990). Excessive glucocorticoid responses upon exposure to single aversive events or through repeated exposures to conditioned fear stimuli are thought to account for the hippocampal damage in these studies (see Bremner, Krystal, et al., 1995). Individuals with PTSD show heightened physiological responses when exposed to conditioned stimuli (Blanchard & Buckley, 1999). Since elevated glucocorticoid response is a biological component of anxiety reactions that are also characterized by sympathetic nervous system arousal (Sapolsky et al., 1990), one could hypothesize that those diagnosed with PTSD will have memory deficits secondary to hippocampal damage. Recent evidence suggests that reduced hippocampal volume is associated with chronic PTSD. Bremner, Randall, Scott, Bronen, et al. (1995) found decreased right hippocampal volume in 26 Vietnam-era PTSD patients relative to 22 comparison subjects. The two groups did not differ with respect to other variables known to cause hippocampal damage (e.g., alcohol abuse). The PTSD group showed an 8% reduction in right hippocampal volume and a 4% reduction in left hippocampal volume relative to the control group. There were no other deficits measured in associated brain regions. Within the PTSD group, there was a positive correlation between hippocampal vol-

ume and deficits in memory function as measured by the WMS. In a follow-up study, Bremner et al. (1997) found evidence of reduced left hippocampal volume (12% reduction) in a sample of adult survivors of childhood abuse. However, in this study, hippocampal volume did not correlate with performance on standardized tests of memory within the PTSD group.

While it is clear that there are memory deficits associated with PTSD, the mechanisms by which this deficit arises is still under question. Preliminary evidence suggests that PTSD may be associated with memory deficits (independent of pretrauma IQ) as a function of chronic activation of neuroendocrine responses upon exposure to conditioned stimuli. Given the small number of studies in this area, these conclusions about the mechanisms of memory deficits are somewhat tentative. We will return to the limitations of these studies and the possible implications of these findings in the discussion section of the paper.

INFORMATION PROCESSING OF THREAT STIMULI

The research in this area has drawn heavily on experimental paradigms and concepts that have their origin in cognitive psychology. Prior to reviewing the experimental literature in this area, brief descriptions of these concepts are outlined here to assist the reader so that the summary of the research to follow may be more easily interpreted. The nature of the experimental paradigms are also laid out in detail in the following sections.

Attention Resources

Attention refers to the resources available to an individual that allows him/her to engage in a task(s) that requires some executive control (Ashcraft, 1994). We have a limited capacity to process information and engage in multiple tasks at any given moment. The more complex the task at hand, there will be less in attentional resources that will be available for concurrent tasks. The prototypical example of a task that initially requires a great amount of attention initially and with extensive practice requires very little attention is driving a car. When initially learning to drive, the novice driver has to remember which foot to use for the brake and which to use for the clutch. Trying to adjust the radio while driving at this stage of learning would surely result in an accident because nearly all of the driver's attention is needed to successfully navigate the car through traffic. However, with time, the behaviors associated with driving a car become so well learned that they require much less attention on the part of the driver. Thus, for the accomplished driver, adjusting the radio while traveling at 40 mph is a much more manageable task because the driver has more in the way of attentional resources that can be allocated toward this second task. Much of the work that is cited in this section of the paper makes reference to PTSD patients allocating such attentional resources toward threatening stimuli and behavioral responses to cope with those threatening stimuli.

Automatic vs. Strategic Processing

The way people process information has generally been viewed as involving two broad classifications of processes: automatic and strategic processes. Automatic processes

have traditionally been defined as those that occur without conscious effort, are involuntary, and capacity free (i.e., do not require additional resources that would detract from performance on a concurrent task). By way of contrast, strategic processing has been defined as involving conscious-controlled effort, and being capacity limited in nature (Posner & Snyder, 1975).

Currently, there is some debate as to whether automatic and strategic processes are best conceptualized as independent constructs, or as two points on a unitary construct that is dimensional with respect to volition, attention, and effort (Ashcraft, 1994). In addition, there is some debate as to whether there is a single type of automatic processing as defined above, as opposed to multiple types of automatic processing (Bargh, 1989).[1] Finally, there is some question as to whether the paradigms alluded to earlier in this paper can assess automatic and strategic processes independently of each other (Jacoby, 1991). An elaboration of these topics is beyond the scope of this paper, and thus, they will not be discussed further. Interested readers are referred to Jacoby (1991) and Johnston and Dark (1986).

As it is relevant to this paper, we refer to automatic processes as those that are involuntary and not available to conscious recognition, but not necessarily capacity free. As discussed by McNally (1995), it is not the case that processes studied in clinical populations fit neatly into either purely automatic or purely automatic or purely strategic processes. Rather, they generally contain some elements of both automatic and strategic processes as currently defined by cognitive psychology. Many of the clinical symptoms of PTSD are involuntary but not necessarily capacity free. Stated another way, the presence of these symptoms tends to detract attention from concurrent tasks (Bryant & Harvey, 1997). Thus, it appears that viewing automatic processes as those which are involuntary and unavailable to conscious recognition is most useful in the study of PTSD symptoms. We will use this definition throughout the paper. With respect to strategic processes, we refer to the paradigms that require subjects to deliberately search memory (e.g., autobiographical memory tasks) as involving strategic processing.

