

# The Emotional Stroop Task and Psychopathology

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Attentional bias is a central feature of many cognitive theories of psychopathology. One of the most frequent methods of investigating such bias has been an emotional analog of the Stroop task. In this task, participants name the colors in which words are printed, and the words vary in their relevance to each theme of psychopathology. The authors review research showing that patients are often slower to name the color of a word associated with concerns relevant to their clinical condition. They address the causes and mechanisms underlying the phenomenon, focusing on J. D. Cohen, K. Dunbar, and J. L. McClelland's (1990) parallel distributed processing model.

Anxiety and depressive disorders remain the most common forms of psychopathology and represent a large challenge for psychological analysis and treatment. Although the various forms of emotional disorder differ in many ways, recent cognitive accounts have pointed out how each of them share a common feature: sensitivity to and preoccupation with stimuli in their environment that represent their concern. Central to these cognitive theories of psychopathology is the notion that such preoccupation arises from biases in attention. For example, hypervigilance to cues signaling impending danger from the environment is an important feature of recent models of anxiety (Beck, Emery, & Greenberg, 1985), and similar hypersensitivity to bodily sensations has been implicated in panic disorder (Clark, 1988; McNally, 1990). In posttraumatic stress disorder (PTSD), attention is drawn to stimuli that remind of past trauma and exacerbate the fear of future similar events (Yule, 1991). In depression, the preoccupation is with past losses, the mind being dominated by ruminations such as "I have lost my friends" and "I'm a failure" (Nolen-Hoeksema, Morrow, & Fredrickson, 1993).

Cognitive models assume that attentional bias is not simply a by-product of the emotional disorder but plays a vital role in its causation and maintenance. It contributes to the vicious cycle, whereby small increases in emotional disturbance result in cer-

tain stimuli becoming more salient, thus biasing the estimate of the danger, with subsequent further increases in emotional disturbance. For example, in patients with panic disorder, the increased salience of bodily sensations is interpreted by the patients to signal imminent collapse or death, causing increased anxiety and further bias in attention toward more bodily sensations (Clark, 1988). In this article, we focus on the attentional bias component of this vicious spiral.

The search for a greater understanding of the association between attentional bias and emotion has motivated a great deal of experimental research using a variety of methods, in both clinical and subclinical groups (see Logan & Goetsch, 1993; and Williams, Watts, MacLeod, & Mathews, 1988, in press, for reviews). Two broad strategies for investigating attentional bias have been used in experimental investigations. The first is to show how the tendency to attend selectively to emotionally relevant stimuli may facilitate performance on certain tasks that benefit from the processing of such information. These include demonstrations that people who are emotionally disturbed have lower auditory thresholds for concern-related stimuli (Burgess et al., 1981; Foa & McNally, 1986; Klinger, Barter, & Maxeiner, 1981; Parkinson & Rachman, 1981) and lower visual thresholds for such stimuli (Powell & Hemsley, 1984).

The second method of demonstrating attentional bias has been to 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. Of all such experimental paradigms, the most frequently used is the emotional Stroop test. On the basis of several demonstrations in the 1980s that color naming of emotional words was slowed in groups of people who are emotionally disturbed (compared with the color naming of neutral words of comparable frequency), but not in control groups, the claim was made that this emotional analog of the Stroop task could be a measure of psychopathology.

Whether this task would prove useful as a clinical assessment tool, its widespread use offers two major opportunities for advancing the understanding of attentional bias and emotion.

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First, the fact that the same paradigm has been used in a range of different forms of psychopathology allows us to compare across the different clinical groups. In a field that has used a number of different paradigms across a number of different patient groups (see Williams et al., 1988), it can be difficult to determine to what extent differences between studies are due to method-specific differences and what are due to genuine differences in type or extent of attentional bias between different types of patient. The emotional Stroop has now been used in comparable forms across a sufficient range of conditions to allow us to reliably assess the extent and nature of the association between psychopathology and attention. Second, from the extensive use of the Stroop paradigm, a cumulative knowledge base has grown, the results of which promises to yield valuable insights into the mechanisms that underlie it.

In this article, we review studies using the emotional Stroop with a range of forms of psychopathology related to anxiety and depressive disorders, in both clinical patients and nonclinical analog populations. Studies cited in *PsycLIT* (1974–1995) were supplemented by studies obtained from searches through all the major journals publishing on cognition, emotion, abnormal, and clinical psychology (*Behaviour Research & Therapy*, *British Journal of Clinical Psychology*, *Cognition & Emotion*, *Cognitive Therapy and Research*, *Journal of Abnormal Psychology*, and *Journal of Personality and Social Psychology*). The following types of disorder have been studied. First, general anxiety disorder (GAD), a disorder characterized by severe and disproportionate worry about life issues (such as possible misfortune to one's child who is not in danger), which persists more or less consistently for 6 or more months and has a 12-month and lifetime prevalence rate of 3% and 5%, respectively (Kessler et al., 1994). Second, panic disorder, consisting of recurrent panic attacks, usually associated with such symptoms as shortness of breath, palpitations, chest pain, dizziness, sweating, and almost always a feeling of impending catastrophe, fear of dying, collapsing, or going crazy, has a 12-month and lifetime prevalence rate of 2% and 4%, respectively (Kessler et al., 1994).

Third, phobias have been studied, including both simple phobias (such as fear of snakes), which have a 12-month and lifetime prevalence rate of 9% and 11%, respectively, and social phobia, characterized by persistent fear of social situations in which there is fear of acting in a humiliating or embarrassing way, a phobia with a 12-month and lifetime prevalence rate of 8% and 13%, respectively (Kessler et al., 1994). Fourth, obsessive-compulsive disorder (OCD) has also been studied. This disorder has a 12-month and lifetime prevalence rate of 2% and 3%, respectively (Karno, Golding, Sorenson, & Burnam, 1988), and is characterized by persistent and distressing ideas, impulses or images such as the intrusive thought that one may have harmed someone, or repetitive compulsions to do certain actions such as hand washing or checking on things.

The fifth type of anxiety disorder studied has been PTSD, in which symptoms develop after a highly distressing event, such as rape or assault, near death, or witnessing others die in war, terrorist attacks, or severe accidents. Immediately following such events, symptoms such as affective disturbance, persistent intrusive thoughts or images, recurrent nightmares, and severe avoidance of stimuli associated with the trauma are the norm (Yule, 1991). However, in a significant minority, these symp-

toms persist into the clinical state of PTSD. The best estimate of the lifetime prevalence (in civilians) of PTSD is 9% (Breslau, Davis, Andreski, & Peterson, 1991).

Finally, attentional bias has been studied in depressive disorders. Around 5% of the population at any one time have major depression, characterized by persistent low mood and lack of interest in usual activities and accompanied by a range of symptoms such as suicidal thoughts or impulses, diminished ability to concentrate, feelings of self-reproach and excessive guilt, loss of energy, and disturbances of appetite and sleep (Williams, 1992).

We included studies only if they were relevant to anxiety and depressive disorders. Although the emotional Stroop has been used with other forms of psychopathology, these forms were not included because either they represent very different etiologies and clinical presentations (e.g., for eating disorders, see Channon, Hemsley, & de Silva, 1988; Cooper, Anatsiades, & Fairburn, 1992; and Cooper & Fairburn, 1992; for persecutory delusions, see Bentall & Kaney, 1989; and Kinderman, 1994) or there were too few studies for there to be sufficient data yet accumulated from which to draw general conclusions (e.g., alcohol abuse, Johnsen, Laberg, Cox, Vaksdal, & Hugdahl, 1994; alexithymia, Parker, Taylor, & Bagby, 1993; occupational stress, McKenna, 1986; secondary traumatization, Motta, Suozzi, & Joseph, 1994; mental control of mood, Wegner, Erber, & Zanakos, 1993; hypomania, Bentall & Thompson, 1990, and parasuicide, Williams & Broadbent, 1986).

Our aim was first to examine the extent to which attentional bias exists in these conditions, as predicted by cognitive theories of emotional disorder (e.g., Beck et al., 1985; Williams et al., 1988) and to consider what artifactual explanations there might be for the phenomenon. Second, we wished to examine how understanding the causes and mechanisms of this attentional bias has been elucidated by the use of the emotional Stroop. We suggest that a recent connectionist model of the Stroop (Cohen, Dunbar, & McClelland, 1990) provides a potentially powerful framework within which such attentional bias for emotional stimuli may be understood. A number of questions follow from this framework, each of which can be asked of the literature. Is the emotional Stroop phenomenon caused by increased "practice" or "expertise" that people have with material relating to their psychopathology? Does therapy that reduces the anxiety or depression (but may expose patients to their feared object) reduce or exacerbate interference on the emotional Stroop? Is attentional bias confined to specific concern-related stimuli characteristic of each type of emotional disturbance (including positive material relevant to such concerns), or is it associated only with negative stimuli in general? On the basis of the findings, we suggest that variation in three components of the connectionist model need to be assumed: increased strength of a processing pathway, following prolonged exposure to certain material; increased resting activation level for concern-related input units; and short-term neuromodulatory control of input units associated with threat or loss. Although this article focuses on interference and attentional effects in clinical populations, the issues we discuss may have wider relevance to social cognition in control populations. For example, words or pictorial stimuli having affective or attitudinal significance to the individual can produce interference and tend to capture attention

more effectively than do neutral stimuli (Pratto & John, 1991; Roskos-Ewoldsen & Fazio, 1992). The extensions to the model of the color-conflict Stroop that are needed to account for the emotional Stroop are likely to be applicable to this wider social cognition literature, and we return at the end of the article to the issue of what distinguishes nonpathological from pathological attentional bias, that is, what constitutes "breakdown."

### The Original Stroop Task and Its Adaptation: Early Research Findings

The Stroop (1935) task has long been used by experimental psychologists to study attentional processes. In the original version of this task, a participant is required to name the color of ink in which an item is printed, while attempting to ignore the item itself. The items in question are meaningless stimuli such as rows of Xs or actual names of colors. In the latter case, a word such as *red* might appear in green ink, the word *brown* in red ink, and so on. Stroop found, as all investigators have found since (see MacLeod, 1991), that it takes participants longer to name the colors when the base items are antagonistic color names than when they are rows of meaningless stimuli. However, it is not only antagonistic color names that cause such interference. Subsequent research has found that any common word produces some interference (Klein, 1964), especially if the word itself tends to be associated with a color (e.g., *sky* and *grass*; Scheibe, Shaver, & Carrier, 1967). Warren (1972, 1974) found that more interference was produced in naming the color of a word if it or its associate had recently been presented auditorily to the participant. Geller and Shaver (1976) found that more interference was produced in the color naming of self-referent words if a participant had to perform the task in front of a camera and mirror, which acted to increase self-awareness. Hence, under those circumstances that make it likely that the meaning of a word is semantically activated, color-naming interference is most probable.