Automatic Processing of Threat Stimuli

Many theories of anxiety propose that at the earliest stages of information processing, individuals with an anxiety disorder are sensitive to global valence effects (i.e., positive vs. negative, Beck & Clark, 1997; Mathews & MacLeod, 1994; McNally, 1995). More specifically, it is proposed that anxiety disorder patients process negative information more quickly than neutral or positively valenced stimuli, whereas nonanxiety subjects do not. The adaptiveness of such an information-processing system has much appeal from an evolutionary perspective and may be best captured in quote from MacLeod and McLaughlin (1995): "For example, it may well be more adaptive to ascertain the physical location of and trajectory of an attacking predator's teeth and claws than to discriminate the particular genus to which that species belongs" (p. 12). From this perspective, the distinction between normal and pathological anxiety is a matter of degree rather than kind because of the adaptive role that fear plays in the survival of the organism.

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[1]For a more detailed discussion of the theoretical and clinical implications of the automaticity debate as it pertains to information processing among anxiety disordered patients, see McNally (1995).

A number of studies have used either facilitation or interference paradigms to determine whether negatively valenced material is preferentially processed, relative to neutral or positively valenced stimuli, by anxiety disorder populations. Facilitation paradigms are those which show how a tendency to attend selectively to emotionally relevant stimuli may facilitate performance on certain tasks that benefit from the processing of such information. Conversely, interference paradigms show how performance can suffer as a result of selective attention to emotionally relevant stimuli on those tasks where the processing of such information would be disruptive. According to the aforementioned theoretical models, one would expect that upon early registration of a threatening stimulus, those with clinical anxiety disorders should show altered processing (as indexed by either facilitation or interference effects) relative to when they are presented with neutral or positively valenced stimuli. Moreover, this pattern of findings should not be present in nonanxiety control groups.

A series of studies have used the emotional analogue of the Stroop task (Stroop, 1935) with subliminal presentation of stimuli to evaluate such hypotheses. The standard Stroop paradigm requires study subjects to name the color of various semantic stimuli (e.g., "XXXX" printed in the color blue or "RED" printed in the color green). Vocal-response latency is the dependent variable in these studies. In standard Stroop studies, participants show delayed color naming of antagonistic color words (e.g., the word "RED" printed in the color blue) relative to non-words or color-congruent words. It has been proposed that the semantic aspects of the stimuli detract some attention from the primary task of color naming.

Clinical researchers have adopted this paradigm to study the attentional processes of anxiety disorder patients. In clinical settings, patients are presented with words that are of central concern to their clinical status (e.g., the words *heart attack* for an individual with panic disorder), as well as words from other semantic categories. If subjects show delayed vocal response latencies towards one word category (relative to the other word categories), then it is hypothesized that the content of those words are preferentially capturing attention and resulting in decreased performance on the primary task of color naming.

The subliminal presentation Stroop paradigm is an interference paradigm similar to that just described, except that the word stimuli are presented too quickly for conscious recognition by the participant (e.g., 16 ms). Immediately following the word stimuli, is a string of random letters composed of the same number of letters and in the same location as the original word stimulus. These random strings of letters are referred to as masks because they cover the same exact position on the computer screen as the initial stimulus. It is the task of the participant to name the color of the mask as quickly as possible. By presenting the stimuli in such a short time period, it allows one to examine the earliest stages of information processing (automatic processing). If anxiety patients show differential processing of negatively valenced threat material at a prerecognition level of information processing relative to neutral material, one could hypothesize that such studies should demonstrate that patients who have an anxiety disorder will show differential response latencies to threat material relative to neutral or positively valenced material. By way of contrast, the nonanxiety control groups in such studies should not show differential response latencies color naming as a function of word type.

With respect to preconscious processing of threat cues in PTSD, McNally, Amir, and Lipke (1996) compared Vietnam combat veterans with PTSD to Vietnam combat veterans without PTSD on vocal response latencies for trauma words, positive words, neu-

tral words, and color words. They found no evidence for preferential processing of threat cues in the PTSD group. In a study with a motor vehicle accident (MVA)-related PTSD sample, an Australian research team found evidence for preconscious processing of threat material using a modified Stroop paradigm. Harvey et al. (1996) found delayed vocal response latencies for trauma-related threat stimuli, relative to neutral stimuli, in a MVA-related PTSD group but not in a MVA non-PTSD group or a non-MVA control group. In addition, in a follow-up study, they have obtained similar results using a modified dot-probe paradigm (Bryant & Harvey, 1997). In their follow-up study, Bryant and Harvey compared the response times of MVA-PTSD patients, subclinical PTSD, and non-PTSD MVA victims in response to high threat words, moderate threat words, positive words, and neutral words in a modified dot-probe experiment. In this experiment, participants view target word stimuli that are presented at different locations on the computer screen throughout the course of the experiment. Sometimes the target words are located adjacent to threat words while at other times they are located distant from threat words. It is the task of the participant to give an appropriate response to the target word (in this case, left and right) as quickly as possible. Thus, it is a facilitation paradigm that would index a processing bias towards threat material if participants with PTSD would be faster to respond to target words when they are located adjacent to threat words as opposed to when they are located distant from threat words. Bryant and Harvey (1997) found a facilitation effect for threat words, relative to neutral words in the PTSD group, suggesting an involuntary processing bias towards disorder-specific threat stimuli. This facilitation effect was not present in the two comparison groups.