With an increased interest in cognitive accounts of emotion in the late 1970s and 1980s, several investigators used Stroop-like tasks to examine cognitive processing associated with emotional disturbance. Although the conceptual structure within which the research was carried out varied, the Stroop being used to measure construct accessibility (Gotlib & McCann, 1984; Williams & Nulty, 1986), activation of danger schemata (Mathews & MacLeod, 1985), the emotional salience of words (Watts, McKenna, Sharrock, & Trezise, 1986), or simply distraction by emotional stimuli (Ray, 1979; Williams & Broadbent, 1986), the different studies had in common the measurement of latency to name colors of negative-affect words (either individual words presented on a tachistoscope or a computer monitor or columns of words presented on a single card). Researchers used both neutral and positive words as control stimuli, compared performance in groups diagnosed as disturbed with controls who are nondisturbed, and contrasted emotional words that are specific to the psychopathology under study against equally emotional words that are unrelated to the psychopathology.

For example, Gotlib and McCann (1984) selected depression-related words for their study of students with mild depression. Fifteen high and 15 low scorers on the Beck Depression

Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) named the colors of 50 neutral, 50 depressive, or 50 positive words presented on a tachistoscope. Results showed that the valence of the word made little difference to the participants without depression speed of color naming. However, the participants with mild depression were significantly slower (23 ms) in naming the colors of the negative words than of the positive or neutral words.

Similar results were found by Mathews and MacLeod (1985) using threatening words with patients with anxiety. In their experiment, 24 patients were grouped on the basis of whether their worries were predominantly social (e.g., patients who found it embarrassing to talk to new people) or physical (e.g., patients who thought it was likely that they would have a heart attack). The patients were tested on four Stroop cards, each containing 96 stimuli (12 words repeated eight times). The words on the first card represented physical threat (e.g., *disease* and *cancer*), those on the second represented social threat (e.g., *failure* and *pathetic*), and those on the two other cards contained non-threatening (mostly positive) words (e.g., *secure* and *holiday*), matched for word frequency.

Control participants showed no difference in color-naming latency between the threat and nonthreat cards. By contrast, not only did patients with anxiety show slower color naming for the threat words than for the nonthreat words (a mean interference of 44 ms), but also there was a relationship between the type of threat word that most disrupted color naming and the type of worries that predominated in the patient. Whereas all anxious patients were disrupted on social threat words, only physical worriers were disrupted on the physical threat words (52 ms); social worriers showed a 44 ms facilitation on these same words. The degree of disruption was significantly associated with depression, trait anxiety (assessed by a self-rating questionnaire asking how anxious a participant feels in general), and state anxiety (assessed by a self-rating questionnaire asking how a participant feels "right now, at this moment"; Spielberger, Gorsuch, & Lushene, 1970). Partial correlation coefficients showed that the main independent predictor of degree of color-naming disruption was state anxiety.

Watts et al. (1986) used both a general emotional Stroop test (containing words such as *fear*, *death*, and *grief*) and a test containing stimuli specifically related to psychopathology—spider words (e.g., *hairy* and *crawl*)—in a study of spider-avoidant participants. They found that these participants showed little disruption of color naming on general emotional words compared with control participants, but they showed a very large interference in color-naming spider words. Indeed, the extent of the interference (190 ms) was almost as great as the interference in naming antagonistic colored stimuli—the original Stroop phenomenon was 260 ms. Furthermore, desensitization treatment significantly reduced the amount of interference. We return to discuss this treatment effect later because pre- and post-testing is a critical aspect of both the interpretation of and the utility of this paradigm. In summary, this early research showed that the emotional Stroop task had the potential to address questions about attentional bias. We now place these studies in the context of a general overview of studies whose researchers have examined attentional bias in this way.

## Overview of Findings Using the Emotional Stroop Task

The experiments that have examined the latency to name the color in which an emotional word is printed are shown in Table 1. We have computed interference effects in each case by subtracting the time taken to name the colors of the matched neutral words from the time taken to name the colors of the target (emotional) words. For computer or tachistoscope (individual item) presentation, these interference values (per stimulus item) are in milliseconds. For the card methodology, we have divided the mean time to complete whole cards by the numbers of words on each card to derive a comparable index of mean interference per stimulus item.

Clearly, emotional Stroop interference is found across the whole range of these different clinical conditions. The studies have used both a card presentation of Stroop material and computer presentation. Although card presentation tends to result in larger interference effects (a grand mean of 84 ms for the 28 interference indices from card presentations compared with a grand mean of 48 ms for the 23 interference indices from individual computer or tachistoscope presentations), both methodologies produce replicable effects.

Several issues emerge from this general overview of studies. First, it shows that, for patients who are emotionally disturbed, performance on color naming is diagnostic for their condition. That is, performance is particularly disrupted when the words they have to color name are related to a specific psychopathology. For example, disruption on physically threatening material (e.g., *cancer* and *blood*) was greater for patients with anxiety who independently report health worries (Mathews & MacLeod, 1985; Mogg, Mathews, & Weinman, 1989). Disruption on spider words by those with a spider phobia (Watts et al., 1986) did not generalize to generally negative words (e.g., *fail*). Other studies show similar specificity: a rape theme for individuals who have been raped (Foa, Feske, Murdock, Kozak, & McCarthy, 1991; Cassiday, McNally, & Zeitlin, 1992); social or physical threatening words for patients with a social phobia or panic disorder, respectively (Hope, Rapee, Heimberg, & Dombek, 1990); catastrophe theme for patients with panic disorder (McNally et al., 1994; McNally, Riemann, Louro, Lukach, & Kim, 1992); Vietnam trauma theme for Vietnam veterans with PTSD (McNally, English, & Lipke, 1993; McNally, Kaspi, Riemann, & Zeitlin, 1990).

A second aspect of the results shown in Table 1 is the involvement of both trait and state aspects of emotion. *Trait* refers to emotion that is experienced as a long-term aspect of temperament, how people feel in general. *State* refers to emotion that is experienced "right now, at this moment." Trait and state emotion was assessed in these studies by a questionnaire that has been validated against psychophysiological and behavioral measures, the Spielberger (Spielberger et al., 1970) State-Trait Anxiety Inventory. Early results using such instruments produced conflicting results. Mathews and MacLeod (1985) found that Stroop interference was more closely correlated with state rather than with trait anxiety, but Mogg et al. (1989) found interference to be more closely associated with trait anxiety than state anxiety.

The use of such questionnaires to examine the state-trait issue have therefore given way to more definitive ways of seeing

whether long-term temperamental factors or short-term state factors are responsible for emotional Stroop interference. First, researchers studied patients who have recovered (assumed still to have the elevated trait emotion but to have reduced state emotion). These studies are reviewed later. Second, the question of whether emotional Stroop is a long-term trait feature has been studied by the use of students tested before examinations or following experimentally induced failure experience (with the assumption that trait emotion will be stable as state emotion increases).

Mogg, Mathews, Bird, and MacGregor-Morris (1990) studied whether trait or state anxiety would produce more color-naming interference on emotionally negative words (both general threat words [e.g., *lonely*] and achievement threat words [e.g., *ignorant*]). They manipulated current state anxiety by the use of experimental stress. They randomly allocated 18 participants with high-trait anxiety and 19 participants with low-trait anxiety to receive difficult or insolvable anagrams (high stress) or easy anagrams (low stress). They administered the emotional Stroop task after this failure experience. Their results showed that, following the failure stress, color-naming interference was greater for words representing achievement concerns (50 ms). This effect of the short-term stress was not mediated by increases in state anxiety. Although such null effects might have been due to the insufficient power in the study, Mogg et al. found other predicted correlations. For example, the level of trait anxiety was associated with the presence of emotional Stroop interference. Irrespective of whether people had undergone failure, individuals with high-trait anxiety showed more interference for all threatening words (both general threat and specific achievement words). In addition to replicating the studies that showed how trait anxiety is associated with color-naming interference for threatening material, they concluded that current context (failure experience) may have a direct priming effect on achievement themes to cause increased Stroop interference and does not need to be mediated by state emotion.

MacLeod and Rutherford (1992) also examined the pattern of color-naming interference observed as a function of trait and state anxiety, in a slightly different version of the emotional Stroop task. Their task used very rapid word presentations, followed in each case with a colored pattern mask that participants were required to color name. As participants, the students with high- and low-trait anxiety were tested on two occasions, in the week before their end of semester examinations when their state anxiety was high and early in the next semester when their state anxiety was low. These researchers found that the tendency to display color-naming interference on negative words related to examinations (e.g., *test* and *inept*)—relative to positive words related to examinations (e.g., *scholarly* and *merit*) on this masked version of the emotional Stroop—was an interactive function of trait anxiety and stress. When state anxiety was low, the groups with low- and high-trait anxiety showed equivalent patterns of color naming. When state anxiety was high because of the imminent exams, however, the participants with high-trait anxiety displayed increasing color-naming interference on the negatively toned examination words. In contrast, the participants with low-trait anxiety showed no such effect.

In summary, the evidence suggests that individual differences

in trait emotion (as assessed by questionnaires) are commonly associated with individual differences in Stroop interference. However, trait differences require some activation by current emotion or circumstances to show the disruption. This interaction is more likely to occur if the current circumstances have had time to incubate (e.g., anticipation of having to take an examination), than if the current emotion disturbance is short term (e.g., failure on an experimental task). This suggests that high-trait anxiety is associated with an increased frequency of rumination about negative themes over a long period of time. The greater the frequency and intensity of rumination, the greater the accessibility (priming) of concepts associated with the theme (e.g., *failure, stupid, and pathetic*).

It is this association of strength of interference with frequency and intensity of rumination that explains a third feature to emerge from the overview in Table 1, that is, the size of effect is much larger in the case of PTSD than any other disorder. The five studies produced interference effects of 300, 290, and 115 ms in Vietnam veterans (Kaspi, McNally, & Amir, 1995; McNally, English, & Lipke, 1993; McNally, Kaspi, et al., 1990) and 200 and 175 ms in individuals who have been raped (Cassiday et al., 1992; Foa et al., 1991). These magnitude differences raise the possibility that different or additional mechanisms might underlie color-naming disruption in these conditions. Because two of these studies used card presentation and three used a computer, the size of interference effect cannot be due to the method of presentation. (Only in the case of Watts et al.'s, 1986, spider phobia study was the interference of comparable size [190 ms], but other studies of specific phobia [Lavy, van den Hout, & Arntz, 1993; Mathews & Sebastian, 1993] produced more modest interference effects [between 39 and 50 ms].) Further studies on this question are needed, although the most likely explanation is that the larger interference in patients with PTSD is due to their particular clinical pathology in which extremely frequent and severe intrusive thoughts and flashbacks are a central diagnostic feature.

Both the larger interference effects in PTSD, and the specificity (diagnostic) effect referred to earlier, raise the issue of whether the attentional bias shown in the emotional Stroop task is due to the sheer frequency with which participants have been exposed to the target material (a practice or expertise effect) rather than the emotional content of the material. That is, it is possible that words differ in their frequency of usage by the patients and participants tested in the experiments. Words that are more frequent in common usage produce greater interference in color naming (Klein, 1964). Whether attentional bias as shown by interference on the emotional Stroop arises from overexposure to, or excessive practice or expertise with, emotional material is an important question that we address in more detail later. For now, it is important to consider whether the effects observed may be due to some artifact of experimental procedure.

### Some Possible Artifactual Explanations

The first possible artifact we need to consider is that interference might be due to priming effects of one word on the next presentation of a word of the same theme. Although the fact that interference is shown whether a card (blocked), computer,

or tachistoscope (individual) presentation is used, Warren (1972) found that priming from an associated word could persist over five intervening items, so even individual presentation of emotional Stroop items might be affected by such priming. Many studies (those in Table 1 that simply designate the control material as neutral) have used control material that is not from a single category, thus confounding emotional salience with the associability of items. However, eight studies did use categorized neutral material, thereby controlling for intercategory priming effects. Each of these studies showed significant interference effects. We conclude that color-naming interference is not due to interitem priming.

A second possible method-specific explanation for the emotional Stroop is that the effect may be due to the repetition of a small set of critical words. Almost all studies use a set of emotional and neutral material that is repeated many times in the experiment (e.g., 12 words repeated eight times; Mathews & MacLeod, 1985). In fact, of course, every experiment balances the presentation of material so that the set of neutral items is repeated as often as the emotional material, making repetition unlikely to be the sole mediator of the difference between different types of material. However, in addition, two studies used 50 words of each type (depressive, neutral, and manic) and presented the 150 words only once (Gotlib & Cane, 1987; Gotlib & McCann, 1984). These researchers reported significant interference effects of 23 and 57 ms, respectively, on depressive words for participants with depression. Although more data would be helpful on this point, our provisional conclusion is that the repetition of items is not the critical factor causing the interference.

A third artifactual explanation for these results is that participants may be consciously attending to the critical words, such that the indirect idea behind the Stroop measure is undermined. However, four studies have found color-naming interference for emotional material using subliminal presentation (MacLeod & Hagan, 1992; MacLeod & Rutherford, 1992; Mogg, Bradley, Williams, & Mathews, 1993; Mogg, Kentish, & Bradley, 1993).

MacLeod and Rutherford (1992) found that students with high anxiety tested before an examination ( $n = 23$ ) showed a significant color-naming interference (10.5 ms) to threat words (e.g., *stupidity and lonely*) versus nonthreat words (e.g., *careful and uncommon*) on a 20-ms subliminal Stroop task. Participants with low-trait anxiety ( $n = 24$ ) showed a 6-ms facilitation in the same condition. The researchers checked subliminality by requiring participants to perform a lexical decision task at intervals during the subliminal Stroop task. Performance for this lexical decision task was at chance (where chance level was .500, the performance of the group with high-stress [examination imminent] was .501 and of the group with low stress, .509).

Using the same task in a longitudinal study, MacLeod and Hagan (1992) measured the degree of color-naming interference for threat words (e.g., *disease and pathetic*) presented subliminally to 31 women undergoing a gynaecological examination. Of these women, 15 later received a diagnosis indicating pathology. The researchers followed up 2 months later to assess the degree of dysphoria (anxiety and depression) that the women had experienced. This emotional disturbance was significantly predicted by the amount of color-naming interference

(text continues on page 13)



Table 1  
*Studies That Examined Color-Naming Disruption by Emotional Words*

Study	Method	Content of word stimuli (matching criteria)	Participants (n)	Group(s) showing interference on target vs. control words (bias sensitive words)	Size of interference effect (in ms)
Clinical anxiety					
Mathews & MacLeod (1985)	Card	Physical threat Social threat Pos (freq)	Anxious outpatient (24) Control; age and gender matched	Anxious (threat words)	44.0
Mogg et al. (1989)	Card	Physical threat Social threat Pos (length/freq)	Anx state (18) Control (18)	Anxious (threat words)	28.0
Martin et al. (1991), Experiment 2	Card	Physical threat Social threat Neutral (freq)	Anxious (12) Matched nonpatient (12)	Anxious (threat words)	20.0
Martin et al. (1991), Experiment 4	Card	Physical threat Social threat Pos (emotionality) Neutral (freq)	Anxious (12) Control (12)	Anxious (a) Threat words (b) Pos words	(a) 72.0 (b) 58.0 (from Figure 2, p. 156)
Golombok et al. (1991)	Card	Physical threat Social threat Neutral (length/freq)	Anxious (24) Control (24); age, gender, and IQ tested before and after either placebo or 10 mg diazepam	Anxious (threat words)	40.0
Mogg, Bradley, et al. (1993)	Computer subliminal vs. supraliminal	Anx relevant Depression relevant Pos (emotionality) Categorized neutral Uncategorized neutral (length/freq)	Anxious (19) Depressed (18) Control (18)	Anxious (neg words) (a) supraliminal (b) subliminal	(a) 7.5 (b) 21.0
Mathews & Klug (1993)	Card	Neg (anx relevant) Neg (anx irrelevant) Pos (anx relevant) Pos (anx irrelevant; length/freq)	Mixed "anxiety neuroses" (20) Control (20); age, gender, and education	Anxious (a) Neg words related to problems (b) Pos words related to problems: cf. (c) Pos words unrelated to problems (d) neg words unrelated to problems	(a) 36.0 (b) 16.0 vs. (c) 21.0 facilitation (d) 19.0 facilitation
Mathews et al. (1995)	Card	Physical threat Social threat Pos (emotionality) Neutral (length/freq)	Anxious (24) tested before and after psychological treatment. Control (23); age, gender, IQ, and test-retest interval	Anxious Pretreatment (threat vs. nonthreat) Posttreatment (anxious patients, no interference)	45.0
High-trait anxiety					
Dawkins & Furnham (1989)	Card	Color conflict Threat Neutral (length/freq)	High anxious (12) "Repressor" (12) Low anxious (12)	(a) High anxious (threat words) (b) Repressor (threat words)	(a) 50.0 (b) 96.0
Richards & Millwood (1989)	Computer	Threat Neutral (length/freq) Pos (length/freq)	High anxious (16) Low anxious (16)	High anxious (threat words)	20.0 (from Figure 1, p. 174)
Mogg et al. (1990)	Card	General threat Achievement threat Neutral (length/freq)	High anxious (18) Low anxious (19) received either stress or no stress	High anxious High stress on achievement words	39.0 50.0 (from Figure 2, p. 1233)

Table 1 (continued)

Study	Method	Content of word stimuli (matching criteria)	Participants (n)	Group(s) showing interference on target vs. control words (bias sensitive words)	Size of interference effect (in ms)
High-trait anxiety (cont'd)					
Richards & French (1990)	Computer (central vs. peripheral word presentation)	Threat Pos Neutral (length/freq)	High anxious (13) Low anxious (14)	High anxious (threat words)	120.0
Mogg & Marden (1990)	Card	Social threat Physical threat Pos (emotionality) Neutral (freq) Household (freq) Rowing (freq)	High anxious (12) Low anxious (12) Rowing club members (12) Nonrowers (12)	High anxious (all emotional words, including pos ones)	Insufficient detail
Martin et al. (1991), Experiment 1	Card	Physical threat Social threat Neutral (freq)	High anxious (12) Medium anxious (12) Low anxious (12)	No significant effects involving group	
Richards et al. (1992), Study 1	Computer (blocked vs. individual item presentation)	Threat Pos Neutral (length/freq)	High anxious (20) Low anxious (20)	High anxious (threat words and blocked presentation)	129.0
Richards et al. (1992), Study 2	Computer (individual item presentation)	Threat Pos Neutral (length/freq)	High anxious (20) Low anxious (20); threat vs. pos mood induction groups)	High anxious (a) On pos words following pos MIP (b) On neg words following neg MIP	(a) 117.0 (b) 72.0
MacLeod & Rutherford (1992)	Computer supraliminal vs. subliminal	Exam-related threat Exam-related pos (length/freq) General threat Neutral (length/freq)	High anxious (23) Low anxious (24); before and 6 weeks after exam	High anxious (before exam on subliminal task)	10.5
Mogg, Kentish, et al. (1993)	Computer supraliminal vs. subliminal	Threat Pos Categorized neutral Uncategorized neutral (length/freq)	High anxious (20) Low anxious (20); stress vs. relax mood induction	Mood induced "relaxed" (a) More interference on subliminal pos words (b) More interference on supraliminal neg words	(a) 17.0 (b) 23.0 (from Figure 1, p. 563)
Fox (1993)	Card	Threat Neutral (length/freq) Color words	High anxious (18) Low anxious (18)	High-anxious on (a) Traditional stimuli (b) Separated stimuli	(a) 80.0 (b) 50.0
Fox (1993)	T scope	Physical threat Social threat Neutral (length/freq)	High anxious (18) Low anxious (18) "Repressor" (18)	No significant effects involving group	
Posttraumatic stress disorder (PTSD)					
McNally, Kaspi, et al. (1990)	Card	Obsessional PTSD Pos Neutral (length/freq)	Vietnam veteran with PTSD (15) Vietnam veteran without PTSD (15)	PTSD group (PTSD words; no difference in neutral, pos, or obsessional words)	300.0 (from Figure 1, p. 400)
Foa et al. (1991)	Computer	Rape related General threat Categorized neutral Nonwords (length/perceived freq)	Rape victim with PTSD (15) Rape victim without PTSD (13) Control (16); age and IQ	PTSD (rape words)	400.0 (from Figure 1, p. 160)
Cassiday et al. (1992)	Computer (blocked vs. random presentation conditions)	Rape related General threat Pos Neutral (length)	Rape victim with PTSD (12) Rape victim without PTSD (12) Control (12); age and IQ	PTSD (rape words)	175.0 (from Figure 1, p. 290)

(table continues)

Table 1 (continued)