The auditory recognition task has also been used to assess automatic processing of information. This task requires subjects to listen to a binaural audiotape consisting of white noise with intermittent target words of different emotional valence played over the white noise. Subjects are instructed to identify words whenever they think a target occurred. If patients with PTSD preferentially scan the environment for threatening stimuli (involuntarily), then they should identify more target words that are negatively valenced, trauma specific, or both, relative to control groups. They should also demonstrate a within-group effect of identifying more trauma relevant words than non-trauma words.

Utilizing the auditory recognition task, McNally et al. (1987), exposed 10 PTSD combat veterans, 10 non-PTSD combat veterans, and 10 noncombat veterans to Vietnam stress words, phonetically similar words (e.g., firefight vs. firefly) and neutral words while collecting concurrent skin conductance (SC) responses. All three groups detected more combat stress words than neutral words. However, only the PTSD group showed elevated SC response in conjunction with identification of combat stress words.

Trandel and McNally (1987) used a similar task to assess automatic processing of threat stimuli in 15 Vietnam veterans suffering from PTSD and 15 Vietnam veterans with a primary diagnosis of alcohol dependence or no psychopathology at all. To prevent momentary shifts in attention to the unattended channel, they synchronized the timing of the stimuli occurring in both channels. Thus, this study was a more stringent test of the hypothesis that PTSD subjects automatically scan the environment for threatening stimuli. They obtained results inconsistent with this hypothesis. The number of shadowing errors and magnitude of SC responses did not differ across groups as a function of word type. This led the authors of that study to conclude that PTSD subjects do not automatically encode auditory stimuli that are trauma relevant.

Summary of Automatic Processing Studies

Clearly, drawing any conclusions from the use of auditory paradigms is not warranted at this time. To date, only two studies have been conducted (each with a different methodology); differential results were obtained. Replication across trauma populations is needed before any conclusions may be drawn regarding the processing of trauma relevant auditory stimuli.

Data from the subliminal Stroop paradigms and dot-probe paradigms are mixed. Bryant and colleagues found evidence for prerecognition processing of threat material with MVA-related PTSD (e.g., Harvey et al., 1996) while McNally and colleagues failed to find such an effect with Vietnam veterans (e.g., Trandel & McNally, 1987). Drawing conclusions from these studies is complicated by the fact that the cross laboratory findings are confounded by trauma type. In addition, the sheer number of studies is small, as are the respective sample sizes of these studies. We will revisit the importance of investigating the possibility of a prerecognition processing bias of threat stimuli in PTSD in the discussion section of the paper.

Strategic Processing of Threat Stimuli-Stroop Paradigms

By far, the most widely used experimental paradigm to study the information-processing mechanisms associated with PTSD is the modified Stroop paradigm with supraliminal presentation times. Supraliminal presentation involves the presentation of stimuli without a mask, as described earlier. Since the stimuli are not degraded upon presentation, it taps both automatic and strategic aspects of information processing, whereas the subliminal presentation studies are thought to tap automatic processing exclusively. This is the only information-processing paradigm whose effects have been systematically replicated across trauma types and laboratories.

Since many cognitive theories of anxiety and PTSD propose that subjects with anxiety preferentially allocate resources to threatening stimuli, the Stroop paradigm has proved to be a useful tool in testing these hypotheses. If PTSD subjects allocate attentional resources to trauma-specific threatening stimuli to a greater extent than nonthreatening stimuli, two predictions can be made when using the modified Stroop paradigm with PTSD subjects and comparable control groups. First, when asked to name the color of trauma-specific threat words, PTSD subjects will respond slower than when asked to color name nontrauma words. Secondly, this effect should be disorder specific. That is subjects suffering from PTSD should display this interference effect towards trauma-threat words as opposed to traumatized non-PTSD populations and other anxiety disorder groups (e.g., panic), who should not. We next present the findings of the modified Stroop task by trauma type.

Two reports were located that used the modified Stroop task with rape victims. Foa et al. (1991) presented 15 rape victims with PTSD, 13 rape victims without PTSD, and 16 nontraumatized controls with four types of words: rape-specific threat words, general threat words, neutral words, and non words. Results showed that rape victims with PTSD took longer to respond to rape-specific threat words relative to the other three categories. The two control groups did not show differential responding as a function of word category. Cassiday, McNally, and Zeitlin (1992) replicated this effect by comparing vocal response latencies to various types of stimuli across three groups of subjects: 12 rape victims with PTSD to 12 non-PTSD rape victims and 12 nontraumatized

controls. Those with PTSD showed delayed vocal response latencies for the PTSD threat words, while the two control groups did not.

Three reports for transportation accident related PTSD and Stroop interference effects were located. Bryant and Harvey (1995) exposed 15 MVA-related PTSD subjects, 15 MVA victims who developed specific phobia of driving, and 15 low anxiety subjects to strong threat words (MVA related), positive words, and neutral words. PTSD subjects showed interference for strong threat words to a greater extent than those in the phobic or low anxiety group. The two control groups did not show differential vocal response latencies as a function of word group. In a follow-up experiment, Harvey et al. (1996) compared 20 MVA-PTSD subjects to 20 MVA survivors without PTSD and 20 non-MVA controls on vocal response latencies using 12 threat and 12 neutral words. The MVA-PTSD group showed more interference on threat words than neutral words. The two control groups did not show this pattern of interference. In fact, the non-MVA group responded more slowly to neutral words than threat words. Thrasher et al. (1994) replicated these findings utilizing PTSD and non-PTSD groups exposed to a ferry boat disaster.