Study	Method	Content of word stimuli (matching criteria)	Participants (n)	Group(s) showing interference on target vs. control words (bias sensitive words)	Size of interference effect (in ms)
Posttraumatic stress disorder (PTSD) (cont'd)					
McNally et al. (1993)	Card	Obsessional PTSD Pos Neutral (length/freq) OOOOs	Vietnam veteran with PTSD (24) Retested 1 week later	PTSD (PTSD words)	290.0 (from Figure 1, p. 39) 310.0
Kaspi et al. (1995)	Computer (blocked vs. random presentation)	PTSD Neg Pos (idiographic emotionality) Neutral	Vietnam veteran with PTSD (30) Vietnam veteran without PTSD (30)	PTSD (PTSD words)	115.0 (from Figure 1, blocked and random combined)
Panic disorder					
Ehlers et al. (1988)	Card	Physical threat Separation Embarrassment Nonthreat (mixed, neutral, and pos; length/freq)	Panic disorder (24) Control (24); age	Panic disorder (physical threat words)	38.0
McNally, Riemann, et al. (1990)	Computer	Fear Body sensation Catastrophe Neutral	Panic disorder (14) Control, therapist "experts" in panic (14); age	Panic disorder (all neg words) Both groups (catastrophe words)	57.0 (catastrophe words and patients with panic disorder; from Figure 2, p. 410)
McNally et al. (1992)	Computer	Fear Body sensation Catastrophe Pos XXXXs	Panic disorder (24) OCD (24) Control (24) High vs. low arousal manipulation, exercise	Panic disorder (catastrophe words)	24.0 (pos vs. catastrophe words)
McNally et al. (1994)	Computer (blocked presentation)	Panic General threat Pos (idiographic emotionality rating/length/freq) Neutral	Panic disorder (16) OCD (16) Control (16)	Panic disorder (threat words)	36.0
Obsessive-compulsive disorder (see also McNally et al., 1992, 1994)					
Foa et al. (1993)	Computer	General threat Contamination Categorized Neutral Nonwords	OCD (33); with washing rituals (23); with checking rituals (10) Control (14); age, gender, and IQ	(a) Washers with OCD (on contamination words) (b) Checkers with OCD (on general threat words)	(a) 26.0 (b) 24.0
Lavy et al. (1994)	Cards	General neg OCD pos OCD neg General positive Neutral (word length)	OCD (33) Control (29); age, gender, and education	OCD (OCD neg words)	108.0
Social Phobia					
Hope et al. (1990)	Cards	Social threat Physical threat Neutral (length/freq) Color words XXXXs	Social phobia (16) Panic disorder (15)	(a) Social phobia (social threat words) (b) Panic disorder (physical threat words)	(a) 77.0 (b) 77.0



Table 1 (continued)

Study	Method	Content of word stimuli (matching criteria)	Participants (n)	Group(s) showing interference on target vs. control words (bias sensitive words)	Size of interference effect (in ms)
Social phobia (cont'd)					
Mattia et al. (1993), Study 1	VDU "card"	Social threat Physical threat Neutral (length/freq) Color words XXXXs	Social phobia (29) Control (50); age and education	Social phobia (social threat words)	93.0
Mattia et al. (1993), Study 2	VDU "card"	Social threat Physical threat Neutral (length/freq) Color words XXXXs	Social phobia (29); treatment study; 12 weeks; Phenelzine, placebo, or CBT; responders (17) and nonresponders (12) across three groups	(a) Treatment responders showed reduced interference on social threat words (b) Nonresponders did not show reduced interference on social threat words	(a) Pretreatment 113.0; posttreatment 24.0 (b) Pretreatment 75.0; posttreatment 86.0
Specific phobia					
Watts et al. (1986), Study 1	Card	Spider words Emotional words Neutral control (length/freq) Color words OOOOs	Spider avoidant (35) Control (18); age, gender, and education	Spider phobia (spider words)	190.0
Watts et al. (1986), Study 2	Card	Spider words Emotional words Neutral control (length/freq) Color words OOOOs	Spider avoidant (28) from Study 1; treatment group (14); no-treatment control (14)	(a) Both treatment and (b) No-treatment groups showed reduced interference; groups were significantly different at second testing only	(a) From 189.0 to 29.0 pretreatment to posttreatment (b) From 204.0 to 79.0
Martin et al. (1992)	Card	Spider words Control words Nonwords Color words	Spider-avoidant child (24) Control child (24); three age bands: 6–7 years, 9–10 years, and 12–13 years	Spider-avoidant child (spider words)	97.0, 154.0, and 159.0 for young, middle, and older children, respectively
Mathews & Sebastian (1993), Experiment 1	Card	Snake words General threat Categorized neutral (length)	Snake avoidant (18) Control (18) All were exposed to 18 in. boa constrictor	No significant effects	Snake Stroop, 1.0 facilitation
Mathews & Sebastian (1993), Experiment 2	Card	Snake words General threat Categorized neutral (length)	Snake avoidant (18) Control (18); different from Experiment 1; no snake exposure	Snake avoidant (snake words)	45.0
Mathews & Sebastian (1993), Experiment 3	Card	Snake words General threat Categorized neutral (length)	Snake avoidant (40); different from Experiment 1 and 2; exposed to tarantula spider (20) vs. no exposure (20)	(a) Spider absent (equivalent to Experiment 2); significant Stroop interference for snake words (b) Spider present but no effect	(a) 50.0 (b) 1.0 facilitation

(table continues)

Table 1 (continued)

Study	Method	Content of word stimuli (matching criteria)	Participants (n)	Group(s) showing interference on target vs. control words (bias sensitive words)	Size of interference effect (in ms)
Specific phobia (cont'd)					
Lavy et al. (1993)	Computer	Spider words General neg Neutral (length)	Spider phobia (36) Control (30); age-education, both groups tested twice, 2½ hr apart, during which those with phobia were given exposure treatment	Pretreatment interference (spider words) reduced at posttreatment	From 39.0 to 16.0
Depression					
Gotlib & McCann (1984)	T scope	Depressed Manic Neutral (freq)	Mildly depressed (15) Nondepressed (15)	Depressed (depression words)	23.0
Williams & Nulty (1986)	Card	Neg Neutral OOOOs	Moderately depressed (19) Nondepressed (19); tested 1 year before Stroop and concurrently	Depressed (past; neg words)	60.0
Gotlib & Canc (1987)	T scope	Depressed Manic Neutral (freq)	Depressed inpatients (34); tested at admission and after discharge Nondepressed control (14); age; retest interval	Depressed at pretreatment (neg words; no main effects or interactions for second-testing session)	57.0
Segal & Vella (1990)	T scope	Neg Pos idiographic selection as self-descriptive vs. non-self-descriptive Neutral nouns Target words presented following primes (related-unrelated)	Depressed (18) Control (14) Control and self-focus manipulation (14)	Depressed group: Self-descriptive words had more interference (a) vs. neutral nouns (b) vs. non-self-descriptive adjectives (unrelated prime condition)	(a) 116.0 (b) 101.0
Klieger & Cordner (1990)	Slides (individual presentation)	Neg Neutral (freq) Color words OOOOs	Mild-moderately depressed (21) Nondepressed (14)	Depressed group (neg words)	34.0
Hill & Knowles (1991)	Card	Neg Pos General neg (length/freq) Color names XXXXs	Mildly depressed (12) Nondepressed (12)	No interaction of group and word valence	
Segal et al. (1995)	Computer	Neg Pos Short phrases used as primes (e.g., hard to trust others) Idiographic selection for self-relevance	Depressed (58) Control (44); education and IQ	Depressed group; interference for self-descriptive adjective primed with self-descriptive phrase (vs. other adjective and prime conditions)	34.0 (vs. self-prime-non-self target)
Ray (1979)	Card	Exam words Body parts (length/freq)	Final year student 4 weeks before examinations (38) Low-state anx (12) Moderate anx (14) High anx (12)	High anx (exam words)	67.0

Table 1 (continued)

Study	Method	Content of word stimuli (matching criteria)	Participants (n)	Group(s) showing interference on target vs. control words (bias sensitive words)	Size of interference effect (in ms)
Self-relevant					
MacLeod & Hagan (1992)	Computer subliminal vs. supraliminal presentation	Threat Nonthreat	Gynaecological out-patient (31) awaiting appointment for colposcopy to diagnose cervical pathology; later received diagnosis of pathology (15)	Concurrent correlation between trait and state anxiety and interference on subliminal condition only Subliminal (but not supraliminal) threat interference predicted dysphoric reaction to diagnosis ( $-.54, p < .05$ )	No mean given
Riemann & McNally (1995)	Computer	Pos self-relevant Pos non-self-relevant Neg self-relevant Neg non-self-relevant (idiographic) Neutral	Student allocated to anx, elation, or neutral mood induction (45)	High self-relevance (pos and neg) more interference than low self-relevance and neutral	Pos self vs. non-self, 23.0 Neg self vs. non-self, 18.0
Dalgleish (1995), Experiment 1	Computer	Threat Pos Neutral Categorized neutral Bird (length)	Anxious (12) Low anxious (12) Ornithologist (12)	(a) Anxious (threat words) (b) Ornithologist (bird words; no difference between semantically related and unrelated neutral words)	(a) 26.0 (b) 62.0
Dalgleish (1995), Experiment 2	Card	Threat Pos Neutral Categorized neutral Bird (length)	Anxious (14) Low anxious (14)	Anxious: emotional words, both (a) Threat (b) Pos	(a) 69.0 (b) 40.0

Note. anx = anxiety; freq = frequency; OCD = obsessive-compulsive disorder; MIP = mood induction procedure; neg = negative; OOOOs = colored meaningless stimuli; pos = positive; T scope = tachistoscope; VDU "card" = screen display where all words are shown together; XXXXs = colored meaningless stimuli.

to threat words on the subliminal Stroop task, given before the diagnosis was made. This predictive power was not mediated by a concurrent correlation with anxiety or depression at the time of initial testing, for the correlation remained significant after partialing out the effect of these mood variables.

Mogg, Bradley, et al. (1993) used negative words (e.g., *embarrassed*) and positive words (e.g., *adorable*), matched for emotionality, and categorized neutral words (*carpet*), matched for word length and frequency, in a study comparing subliminal with supraliminal presentation. Twenty patients with anxiety and 18 control participants took part. The display of the subliminal material was replaced by a random letter mask after 14 ms (the timing was checked by a light sensitive diode and oscilloscope). Researchers checked subliminality by requiring participants to perform a lexical decision task and a presence-absence discrimination task (in counterbalanced order and using the same stimulus presentation format) after the subliminal Stroop task. Performance for this lexical decision task was at chance (where chance level was .500, the performance of the control group, group with anxiety, and group with depression was .505, .507, and .500, respectively). Performance at the detection task produced the same pattern of results—.515, .517, and .501—for the three groups—which did not differ from chance. Despite this indication that participants were unaware

of the presence of stimulus words in the subliminal condition, results showed the predicted bias for subliminal negative information in patients with anxiety (21 ms vs. 2 ms in the control group).

Finally, Mogg, Kentish, et al. (1993) used threat words (e.g., *paralysis*), positive words (e.g., *bliss*; matched for emotionality with the threat words), categorized neutral words (household terms, e.g., *bookcase*), and uncategorized neutral words (e.g., *emblem*) in an experiment with 46 students, varying in level of trait anxiety. The researchers randomly allocated the students to receive either a stress or relaxation mood induction. In the emotional Stroop task, the researchers matched all words for word length and word frequency, and the students were tested on both a subliminal and supraliminal version of the task. In the subliminal condition, words were pattern masked after 14 ms, leaving only the color patch visible. Researchers checked awareness in this experiment using a presence-absence, forced-choice discrimination task. The mean percentage of trials with correct responses was 51.3% which did not differ from chance. Despite this, they found, as predicted, a significant correlation between the degree of interference in color-naming threat stimuli and trait anxiety.