We located five reports of Stroop interference and Vietnam veterans suffering from PTSD. McNally, Kaspi, Riemann, and Zeitlin (1990) compared 15 Vietnam veterans with PTSD to 15 Vietnam veterans without PTSD on Stroop interference related to neutral, positive, PTSD, and obsessional words. Controls showed no difference in response latency scores as a function of word type, while the PTSD group showed marked increases in response latency for PTSD words relative to other word categories. Kaspi, McNally, and Amir (1995) replicated this effect using 30 Vietnam veteran with PTSD and 30 Vietnam veterans without PTSD as a control group. The stimulus words were slightly different from McNally et al. (1990), but the effect was the same, PTSD subjects exhibited delayed response for PTSD words relative to other word groups while the control groups did not show this pattern. McNally's group replicated these findings again in later studies (McNally et al., 1996; McNally, English, & Lipke, 1993). The effects found by McNally's group have also been replicated in an independent laboratory by Vrana et al. (1995).

Litz et al. (1996) compared the vocal response latencies of both trauma-specific and nontrauma threat words across three diagnostic groups: a group of Vietnam veterans suffering from PTSD, a well-adjusted control group of veterans from the Vietnam era, and a veteran group suffering from an Axis I disorder other than PTSD. The authors of this study used four threat word categories: PTSD-high and low threat, and education-high and low threat words: The PTSD group showed delayed color naming of high threat words (collapsed across category); however, there was no evidence of trauma-specific interference effects. Thus, in this study the PTSD group evinced a global valence effect rather than a trauma-specific effect. It should be noted however, that this study did not employ a neutral word control category. Thus, it differs from the other modified Stroop studies alluded to in this paper that generally compute vocal response delay by subtracting neutral word color naming latency from threat word color naming latency.

The Stroop interference effects noted in these studies are generally viewed as evidence for an attentional bias towards threat words. It is proposed that the semantic aspects of the threat words detract attention from the primary task of color naming the words. Others have proposed that the interference effects could be a function of cognitive avoidance of stimuli as opposed to attentional bias (Ruiter & Brosschot, 1994). However, studies that follow Stroop tasks with implicit memory tests show a facilitation

effect for words that produced interference relative to word items that did not (e.g., Kaspi et al., 1995). Thus, if subjects were actively avoiding stimuli during Stroop tasks, then one would expect a decrement in performance on subsequent implicit memory tests. Moreover, recent work with dot-probe paradigms and PTSD patients (Bryant & Harvey, 1997), as well as dot-probe studies with social phobia (Asmundson & Stein, 1994), and panic disorder populations (Asmundson, Sandler, Wilson, & Walker, 1992) have shown that these various anxiety disorder populations show a facilitation of color naming patches that replace the location of threat cues, relative to the color naming of neutral cues. This is also consistent with an attentional bias interpretation of these findings because the dot-probe is a more direct measure of visual attention than the Stroop paradigm (Bryant & Harvey, 1997).

The aforementioned studies suggest that individuals with PTSD evince an attentional bias towards trauma relevant stimuli at a postrecognition stage of information processing. That is to say, patients in these studies preferentially allocate attention towards threatening stimuli at later stages of information processing. These biases in attention for disorder specific information (e.g., somatic concerns for panic disorder patients vs. trauma threat words for PTSD patients) should vary across diagnostic categories in higher order processing. What keeps these findings from being more conclusive is that many of the studies lacked an anxiety disorder control group and/or included only one type of threat word category, disorder-specific threat words. Thus, without multiple threat word categories, it is not possible to know whether the bias is relevant for all negatively valenced material or just disorder specific threat material. Secondly, without the inclusion of multiple anxiety disorder groups for comparison purposes, we cannot know if the effects are truly *disorder-specific.* There is some evidence that PTSD groups are slower than nonanxiety controls to color name threat words; however, few studies have included multiple anxiety disorder groups. Without direct comparisons across the various diagnostic categories, one cannot know if all anxiety disorder populations are similarly sensitive to global valence effects at the early stage of information processing and content specific effects at the later stages of processing.

Memory Bias for Trauma-Related Stimuli

Information-processing accounts of PTSD propose that representations of traumatic experiences are organized into propositional fear structures that reside in memory (Foa et al., 1989). These structures are thought to contain information about the meaning of threatening stimuli, overt behavioral impulses to fight or flee the threatening stimuli, and physiological responding as part of a preparatory response (Foa et al., 1989). These fear networks are thought to reside in partially primed states and may be responsible for the re-experiencing symptoms of PTSD if their level of activation is pushed above the threshold of conscious awareness. Since studies from cognitive psychology have shown that performance on tasks that tap memory for novel material is facilitated if the material is preceded by something that primes its representation in memory (Marcel, 1983), it is reasonable to hypothesize that PTSD patients will show facilitated recall for trauma-relevant information during implicit or explicit memory tasks. By utilizing tests of implicit and explicit memory, it may be possible to examine the extent to which these theoretical predictions are true.