In summary, studies using subliminal Stroop confirm that such biases can be found using presentation times that do not

allow participants time to construct strategies based on conscious awareness of the material. We conclude that emotional Stroop interference is not dependent on conscious strategies.

Because emotional Stroop interference is unlikely to be due to such artifacts, we move now to consider psychological explanations for why they occur. There are two related types of explanation that can be sought for such effects. First, what are the cognitive mechanisms underlying the emotional Stroop phenomenon; what components or stages within the information-processing system are giving rise to the observed interference? Second, what causes these mechanisms to come into play (the triggers)? These causes may be a trait characteristic of the person, such as their tendency to ruminate over past or future stress. Or the cause of the information-processing disruption might lie in the interaction between the characteristics of the person and of the situation or task (e.g., specific matching of Stroop stimuli with a person's current concerns).

### Mechanisms Underlying Stroop Interference

Most investigators use the emotional Stroop task to assess the extent to which emotional stimuli "capture attentional resources." The most common explanatory models have been Beck's (Beck et al., 1985) schema theory or Bower's (1981) network theory. Emotional stimuli are said to attract disproportionately more processing resources due to the activation of specific knowledge structures representing personal threats (Mogg et al., 1989). Others have suggested that interference may arise from the emotional material activating task irrelevant, self-preoccupying processes that consume attentional capacity, thereby slowing color naming (Dawkins & Furnham, 1989), or from the greater cognitive effort that is required to shut out the perception of negative stimuli or to render such stimuli unconscious (Holmes, 1974; Ruiter & Brosschot, 1994).

These models have only been used as general heuristic frameworks to guide experiments within specific domains of pathology, rather than systematically applied to the whole range of findings across pathologies. One more general model, however, is that of Mathews and MacLeod (1994). They concluded that the data were best explained by a prioritization model. Following Oatley and Johnson-Laird (1987), they suggested that the role of emotion is to signal a juncture in the pursuit of desired outcomes or avoidance of undesired outcomes. Emotions elicit changes in information-processing modes to deal with a potentially new situation that may require action to be taken. For example, anxiety represents a shift into a mode of hypervigilance, such that the person scans the environment for any threatening stimulus, particularly those which have been associated with threat before. In this mode, the cognitive system prioritizes the initial automatic encoding of threat stimuli but not the strategic rehearsal of such material for explicit encoding into memory. This is analogous to the physiological response to threat, which involves blood being pumped to the muscles to prepare them for action but away from the digestive system.

What mechanisms underlie such changes in priorities? In the following section, we discuss whether a recent connectionist model of the color-conflict Stroop (Cohen et al., 1990) may provide a framework within which emotional Stroop phenomena could be explained.

### Modeling Color-Naming Interference in the Emotional Stroop Task

Researchers who have examined the time course of each sub-component of the original color-conflict Stroop effect (e.g., Glaser & Glaser, 1982; Naish, 1985; see MacLeod, 1991, for a review) have concluded that neither a perceptual nor response interference model is sufficient to account for the pattern of findings. After reviewing 50 years of color-conflict Stroop research, MacLeod (1991) concluded that the developed connectionist model by Cohen et al. (1990) provides the best account of the data. Cohen et al. suggested that interference effects on the Stroop task arise from the action of a common, underlying variable which they term *strength of processing*. Performance of any task that requires a particular processing pathway involves establishing a pattern of activation in the relevant sensory modules to generate the appropriate pattern of activation in the relevant output modules. The *strength* of a pathway is defined as those connections between the units that make up the modules in a pathway. These determine the speed and accuracy of activation flow along the pathway, which in turn determine the speed and accuracy of a response.

Because individual modules send and receive information to and from several other modules, each can participate in several different pathways. Cohen et al. (1990) discussed two pathways: one for color naming, the other for word reading. Each has input units (representing colors or words, respectively), intermediate units, and output units (for the responses to name the color or read the word). These pathways interact, interfering and facilitating the action of each other. Interference takes place when dissimilar patterns of activation converge on a single point of intersection, at any point in processing after sensory registration has occurred.

Following Treisman (1960), Cohen et al. (1990) suggested that attention is a modulator. They modeled its effects by having attention alter the responsiveness of the processing units in a pathway, with task demand units (one representing the demand to name the color, the other representing the demand to read the word) that are able to modify the behavior of the intermediate units (see Figure 1). Attention is thus seen not as a qualitatively different entity within the information-processing system but as an additional source of input within a processing pathway.

It is beyond the scope of the present discussion to give a detailed account of a connectionist model of the emotional Stroop. However, in the next section, we indicate how, in principle, such a model could account for the data. We suggest that there are three possible ways of modeling color-naming interference by emotional words within Cohen et al.'s (1990) model. First, input units denoting stimuli related to current concerns may be more highly practiced than others. The result of each of these would be greater relative interference at the output stage in color naming a salient word (e.g., *spider* for a spider phobic). In fact, of course, this way of modeling emotional Stroop is closest to the Cohen et al. account because their model was built to capture the practice data of MacLeod and Dunbar (1988). However, we suggest that modeling emotional Stroop phenomena in terms of practice is insufficient because it is possible to eliminate or reduce color-naming interference for emotional

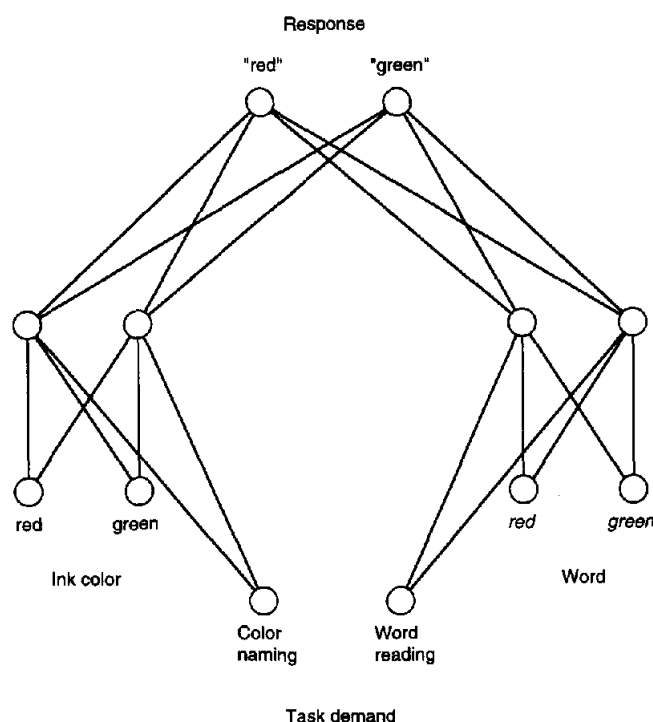


Figure 1. Diagram of Cohen et al.'s (1990, p. 336) network showing connections between input units, intermediate units, and response units. Task demand units connect to intermediate units, modulating processing by adjusting the resting levels of activation (and thus the responsiveness) of intermediate units.

words with therapy that gives additional practice but reduces the emotional impact of threatening material. Two additional ways of modeling interference, therefore, need to be considered: (a) The resting level of activation of input units for emotional words may be higher for concern-related stimuli; and (b) any such input unit, if associated with threat, might be subject to neuromodulatory control affecting the responsivity of those units. Under these circumstances, increasing the gain parameter would increase the output of these units for any given input activation level.

The model assumes color-naming interference occurs despite the fact that the task demand unit—"name color"—is operating. The task demand unit places the intermediate units for naming the ink color in the most responsive part of their dynamic range. However, the emotional salience of *spider*, its greater input activation level, or stronger connections in the word pathway means that more activation accumulates at the intermediate units, despite the task demand units for name color. The result is that, although the participant is attempting not to attend to the word, information flows along this pathway anyway.

Note the assumption that, in telling participants to name the color (attend to color naming or activating the task demand unit for color), information in the irrelevant (word reading) channel is not allocated strategic attention by the participant. The fact that it can produce interference, without relying on such attentional allocation, is consistent with the notion of the bias being

"preattentive" or "automatic" (i.e., one that does not require a strategic switch of attention). However, as Cohen et al. (1990) indicated, automatic processes are rarely completely independent of attentional control. They simply vary in how susceptible to control they are. In the emotional Stroop, like the color-conflict Stroop, word reading interferes with color naming, but participants still name the color and not the word. To see how the model accounts for emotional Stroop interference, we turn to those studies whose researchers have examined person or situational variables associated with such interference.

### Causes and Correlates of Emotional Stroop Interference

#### *Is Emotional Stroop Interference Due to Extended Practice (Expertise)?*

Cohen et al.'s (1990) connectionist model was designed to explain variation in color-conflict Stroop interference that arises from variation in the amount of practice that individuals have had with the different task components (MacLeod & Dunbar, 1988). Do interference effects on the emotional Stroop also reflect extended exposure, practice, or expertise in processing such information? Although increased expertise might be expected to produce less interference (if a word is processed faster, it might be processed before a participant needs to output the color name), MacLeod's (1991) review of the color-conflict Stroop shows how such a speed of processing view cannot account for the data. In this section, we consider what evidence there is for an expertise (or extended practice) account of the emotional Stroop.

Such an account seems, on the surface, quite plausible. In the standard emotional Stroop experiment, patients who are emotionally disturbed, who are known to ruminate on certain themes, are presented with words related to these themes which are likely to be frequently thought about and which may come to form a highly interconnected category for these individuals (Segal, Truchon, Horowitz, Gemar, & Guirguis, 1995). In short, they may have become experts in processing information related to their problem. Many of the research findings above might simply reflect this expertise: the increased frequency with which certain concepts are used or the increased intercategory associations for the particular domain of interest. Klein (1964) found that common words (e.g., *friend*) produced almost twice as much interference as did rare words (e.g., *abjure*; 12.0 s versus 7.5 s for the stimulus card for common or rare words, respectively). Although emotional and neutral words are matched for frequency in these experiments, frequency norms are unable to assess idiosyncratic frequency of usage within the domain of words representing an individual's current concerns. Any event or emotional state that increases the frequency with which an individual thinks or uses a word, if Klein's result can be generalized, increases the amount of color-naming interference for that word. The interference effects are then likely to spread to high-frequency associates of these recently used words (Warren, 1974).

**Expertise studies.** In one study relevant to such a practice or expertise effect, Mogg and Marden (1990) did not find any evidence that it contributes to the pattern of color-naming latencies. They found no more color-naming interference on

words related to rowing for members of a boat club (e.g., *sculling*) than unrelated words (e.g., *teacup*). However, the researchers were interested in examining participants' personal interest rather than their expertise per se, so this may have been a relatively weak manipulation. Consistent with the suggestion that the group to be examined must be genuine experts, Dalglish (1995) has found that keen ornithologists show color-naming interference (62 ms) for the names of rare birds (e.g., *plover*) compared with the names of musical instruments (e.g., *guitar*). Of course, it is possible that this effect was due to control participants not knowing the bird's names (treating them as nonwords). However, if this were the case, then control participants would have been predicted to show less interference in color naming the birds than the control category (musical instruments; Klein, 1964). This did not occur, suggesting that control participants were not treating the rare birds' names as nonwords. However, given the conflicting results between the two studies, we suggest that there is insufficient data to use these studies alone as a guide to whether sheer frequency of exposure accounts for the emotional Stroop.

Furthermore, the problem with studying experts who are very committed to their field, and show high frequency of expert word usage and high intercategory associations among such materials, is that these stimuli are very likely to represent concepts of emotional significance to such individuals. This is analogous to the way in which food words may come to possess considerable emotional significance for individuals who have starved for 24 hr (Lavy & van den Hout, 1993). However, it is possible to separate emotional salience, or relevance to current concern, from expertise effects by using therapy studies.

**Therapy studies.** Therapy studies are important on two counts. First, they have great practical significance. If the emotional Stroop is to have clinical currency, researchers need to be able not only to diagnose clinical psychopathology but to diagnose the efficacy of treatment from its results. Second, and relevant to the present discussion, they have a significant theoretical contribution. If emotional Stroop phenomena were due to extended practice analogous to extended practice on non-emotional tasks (MacLeod & Dunbar, 1988), one would not expect recovery to be associated with reduction in interference. This is especially true if the therapy itself involves giving patients extended exposure or practice on the object of their emotional disturbance. Such exposure should increase interference, not alleviate it.

In a study of recovery from emotional disturbance, Gotlib and Cane (1987) tested 34 inpatients with depression, comparing them with 14 controls. They found that the patients with depression showed greater color-naming interference than the controls on 50 depressive words (e.g., *gloomy*) compared with 50 neutral (e.g., *harmless*) and 50 positive (e.g., *happy*) words. However, when the patients with depression were tested again following clinical improvement that had resulted in their discharge, there was no difference between the time taken to color name the negative words and the neutral or positive words. They concluded that emotional Stroop interference was due to current depressed mood state, rather than to a chronic vulnerability to depression. One problem with this study was that the retest procedure used the same sample of 150 words, so the reduced interference might have been due to repeat testing.

Gotlib and Cane (1987) had studied recovery due to standard inpatient treatment for depression. It was unclear how much psychological therapy or exposure these patients had. However, this aspect was closely controlled in Watts et al.'s (1986) study involving therapy for the spider phobia referred to earlier. Individuals were given 6 weeks of group desensitization therapy in which they were exposed to many spider stimuli. Because they were encouraged to observe and attend to the size, shape, and other characteristics of spiders, such participants were much more practiced on spider concepts at the end of treatment than at the outset. Yet, color-naming interference for spider stimuli within this group with the spider phobia was significantly reduced (from 189 to 29 ms) as the fear of spiders reduced across the course of treatment.

Lavy et al. (1993) gave exposure treatment lasting 2½ hr to 36 participants with spider phobia. Stroop interference on spider words (e.g., *hairy*) compared with neutral words (e.g., *potato*) was 39 ms before treatment, but it reduced to 16 ms after treatment. Furthermore, there was a significant correlation between the extent of reduction in interference and the improvement in a behavioral measure of phobic avoidance (a 13-point scale representing how closely a participant would pull a glass jar containing a live spider, *Tegenaria atrica*, 3 cm long toward himself or herself).

The problem with these sort of experimental designs is the unknown extent to which general practice effects on the emotional Stroop task may reduce color-naming interference on the second occasion of testing. Considerable test-retest practice effects occurred in the nontreated group in Watts et al.'s (1986) study, and they concluded that it would have been better to use a matched list of words counterbalanced for the pretest and posttest. Similarly, Lavy et al. (1993) used the same list of words before and after treatment, and although they had a control group without phobias which did not show any change in interference, this may have been due to a floor effect.

However, a recent study by Mathews, Mogg, Kentish, and Eysenck (1995) did use parallel forms of the Stroop task and still found that patient's Stroop interference disappeared on recovery. They studied 24 patients with anxiety undergoing group anxiety management training. The patients were tested while in episode and again when recovered, using parallel forms of the emotional Stroop task: physical threat words (e.g., *disease*), social threat words (e.g., *pathetic*), positive words (e.g., *adorable*), and neutral words (e.g., *geometry*). They found that the pretreatment difference between patients and controls in the degree of emotional Stroop interference (45 ms) disappeared by the end of the treatment 17 weeks later (1 ms). Thus, color-naming interference for threat words, which had been present in these patients before treatment, had normalized at posttreatment and was not due to repetition of the same words at pre- and posttest.

Finally, Mattia, Heimberg, and Hope (1993) examined emotional Stroop interference on words representing social threat (e.g., *inadequate*), in patients with social phobias who were undergoing a 12-week group cognitive-behavioral program or phenelzine treatment. They did not report whether these treatments had differential outcome but rather divided the entire sample of patients into those who responded to treatment ( $n = 17$ ) and those who did not ( $n = 12$ ; as rated blind on a clinicians



severity rating). Treatment responders showed a reduction in the amount of color-naming interference shown on social threat words ( $-89$  ms), whereas the nonresponders displayed increased color-naming interference on such stimuli ( $+11$  ms).

The best test of whether practice plays a role in emotional Stroop interference remains the comparison between a treated and an identical but untreated group. The spider phobia desensitization study of Watts et al. (1986) showed that, despite multiple exposures to spiders during treatment, far from increasing Stroop interference such practice or increased expertise significantly reduced it. We conclude that frequency of usage or intercategory association due to practice or expertise does not explain Stroop interference in emotional disorders.

This conclusion has consequences for the Cohen et al.'s (1990) model discussed earlier. This was designed to explain how variation in automaticity (brought about by different amounts of practice) affects color naming. To account for reduced interference on negative material brought about by therapy, we need to assume that other parameters in the model are responsible for emotional Stroop interference and that these are affected by treatment. There are two other ways of accounting for color-naming interference by emotional words within Cohen et al.'s model. First, input units for such words may have a higher resting level of activation. Second, any such input unit, if associated with threat or loss, might be subject to neuromodulatory control, affecting the responsivity of those units.

To understand how this occurs, consider an input unit for the word *spider*. Whether the unit is active depends on its *net input* (a weighted sum of the inputs) and the unit's *activation function*. Different models use different activation functions (see Williams & Oaksford, 1992). Following Cohen et al. (1990), we assume a sigmoid activation function, which produces a continuous output between 0 and 1 for various levels of activation input. At very low or very high input levels, small changes in levels of input activation make little difference to output levels. However, in the middle range of activation, relatively small changes have a larger effect on output—the unit is at its most sensitive.

Returning to our example of the input unit for the word *spider*, let us assume that its resting level of input activation is higher for people who are spider avoidant (e.g., 0.6; compared with controls not having phobias, 0.4). Let us also assume that the resting level of input activation for a neutral word (e.g., *fireplace*) is 0.3 for both patients with the phobia and controls. The result is chronically higher activation output when a patient with the phobia sees the word *spider*, increasing the activation level throughout the word-reading pathway and resulting in greater interference with color naming at the response module. The patient with the phobia normally shows little interference for the word *fireplace*, and the control shows little interference for either word.

Higher trait anxiety involves frequent rumination on negative themes and worries, which increases the resting activation level for input units representing these worries. In a similar way, relatively short-term goals increase resting activation levels of the input units representing them. So if a person is currently searching for a fireplace for his or her new house, the resting activation level for *fireplace* increases. Any stimulus input in the environment to do with fireplaces (magazine advertise-

ments, etc.) has a greater relative output and interferes more with other ongoing task demands.

The activation function also makes clear the third way in which emotion may affect color-naming interference because the gain parameter itself can be changed, steepening or flattening the activation function. A similar methodology was adopted in Cohen and Servan-Schreiber's (1989) model of cognitive deficits in patients with schizophrenia, where the gain parameter was turned down in a subset of units in the model. They treated this intervention as analogous to the biological effects of dopamine deficiency.

We assume that there is similar neuromodulatory control of those input units that have been associated with threat or loss for an individual. For example, the neurotransmitter norepinephrine may act in just such a way on anxiety. It is distributed throughout the brain, with a major site of origin being the locus coeruleus. Lesions at this site lead to decreased levels of norepinephrine and impair a number of tasks that depend on the organism's sensitivity to punishment or nonreward (Gray, 1990).

We suggest that any input unit that has been associated with punishment or fear in the past acquires a threat "tag," becoming thereby susceptible to such neuromodulatory influence. The result of such neuromodulatory increase in the gain parameter is that all such tagged units increase output for any given level of input. Thus, the effect of increased neurotransmitter for anxiety is a general increase in activity in pathways representing words related to threat for that individual. Note that this does not require the assumption that these words be associated with each other, avoiding the need to assume increased interitem association in people with anxiety. So if a person has a history that has given rise to a fear of spiders, dark closets, and German Shepherds, each of these are separately tagged for threat. Increased neurotransmitter activity for anxiety increases the activation function for each concept without the need to assume they are part of the same "danger schema."

In summary, there are two ways (apart from increased practice) of modeling emotional Stroop performance. First, emotional or personal salience ("current concern") may be represented by the resting activation level of input units. Second, input units may become tagged by a history of association with threat or loss and thereby be subject to neuromodulatory control affecting the responsivity of those units. If only the first of these processes operate, then we would predict that Stroop interference would occur for any material that is relevant to a person's current concern (whether positive or negative). If the second of these processes operate instead of or in addition to the first, then we would predict that the negativity (threat or loss value) of material would have an added interference effect over and above the effect of personal relevance. We therefore turn to consider studies whose researchers have examined the question of personal salience versus negativity.

### *Specificity of Interference Effects to Stimuli of Personal Concern*

Martin, Williams, and Clark (1991) were the first to examine emotional Stroop interference for both positive and negative material matched for emotionality. Compared with their performance on neutral words, patients with anxiety showed sim-

ilar color-naming interference on positive words (e.g., *joyful*, 58 ms) as on threat words (e.g., *lonely*, 72 ms). Similar effects have been found in other studies. Mogg and Marden (1990) used frequency matched positive (*ecstasy*), neutral (*teacup*), and negative (*assault*) words. The positive and negative words were also matched for emotionality (rated by six independent judges). They found participants with high-trait anxiety showed interference on positive and negative words, compared with neutral words.