Amir et al. (1996) utilized a noise judgment task to investigate implicit memory bias in PTSD. This paradigm involves having subjects listen to sentences of different threat con-

tent (in this case, Vietnam specific vs. neutral sentences) in the first part of the experiment. Following this, subjects then hear a mix of the previously presented sentences with new sentences accompanied by background noise of different decibel levels. It is the task of the subjects to rate the level of the background noise accompanying the sentences on a Likert-type scale. Implicit memory for trauma-relevant information is revealed if PTSD patients rate the background noise accompanying previously presented trauma sentences as lower than previously presented neutral sentences. This pattern of findings should not be present in the non-PTSD group. At the highest decibel levels rated (64 DB), Amir et al. (1996) found evidence for implicit memory bias towards disorder specific threat stimuli.

Two of the modified-Stroop studies cited earlier followed the Stroop task with free recall and recognition tasks of the semantic stimuli. The findings in both studies showed that PTSD patients recalled more trauma-related stimuli relative to other stimulus categories. This facilitation effect for trauma-related words was not present in the comparison groups in either study (Kaspi et al., 1995; Vrana et al., 1995).

The findings of a facilitation effect on memory tasks that involve trauma-relevant stimuli is interesting given that on standardized tests of memory (e.g., WMS), PTSD subjects show decrements in short-term and long-term memory relative to comparable non-PTSD populations (Bremner et al., 1993; Uddo et al., 1993). This pattern of findings suggests that when threat stimuli are present, individuals with PTSD evince an attentional bias towards the recognition of those threatening stimuli that may disrupt the processing of neutral or positively valenced stimuli.

Autobiographical Memory

To further investigate memory processes associated with PTSD, McNally et al. (1994) utilized an autobiographical memory paradigm with Vietnam veterans suffering from PTSD. Within this paradigm, subjects are presented with words (one at time) and asked to identify a specific personal memory associated with the word. The words are generally positively valenced, negatively valenced, or neutral. This paradigm has also been used to study memory bias associated with depressive disorders (Brittlebank, Scott, Williams, & Ferrier, 1993). It has been shown that depressed patients have difficulty identifying specific personal memories in response to positively valenced cues. Rather, they tend to generate overgeneral memories in response to these cues. It has been suggested that this overgenerality of memory helps maintain depressive disorders because if patients cannot retrieve specific positive memories or attributes of themselves, they may not be able to alter general negative schema about themselves (Beck, Rush, Shaw, & Emery, 1979). Given the high degree of overlap between the symptoms of PTSD and the clinical symptoms of depression (Blanchard, Buckley, Hickling, & Taylor, 1998), this type of paradigm may hold promise in the search for identifying some of the strategic information processing mechanisms associated with chronic PTSD.

McNally et al. (1994) compared Vietnam veterans with PTSD (n = 39) to Vietnam veterans with a psychiatric disorder other than PTSD (n = 20) and to a well-adjusted control group (n = 23). Half of the subjects in each group were emotionally primed by viewing a combat relevant videotape. The other half viewed a neutral tape. Following the priming, subjects completed the autobiographical memory task. Results showed that the PTSD group was characterized by a tendency towards overgeneral memory retrieval in response to positive cues, much the same way depressive patients are. The result for positive cues was markedly increased for those who viewed the combat relevant prime tape as opposed to those who viewed the neutral prime. Overgen-

erality for negative memories was unchanged by the priming condition. Moreover, the overgenerality among the PTSD group was greater for neutral and positive material relative to negative words. Finally, the PTSD had a greater tendency towards overgenerality relative to the psychiatric and well-adjusted controls. This interesting study suggests that emotional numbing associated with PTSD may be governed by the same strategic processes as those involved with major depression.

In a similar experiment, McNally et al. (1995) compared Vietnam veterans with PTSD ($n = 19$) to veterans without PTSD ($n = 13$) on a measure of overgenerality of autobiographical memory in response to negative or positive cues. The results of this study were less clear than those of McNally et al. (1994). Overall, there was no group difference in overgenerality. However, consistent with the hypothesis that overgenerality should be greater for the positive words in PTSD subjects relative to control subjects, planned comparisons substantiated this a priori hypothesized effect, despite the nonsignificant group × cue type interaction.

Thus far, this article has covered numerous studies that have examined both pre- and post-trauma cognitive functioning in relation to PTSD. We have organized the Discussion section of the article around questions within the topic areas outlined earlier. We offer directions for future research in each area of interest.

DISCUSSION

Does Pre-Trauma IQ Predict PTSD?

The answer to this question appears to be yes. Studies that have examined pre-trauma indices of intelligence have found that IQ is predictive of both diagnostic status and the number–intensity of PTSD symptoms (Macklin et al., 1998). The strength of this negative correlation is moderate; on the order of .35 (McNally & Shin, 1995; Vasterling et al., 1997). The effect is robust even after controlling for well-known predictors of PTSD and has been replicated across laboratories.

What remains to be studied is the way in which IQ and PTSD interact. It seems likely that a variety of variables might mediate the relationship between PTSD and IQ. Future studies with longitudinal designs may focus on a number of different variables to examine the nature of this relationship.

Longitudinal studies that examine the relations between IQ, threat appraisal at the time of trauma, access to health care, and coping style will help to elucidate the mechanisms by which these variables interact. If the relation is mediated by threat appraisal, which has been shown to be predictive of PTSD (Blanchard et al., 1995; Ehlers et al., 1998), cognitive strategies aimed at catastrophic misinterpretation of life events may be a needed element of treatment when working with traumatized individuals (Beck et al., 1979). If on the other hand, the relationship is mediated by differences in coping style (Schnurr et al., 1993), then interventions with a focus on problem-focused strategies would be indicated. Finally, if the relationship is mediated by access to third-party coverage of health care, disaster-response health care professionals would want to target individuals who do not have access to professional services for early intervention.

Is PTSD Associated with Memory Dysfunction?

Nearly every study that has examined memory functioning in PTSD samples has found evidence of deficits. The majority of the studies find evidence of deficits in ver-

bal memory (e.g., Yehuda et al., 1995). However, fewer studies find deficits in tasks of attention and visuospatial memory (Vasterling et al., 1998). Such a pattern of findings is consistent with the interpretation that the observed memory deficits are associated with problems at the retrieval stage of memorial processing. It should be noted, however, that part of the difficulty in interpreting this literature is the fact that some studies utilized only tasks of verbal memory, others only tasks of attention, and yet others have assessed both. The strongest way to disentangle these effects would be to assess both in the same sample. Studies that have taken this approach are somewhat mixed (Vasterling et al., 1997, 1998). At this point in time, the evidence is not definitive, but consistent with the notion that PTSD patients evince verbal memory deficits that are due to deficits at the retrieval stage of processing. Future studies would benefit by assessing the domains in attention, verbal memory, and visuospatial memory in the same sample in order to best ascertain at what stage of processing these deficits occur.

Preliminary evidence also suggests that the deficits may be a function of hippocampal damage. The studies that have examined this issue have utilized samples that were many years posttrauma. The animal literature suggests that damage to the hippocampus can occur upon exposure to an extremely aversive stimulus or through repeated exposure to conditioned-fear stimuli. Since traumatized individuals without chronic PTSD do not show memory deficits (Vasterling et al., 1998), it is unlikely that hippocampal damage occurs secondary to glucocorticoid responses at the time of trauma. Prospective studies that follow acute PTSD patients who develop chronic PTSD may help to shed light on neuroendoctrine changes as well as neuroanatomical changes that might coincide with deficits in memory function. The literature that has examined the neuroanatomical correlates of memory deficits have done so with populations that are many years posttrauma (Bremner, Randall, Scott, Bronen, et al., 1995). It is unknown at what point in time posttrauma memory deficits begin to emerge.

Is PTSD Associated with Automatic Processing of Threat Stimuli?

The finding, or lack thereof, of a preconscious–recognition information-processing bias is potentially important from a treatment perspective. McNally (1995) suggested that if anxiety patients are characterized by such an automatic processing bias, exposure-based therapies may be more appropriate than cognitive therapy. Cognitive therapy is designed to help patients exert control over voluntary cognitive functions (Beck et al., 1979). Thus, if anxiety patients suffer in part due to this automatic processing of threat stimuli, volitional cognitive therapy strategies may be ineffective. Recent work by Mogg and colleagues suggested that such an automatic processing bias may exist with groups diagnosed with generalized anxiety or those high in trait anxiety (Mogg, Bradley, Williams, & Mathews, 1993; Mogg, Kentish, & Bradley, 1993).

With respect to PTSD,the auditory paradigms employed by McNally et al. (1987) and Trandel and McNally (1987) were conducted to evaluate automatic processing biases. These two studies produced conflicting results. McNally et al.'s (1987) results on the skin conductance data suggested that the emotional response to threatening stimuli can occur automatically. However, this study did not have a word group that was negatively valenced but not disorder specific. Thus, the extent to which this PTSD group was reacting to the emotionality of the words or the content specificity of them is unknown. Trandel and McNally (1987) included such a word condition and they did not find evidence of automatic processing of threatening stimuli. Clearly, the use of auditory paradigms with PTSD populations to study automatic processes has been under researched.

The implicit memory studies reviewed suggested that PTSD subjects involuntarily encode trauma-relevant information (Amir et al., 1996; Kaspi et al., 1995; Vrana et al., 1995). These results would also seem to suggest that the processing of such information is sensitive to trauma-specific stimuli rather than global valence effects. However, the design problems alluded to earlier in this paper preclude the interpretation of these studies from being definitive.

Stronger tests of the automaticity hypothesis have been conducted by Harvey et al. (1996) and McNally and Amir (1996). Both of these studies presented PTSD subjects with subliminal as well as supraliminal threat words in computerized Stroop experiments. The subliminal presentation of the Stroop should tap automatic processing exclusively, since the presentation of the stimuli is too brief for recognition. Harvey et al. (1996) found that PTSD subjects respond to disorder-specific threat information at a prerecognition level of information processing. In a follow-up experiment, Bryant and Harvey (1997) found similar effects in a dot-probe detection task. McNally and Amir utilized a supraliminal–subliminal Stroop paradigm and found no evidence for prerecognition processing of threatening information. The discrepancy between the McNally and Amir (1996) study and the previous two may be a function of lack of power, or the fact that the McNally and Amir (1996) study was conducted on a population that was 20 years posttrauma, whereas the Harvey et al. (1996) and Bryant and Harvey (1997) studies were conducted on populations that had suffered the trauma (MVAs) only weeks to months earlier. Nonetheless, there is some limited evidence that PTSD subjects preferentially process threatening stimuli at a prerecognition level of information processing. However, it appears that this bias in automatic processing may be sensitive to disorder-specific threat material. It appears that the most useful paradigms used to date to answer this question may be the subliminal stimulus presentation studies (subliminal Stroop paradigms). Two of the three experiments that utilized this subliminal Stroop paradigm illustrate interference effects associated for trauma-relevant stimuli associated with PTSD.