The finding that color-naming interference may be shown on emotionally valent stimuli whether positive or negative is potentially important. It calls into question those explanations of the emotional Stroop that assume that emotionally disturbed people have increased accessibility only to threat information (danger schemata; Beck et al., 1985). However, it is possible that interference due to the emotionality of the words reported earlier was not due to their emotionality per se, but rather it was due to the degree to which the words were semantically related to the schemata of the individuals tested. The word *achievement* may be positive in tone, but for a person with anxiety and concerned with an imminent examination, the important aspect of the concept is its relevance to the person's current concern, his or her current goals and intentions (Klinger, 1987; Klinger et al., 1981). This would be consistent with the pattern of data emerging from a number of studies showing a greater degree of interference on words that refer specifically to the theme of the emotional disturbance (see initial discussion of Table 1) and reflected in other studies outside the domain of emotion, for example, increase in specific interference for words with a food theme for participants who have fasted for 24 hr (Lavy & van den Hout, 1993). In each case, words of equivalent emotional valence, unrelated to the theme, were not so likely to produce interference as were specific theme-related words.

Does the relatedness of words to a person's current concern explain the findings of color-naming interference on emotional stimuli? To examine this, we need to find a study that independently varies the degree of specific relevance to personal concern and the emotional valence of the word stimuli.

Mathews and Klug (1993) addressed the issue of relatedness versus emotionality. They tested patients with anxiety (a mixed diagnostic group of GAD, panic disorder, and social phobia) and controls using words that varied independently in their hedonic tone (*positive-negative*) and degree of relatedness to anxiety (*related-unrelated*). Thus, some words were emotionally negative and related specifically to anxiety (e.g., *shaking*, *crazy*, *nervous*, and *panic*); others were negative but unrelated to anxiety symptoms (e.g., *negative*, *sin*, *quarrel*, and *destructive*). Similarly, positive words were either related to the concerns of people with anxiety, by referring to traits that these individuals strive for (e.g., *fearless*, *competent*, *relaxed*, and *confident*), or unrelated to such concerns (e.g., *beauty*, *brilliant*, *pride*, and *mercy*). There were also a set of matched neutral words, totaling five sets in all. Each set of eight words was printed on cards, repeated 12 times on each card (96 words per card).

Results showed that it was the relatedness of the words to anxiety (either positive or negative) and not the emotional valence of the words that accounted for the patterns of color-naming interference. Patients with anxiety showed significantly more interference on anxiety-related words than anxiety-unre-

lated words, irrespective of hedonic tone, whereas controls showed no difference in color-naming latencies across the different word lists. Mathews and Klug (1993) suggested that differences in whether participants in previous experiments showed interference, and whether such disruption was shown for positive words as well as for negative words, depended on whether the words happened to relate to the concerns of the participants (by referring to their feared situations, to their anxiety symptoms, or to traits they actively desired due to their anxiety symptoms).

Further evidence to support this conclusion has been found by Riemann and McNally (1995). They produced idiographic lists for their group of students ( $N = 45$ ), choosing words for a computer version of the emotional Stroop for each student based on the results of an earlier administration of Cox and Klinger's (1988) Motivational Structure Questionnaire (MSQ). The MSQ lists 15 content areas (family and home; friends; marriage, relations, love, and sex; physical health; mental and emotional health; employment, job, and money; education; organizations; religion; government, politics, and labor union activities; hobbies and pastimes; sports and recreation; entertainment; travel; and crime). Participants chose the 2 most positive and the 2 most negative content areas for them at that time and were then asked to write a brief explanation of the particular concerns they had within each domain. In this way, the researchers were able to choose words that varied in degree of relatedness to current concern (low and high) and in valence (positive and negative). Results showed that the words related to high-negative current concern and high-positive current concern produced more color-naming interference than did low-negative and low-positive current concern and neutral words. We conclude that relatedness to current concern is necessary for interference on the emotional Stroop to occur. In nonclinical groups, it may also be sufficient. However, is relatedness to current concern sufficient to explain patterns of interference in clinical groups?

In fact, the evidence suggests that patients show interference to negative material over and above interference that can be explained by relatedness of material to personal concerns. Cassidy et al. (1992) used positive words as well as a range of threatening words with 12 individuals who had been raped who had PTSD (compared with 12 individuals who had been raped without PTSD and 12 controls). Not only did they find increased color-naming latencies on the positive words, compared with the neutral words, but also for these participants threat words were even more interfering (175 ms) than were the positive words (80 ms). Furthermore, in McNally et al.'s (1992) study, patients with panic disorder showed more interference on catastrophe words, despite rating the positive words as more emotional. Similarly, McNally et al. (1994) found that emotional Stroop interference in 16 patients with panic disorder was greater for specific panic words (*fear*, *dizzy*, and *anxious*; 36 ms interference) than their near antonyms (*safe*, *steady*, and *carefree*; 8 ms facilitation).

One problem with McNally et al.'s (1994) study was that the words had not been chosen to represent the traits of particular relevance to individual patients. However, other researchers had chosen the words idiographically yet still found negative personally relevant stimuli to be more disruptive than positive

personally relevant material. Lavy, van Oppen, and van den Hout (1994) examined color-naming interference in 33 patients with OCD. They used a 2 × 2 matrix of words, related-unrelated to OCD and positively-negatively valenced (related: *clean* and *filthy*; unrelated: *hate* and *love*). They also found color-naming latencies to be increased on negatively valenced words for the patients with OCD, but specific relatedness of words to the disorder was not associated with any further elevation of color-naming latencies in these patients (OCD-negative words, 108 ms interference; OCD-related positive words, 15 ms interference).

Similarly, Segal et al. (1995), following up a previous study (Segal & Valla, 1990), examined Stroop performance of patients with depression using positive and negative trait adjectives (such as *trustworthy* or *quarrelsome*) that had been selected by the patients as self-descriptive. These words were presented to patients or matched controls without depression following primes denoting interpersonal situations such as "able to feel close" or "I often feel judged," a manipulation intended to activate the individual's self schema. The results replicated Pratto and John's (1991) finding that negative trait adjectives were in general more disruptive to color naming than were positive adjectives. Furthermore, trait adjectives that had been rated as self-related took longer to color name than trait adjectives that were not self-related, consistent with Mathews and Klug (1993) and Riemann and McNally's (1995) finding. However, Segal et al. (1995) also found that, for patients with depression, being exposed to a prime that was self-relevant disproportionately delayed color naming of a self-relevant trait word if it was negative. They suggested that, although relatedness to personally relevant concerns is an important variable, the greater interconnectedness of negative current concerns for people who are emotionally disturbed may make words related to these concerns particularly liable to interfere with color naming.

In summary, relatedness to current concern is necessary to explain Stroop interference in nonclinical participants. However, in clinical patients, it is not sufficient. In patients, both the relevance to schemata and the negativity of the material is important in determining the extent to which color naming will be disrupted.

### *When Stroop Interference Is Absent: Strategic Override or Null Effects?*

Not all the studies listed in Table 1 show emotional Stroop interference in all the experimental conditions predicted. In this section, we consider whether these are best considered as non-replications or whether there is any pattern to suggest that, under some circumstances, individuals may override the tendency for salient stimuli to interfere. Martin et al. (1991) compared 12 participants with high-, 12 participants with medium-, and 12 controls with low-trait anxiety in color naming of threat (*disease* and *pathetic*) versus nonthreat (*contented*) words and found no difference in emotional Stroop interference between the groups. Although the number of participants might have been too small to show any effect, other studies have found effects with similar numbers (e.g., Richards & French, 1990,

showed 120 ms interference effect with 13 and 14 participants in the high- and low-trait anxious groups, respectively).

Furthermore, Martin et al. (1991) went on to examine emotional Stroop performance in 12 patients that were clinically diagnosed as anxious (diagnosed as suffering from GAD) who had equivalent levels of trait anxiety to the nonclinical controls who were high-trait anxious. The patients who were clinically diagnosed as anxious showed emotional Stroop interference (20 ms), whereas the matched nonclinical participants with high-trait anxiety showed facilitated performance on threat words (27 ms). This study, therefore, suggests that it was clinical status rather than high-trait anxiety per se associated with emotional Stroop interference.

This study can be criticized. First, although Martin et al. (1991) reported two studies in which nonclinical participants with high-trait anxiety did not show emotional Stroop interference, in their Experiment 2, comparing nonclinical participants having high-trait anxiety with patients with anxiety, they used the same sample of nonclinical participants they had used in Experiment 1. Because it had been this first study that had found, contrary to prediction, no difference between participants with high- and low-trait anxiety in Stroop performance, to use the same participants as controls in a second study is to capitalize on the possibility that the sample might have been unrepresentative.

Nevertheless, Martin et al.'s (1991) result was the first to raise the important possibility that there were circumstances in which participants might be able to use explicit strategies to override the tendency for threatening material to cause disruption in color naming. Other researchers have found similar results. For example, MacLeod and Rutherford (1992) and Mogg, Kentish, et al. (1993), in experiments that examined both subliminal and supraliminal presentation of emotional stimuli, found that the degree of interference in color naming correlated with trait anxiety for subliminally presented but not supraliminally presented stimuli.

Note that no researchers testing patients who were clinically diagnosed as anxious have found such null results. Mathews and MacLeod (1994) suggested that participants who were anxious but nonclinically diagnosed as such are able to override the tendency to be distracted by emotional material. If so, this would have important implications for how breakdown occurs. We need to address the question of when such an explicit strategy is used and what its signature is (that is, how do we know that a participant is using a strategy, rather than simply not showing the effect). To do so, it is helpful to examine a study by Mathews and Sebastian (1993) that brought the occurrence or nonoccurrence of emotional Stroop interference under experimental control.

Mathews and Sebastian (1993) varied the context by having the object of participants' fear either present or absent. They tested participants who are snake avoidant and controls on words related to snakes (e.g., *cobra*), to a general threat (e.g., *fail*), or to a neutral household theme (e.g., *spoon*). All participants were tested in the presence of a boa constrictor (and were told there would be a behavioral test after the emotional Stroop task to see how close they could get to the snake). Under these conditions, they did not find, within the color-naming latency data, the predicted interference in patients with phobias. There

was no interaction between word type (snake-related, general threat, and control words) and group (snake avoidant vs. control). In a further experiment without the snake, the predicted effect was obtained, with snake-avoidant participants showing greatest color-naming interference on words related to snakes. In a third experiment focusing only on participants who avoid snakes, the situational stress was reimposed, but a large spider was substituted for the boa constrictor for half the participants. When the spider was absent, participants showed the predicted Stroop interference on snake words. Participants tested with a spider, however, showed no such interference.

If this pattern of results is due to the ability of nonclinical participants to override Stroop interference, as Mathews and MacLeod (1994) have suggested, what is the signature of such override?