Unfortunately, the literature is not at such a juncture that definitive conclusions can be drawn about such processes in PTSD populations (either through meta-analysis or narrative review). Clearly, there is a need for investigation into the theoretically driven hypothesis that PTSD patients should evince an involuntary processing bias of threat-related material. Given the relatively small effect size of such processes in the studies conducted to date, future studies should pay particularly close attention to issues of power and sample size. Moreover, systematic replication of effects across trauma types would be a welcome addition to the literature. Future studies need to employ negatively valenced threat stimuli that are both disorder specific and nonspecific. This design factor, in addition to the inclusion of anxiety disorder comparison groups, should allow for rigorous tests of these hypotheses.

Do Individuals with PTSD Show Attentional Bias Towards Trauma-Related Stimuli?

The numerous supraliminal Stroop studies support the hypothesis that there are disorder-specific effects that may be partially a function of strategic processing. There is some debate as to the extent to which the supraliminal Stroop effects are governed by strategic or automatic processes (Jacoby, 1991). However, given the inconsistent findings in the Stroop studies with subliminal presentation times and the very reliable findings among those with supraliminal presentation times, it is likely that the effects in these studies are due largely to strategic processes.

The delayed vocal responses towards trauma-related stimuli interference effects on the modified Stroop seen in PTSD populations tends to be greater than those evinced by other anxiety disorder groups (Williams et al., 1996). Whether this interference effect is a function of attentional bias or cognitive avoidance is a question of debate (Ruiter & Brosschot, 1994). However, the Kaspi et al. (1995) study followed the Stroop with a free recall test for the interference stimuli. Such performance on these recall tests is indicative of an attentional bias interpretation of the emotional Stroop effect as opposed to a cognitive avoidance interpretation. Similar findings have been reported by Vrana et al. (1995).

This Stroop interference effect has been deemed disorder specific by most who have used this paradigm because PTSD subjects show the interference effect for trauma-relevant words as opposed to negatively valenced nontrauma words. Thus, it has been suggested that the information-processing biases are associated with disorder-specific words rather than being a function of attentional bias towards all negatively valenced stimuli. Most Stroop studies match the emotionality of words in pilot work by having subjects rate their negativity on a Likert-type scale. Thus, this interpretation seems to have some support. However, a stronger test of this content specificity hypothesis would involve comparing PTSD subjects to another anxiety disorder control group (e.g., panic disorder) and nonanxiety controls on negatively valenced words, trauma-specific words, and panic-related words during both subliminal and supraliminal presentations of stimuli. Group by word-type interaction contrasts should reveal that anxiety disordered groups do not differ in the interference effect for any negatively valenced words in the subliminal presentation condition. Moreover, each anxiety disorder group should be slower than the other two groups to color name their disorder-specific threat words in the supraliminal condition. Since the emotional Stroop effect has been demonstrated across all the anxiety disorders (Williams et al., 1996), these types of comparisons with PTSD subjects should be readily accomplished. However, to the best of our knowledge, no such studies have been conducted to date with PTSD populations.

Areas for Future Investigation

Given that PTSD presents with a multidimensional symptom picture, it may be the case that different processes contribute to the presence of different symptoms. More specifically, automatic processing biases may underlie the hyperarousal symptoms of PTSD such as hypervigilance and exaggerated startle response. In addition, automatic processing biases may be responsible for the involuntary re-experiencing symptoms of the disorder. If PTSD subjects preferentially scan the environment for trauma-specific threatening stimuli, then identification of such stimuli, may involuntarily activate trauma networks to a level above conscious awareness and produce intrusive recollections, flashbacks, and nightmares. We are aware of only one study that has correlated the interference–facilitation biases with particular symptom cluster scores. Cassiday et al. (1992) found that Stroop interference scores correlated with intrusion subscale scores on the Impact of Event Scale (Horowitz, Wilmer, & Alvarez, 1979) but not the avoidance subscale scores.

The numbing symptoms of PTSD, which bear a resemblance to the clinical presentation of depression, may be governed by strategic processing biases that result in overgeneral memory retrieval in response to positive cues and specific memory re-

trieval in response to negatively valenced cues (McNally et al., 1994, 1995). Prospective data from studies of trauma victims suggest that these numbing symptoms may occur later in the course of disorder (Buckley, Blanchard, & Hickling, 1996; Green, McFarlane, Hunter, & Griggs, 1993; Horowitz et al., 1979), as opposed to the intrusive symptoms that appear to be a function of automatic processes and are more prevalent early in the course of the disorder.