Consider Mathews and Sebastian's (1993) experiment in terms of Cohen et al.'s (1990) connectionist model. If we assume that the input unit for *snake* and related concepts become most active with the snake present, then the word *snake* tends to be output, *unless* the color-naming task demand unit is strengthened. To complete the task at all, participants have to expend more effort in following the task instructions of "name the color." We suggest that the reduced interference is explained by the increase in an effort required to perform the task under these conditions. Cohen et al. (p. 351) showed that when the task demand unit associated with color naming is increased, interference is reduced. However, the model also showed that as task demand to name color increases, overall latency to respond is reduced, that is, participants become generally faster in performing the entire task.

We, therefore, returned to the data of Mathews and Sebastian (1993) to see if such a reduced latency to respond occurred. The data, shown in Figure 2, show that this is precisely what happened in their experiment. Furthermore, the latency for nonemotional words was also reduced with the feared object present, consistent with the Cohen et al. (1990) model's findings that such an effect of increased task demand unit activation for name color is generalized across all material.

The connectionist model thus not only gives an account of how participants may be able to override attentional bias by increasing effort expended in naming the color (increasing the task demand units) but also suggests a potential signature for such override: a general speeding of response, including speed on color naming neutral stimuli. If such an override phenomenon is used to explain the lack of color-naming interference in other studies, then this signature of override should be present. There are four studies that report such null findings that also give sufficient details to determine overall speed of performance (Martin et al., 1991, Experiment 1; Martin et al., 1991, Experiment 2; MacLeod & Rutherford, 1992; Fox, 1993).

Data from Martin et al. (1991) Experiment 1 show that, overall, the participants with high-trait anxiety were indeed 18 ms faster than the participants with low-trait anxiety. In Experiment 2, in which patients with anxiety were compared with nonpatients with high anxiety (matched for trait anxiety levels), their Figure 1 (p. 152) shows the nonclinical group to be approximately 125 ms faster than the group clinically diagnosed as anxious.

MacLeod and Rutherford (1992) found that controls with

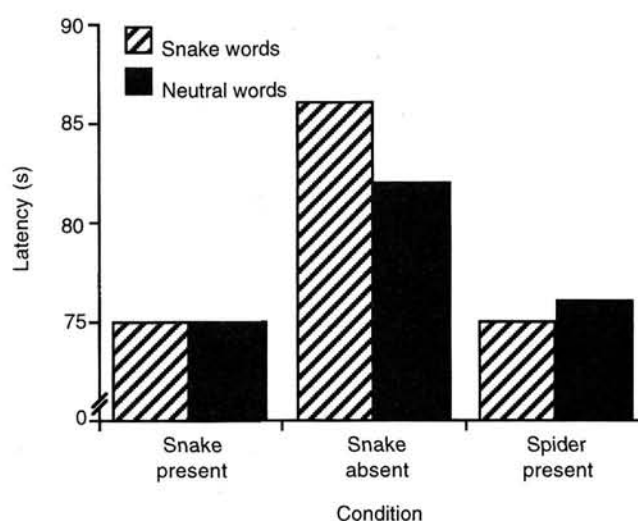


Figure 2. Mean latency to name snake-related or matched neutral words by participants who are snake avoidant when with or without snake (Experiment 1) or spider (Experiment 3) (data from Mathews & Sebastian, 1993).

high-trait anxiety did not show color-naming interference to examination threat or general threat words if these words were presented supraliminally. Once again, if this was override rather than a null result, then there should be evidence of generally speeded performance. Indeed, a reexamination of the results show that, overall, the group with high-trait anxiety was 9.5 ms faster than the low-trait anxious group for threat words and 17.5 ms faster than the group with low-trait anxiety for color-naming neutral words.

Finally, Fox (1993) found that participants with high-trait anxiety did not show the predicted color-naming interference across any of three conditions: traditional Stroop, separation of color patch and word by 1.5 degrees, and separation by 2.5 degrees. Reexamination of her results shows that the group with high-anxiety were generally faster to respond to the stimuli by 10, 29, and 31 ms for the traditional, 1.5 degree separation, and 2.5 degree separation, respectively. Looking at only the neutral words, the data show that participants with high-trait anxiety named the color of these stimuli on average 16 ms faster than did the participants with low-trait anxiety.

Only in the case of Martin et al. (1991) was the group main effect for overall speed of performance significant. This is not surprising because the number of participants that would be required to test for such a between-groups difference is much higher than that required to yield a significant interference effect (a within-subject effect). Nevertheless, the consistency of the finding across four experiments that, when individuals with high-trait anxiety do not show interference, they show a general speeding of all responses, added to the finding of a similar phenomenon in Mathews and Sebastian's (1993) study, suggests that such speeding may well signify that participants are adopting a conscious strategy to override the effect of the salient stimuli by increasing the task demand unit name color.

Further experiments are needed to determine the precise conditions under which exposure to such manipulations increases

or decreases interference and to answer the question why increased anxiety in other contexts does not also increase the task demand unit activation. One possibility is that reduced interference occurs (as in the case of direct exposure to a feared object) when completion of the task at all demands large increases in task demand unit activation. Although this remains speculative at this time, the connectionist framework offers a useful heuristic within which experimental predictions may be made.

### The Emotional Stroop and Psychopathology

How far has the emotional Stroop task been able to meet the goal of explaining attentional bias in emotional disorders? The most common use of the task has been to demonstrate that attentional bias exists in a disorder. We have seen that color-naming bias is to be found across a wide range of disorders. However, it is in the domain of anxiety that most research has been carried out on the questions of the causes and mechanisms mediating the bias.

We have suggested that Cohen et al.'s (1990) connectionist model of the original Stroop can serve as a heuristic framework for modeling the attentional bias associated with emotion. In particular, it offers a way of understanding the mechanisms underlying emotional Stroop performance, including notions of current concern, danger schema, and expertise. Each of these explanations can be represented in the model. Thus, we have seen that individuals are sensitive to how related a theme is to their personal concerns (Mathews & Klug, 1993; Riemann & McNally, 1995). We suggest that this attentional bias toward personally relevant themes may arise from differences in the resting activation level of input units.

However, our review has also shown that individuals with emotional disturbance show disproportionate color-naming interference for negative stimuli over and above the attentional bias toward stimuli of current concern (Cassiday et al., 1992; Lavy et al., 1994; McNally et al., 1994; Segal et al., 1995). We have suggested that this additional interference by threat stimuli may arise from the neuromodulatory control of input units that represent items having a history of association with threat.

Finally, although our review found that expertise explanations of emotional Stroop interference was unlikely to explain the majority of the findings, it remains possible that some long-term personal concerns will be best understood as increased expertise in processing that domain of information (Daggleish, 1995). We suggest that emotional Stroop interference arising from such expertise may arise from the greater strength of the processing pathway for those inputs following prolonged training with that material.

How generalizable is the connectionist framework likely to be? Its utility would be further enhanced if it could model other biases in attention associated with emotional disturbance, such as the visual dot probe task (MacLeod, Mathews, & Tata, 1986) or dichotic listening tasks (Mathews & MacLeod, 1986). In the connectionist model, *attention* is defined as the modulation of processing, causing a shift in the responsiveness of units in competing processing pathways. Attention is viewed as simply an additional source of information, providing a sustained context for the processing of information in a particular pathway. Few

changes are therefore necessary, such that the same model of pathway modulation that explains task selection (color naming or word reading) in Stroop can be used to account for spatial allocation of attention in the dot probe tasks or channel selection in dichotic listening tasks. For these paradigms, the feature dimensions of the Stroop need only be replaced by networks of units corresponding to, for example, different spatial locations. In such a system, attention bias units are assumed to represent different locations, with attention able to be "allocated" to different locations such that information in those locations are processed to a greater degree. The ability of the connectionist model to generalize to these other selective attention tasks is explicitly seen as one of its major advantages (Cohen et al., 1990, p. 355).

How can such a model be integrated into the more general picture of what occurs when emotional stimuli are encountered? Given that all participants, both clinical and nonclinical, show interference with material that is personally relevant, can it explain emotional breakdown—the transition from high-trait to clinical status?

Following Oatley and Johnson-Laird (1987) and Mathews and MacLeod (1994), we assume that stimuli in the environment that represent a juncture in pursuit or avoidance of desired or undesired outcomes produce a change in processing priorities. In terms of the current model, input units associated with the new processing mode become activated by way of neuromodulatory control of the gain parameter of such units. Depending on the frequency and variety of contexts in which such units have been activated in the past, this activation may be relatively generalized (modeling the effect of high-trait anxiety) or relatively specific (modeling the effect of exam stress in individuals with low-trait anxiety).

The model explains the ability of participants to override attentional bias in some circumstances by increasing effort expended in naming the color (increasing the task demand units). Whereas such an override has been found in nonclinical participants, such as controls with high-trait anxiety and students who are snake avoidant (Martin et al., 1991; Mathews & Sebastian, 1993), it has not been observed in clinical groups. This is consistent with the suggestion by Mathews and MacLeod (1994) that breakdown occurs when an individual can no longer expend the extra effort required to override the tendency for concern-related stimuli to capture attention. When able to override attentional bias, nonclinical participants are able to "exit" the vicious spiral described at the outset of this article: emotional disturbance (associated with goal junctures) causing attentional bias, leading to increased salience of negative material, leading to increased probability of harm and increased emotional disturbance.

Breakdown occurs as the task demand units' greater activation eventually gives way to the increased strength in the competing processing pathway. Because this strength from input units denoting current concerns may have been increasing for some time (though compensated for by increases in activation of task demand units), removal of the influence of the task demand units results in an abrupt and catastrophic increase in input from the processing pathways associated with the concern. The misinterpretation of such stimuli (e.g., bodily sensation in people who panic) may be due to the abruptness and size



of the switch of processing pathways when the effort to override input from concern-related units reaches its limit. The bias in color naming found in subliminal Stroop tasks is not so amenable to such override strategies and may therefore be a more sensitive measure of current concern. Consistent with this, MacLeod and Hagan (1992) found that the degree of bias on a subliminal Stroop (representing physical health concerns) performed before receiving results of a physical examination predicted the degree of a patient's emotional disturbance when they received the results. The degree of disturbance on the supraliminal version of the same task did not predict emotional disturbance. An important issue for further research to determine is whether the loss of ability to use such inhibitory (override) strategies are a symptom of clinical status or the cause of it. The most promising experimental paradigm to examine this question is used by Mathews and Sebastian (1993), in which such inhibitory mechanisms are brought under experimental control by the presence or absence of a phobic stimulus.

Such results show that the emotional Stroop task is fulfilling much of its early promise as a way of establishing the extent to which attentional bias is involved in the maintenance of emotional psychopathology. It is not due to artifactual variables. It is sensitive to the differences between types of psychopathology and shows whether individuals have recovered from their emotional disturbance. The next phase in research is to match the advances made in understanding the circumstances in which such attentional bias is found with advances in specifying more precisely the mechanisms that mediate such bias. For this to occur, we need to have models that can apply to both the original color-conflict situation and the emotional Stroop. We have seen that models now exist that promise that further bridges can be built between understanding normal and pathological attentional processes.

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