As can be seen from the literature reviewed, psychopathology researchers have employed a number of different paradigms to ascertain which processes can account for PTSD symptomology. Problems arise with the use of single paradigms within a study because most, if not all, of the paradigms studied involve the use of both automatic and strategic processing (Jacoby, 1991). However, much of this research reviewed here has been conducted under the assumption that particular tasks (e.g., Stroop) are pure measures of a particular process (e.g., automatic processing). Because it is assumed that the measures are "process pure," performance on those measures are taken to be true indicators of either automatic or strategic processing. We take the stance that this assumption may be erroneous and suggest that future studies employ multiple paradigms (conducting interference tests and facilitation tests with the same population) under varying degrees of emotional priming and divided attention. This will more effectively disentangle the relative contributions of automatic and strategic processes by studying process dissociations rather than task dissociations (for a complete account of process dissociations, see Jacoby, 1991).

In addition to studying process dissociations as previously mentioned, we would suggest that concurrent psychophysiological data be collected during such tasks. In particular, central nervous system measures such as P300 event-related potentials (ERPs) that are thought to be associated with the allocation of attentional resources (McFarlane et al., 1993), may be especially helpful in ascertaining when such allocation occurs if the measures are taken in synchrony with stimulus onset. In fact, recent work by Pauli et al. (1997) with panic disorder patients showed that relative to nonanxiety controls, panic patients evince larger P300 responses upon presentation of threatening stimuli. Studies such as this, which gather electroencephalograph data, may be able to shed light on this issue because differences in even-related potentials can be taken only milliseconds after the presentation of threatening stimuli. Studies such as these with PTSD populations would be a welcome addition to the literature. To date, only one study has employed such a design with a PTSD sample. Metzger, Orr, Lasko, McNally, and Pitman, (1997) examined P300 ERPs to various types of semantic stimuli across two groups: a PTSD group and a non-PTSD control group. There was no word by group interaction on ERP measures, indicating that the source of Stroop interference for trauma-related words is not a function of automatic processes, but rather due to more ruminative processes that are strategic in nature. However, this study was limited by a very small sample size and must be interpreted cautiously.

Startle response research with PTSD populations has shown that relative to non-PTSD controls, PTSD subjects show large startle responses to loud tones as measured by heart rate, SC, and obicularis electromyogram responses (Orr, Lasko, Shalev & Pitman, 1995; Shalev, Orr, Peri, Schreiber, & Pitman, 1992). Moreover, these studies suggest that there may be a failure to habituate to such stimuli among PTSD populations. Thus, the extent to which this automatic response is associated with the information biases seen in various populations may be a useful strategy for future research. It should be noted, however, that the use of sympathetic nervous system arousal mea-

sures may not always be feasible. For example, with computerized applications of the Stroop paradigm, the interstimulus interval is often quite short (1–4 seconds). Thus, gathering SC responses secondary to processing such information may be difficult because of the latency between stimulus presentations and SC responses. Situations such as this necessitate careful scrutiny of experimental design when planning such a study. The use of blocked formats of the Stroop stimuli rather than randomized formats would allow for the use of peripheral nervous system measures (blocked formats present all words of a particular category consecutively rather than randomly intermixed with nonthreat words).

The extent to which the information-processing biases as well as the physiological and behavioral correlates of such biases are a function of automatic vs. strategic processes has clear clinical implications. To the extent that these biases are more automatic in nature (i.e., not under voluntary control of the patient) treatment packages with exposure-based elements should be more efficacious than cognitively oriented therapy (McNally, 1995). Conversely, if these biases are mediated by voluntary strategic processes, then verbal (cognitive) treatment packages should be just as efficacious as exposure-based treatments (Beck & Clark, 1997). If the symptoms associated with PTSD seem to operate as a function of both automatic and strategic processes, the relative contribution of each process should be studied via process dissociation methods (Jacoby, 1991). Treatment packages can then be constructed with the appropriate allocation of time dedicated to behavioral and cognitive strategies that are aimed at the different information-processing mechanisms associated with PTSD.

It would follow that these various indices of information-processing biases could be used as outcome measures for treatment studies. Following apparently successful treatment for anxiety problems, one could ask: "do the information processing biases towards threat stimuli still exist?" Theoretically, one would expect that the biases would no longer exist. Foa, Franklin, Perry, and Herbert (1996) showed that successful treatment of social phobia is followed by a reduction in strategic information-processing biases. However, we are unaware of any studies that have looked at within subject, pre-to-post treatment effects for information-processing paradigms utilized with PTSD patients.[2] It would also be of theoretical and practical interest to know if post-treatment information-processing bias indices (e.g., Stroop interference effects) would be predictive of follow-up status (relapse).

The experimental paradigms reviewed in this paper have been shown to be useful in studying the information-processing characteristics associated with PTSD and other Axis I diagnostic groups. The literature provides some provisional evidence to support the current information-processing theories about the nature of PTSD symptoms. While some paradigm findings have been systematically replicated across trauma groups and laboratories (e.g., Stroop), some of the paradigms have not been used in this systematic manner. Future studies need to focus on replication (with particular attention paid to the issue of statistical power), as well as the methodological suggestions outlined earlier. The findings of the summarized literature address some inter-

[2]Foa et al., (1991) compared the Stroop interference effects of rape victims who underwent successful behavioral treatment for PTSD to rape victims suffering from PTSD who had yet to undergo treatment. The nontreated group showed a Stroop interference effect for trauma-related words while the treated group did not.

esting theoretical questions; however, the clinical utility of these findings and the application of these paradigms to clinical settings await future investigation.

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