THE AUTOMATICITY OF EMOTIONAL STROOP: A META-ANALYSIS

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Abstract

An automatic bias to threat is often invoked to account for color-naming interference in emotional Stroop. Recent findings by McKenna and Sharma (2004), however, cast doubt on the fast and nonconscious nature of emotional Stroop. Interference by threat words only occurred with color naming in the trial subsequent to the threat trial (i.e., a ‘slow’ effect), but not immediately (i.e., a ‘fast’ effect, as would be predicted by the bias hypothesis). In a meta-analysis of 70 published emotional Stroop studies the largest effects occurred when presentation of threat words was blocked, suggesting a strong contribution by slow interference. We did not find evidence, moreover, for interference in suboptimal (less conscious) presentation conditions and the only significant effects were observed in optimal (fully conscious) conditions with high-anxious nonclinical participants and patients. The emotional Stroop effect seems to rely more on a slow disengagement process than on a fast, automatic, bias.

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Emotion deals with things that are important and should, therefore, receive information processing priority (Compton, 2003). It is plausible that some emotional stimuli are picked up very quickly and set up the system in a particular emotional processing mode (Oatley & Johnson-Laird, 1987). Evolution has enabled the brain to shift processing priorities on the basis of stimuli that are not even fully perceived. Particular classes of privileged stimuli, such as several types of vermin, facial expressions, but also blood and mutilations, have signaled emotional relevance throughout evolutionary history. These evolutionary prepared stimuli (e.g., Öhman & Mineka, 2001) may have become engraved in our brains and activate emotional processing modes even at weak strengths or short durations. Evolutionary preparation is probably responsible for the paradoxical finding that affective priming by happy and angry faces gets stronger when presentation becomes weaker and conscious processing is presumably reduced (i.e., stronger-suboptimal-than-optimal affective priming; Murphy & Zajonc, 1993; Rotteveel, de Groot, Geutskens & Phaf, 2001).

A stronger-suboptimal-than-optimal pattern has also been claimed for the emotional Stroop task (Fox, 1996). The slowing of color naming by fear words in high anxious groups is traditionally accounted for by an automatic bias directing attention towards the emotional meaning of the words (Williams, Watts, MacLeod & Mathews, 1988). In classic Stroop, when naming the color of the letters of color words, automaticity of word reading has been inferred from asymmetrical interference effects. Only color naming is affected by word meaning, but word reading remains impervious to letter color (but see Durgin, 2000, for a reverse classic Stroop effect). This argument does not hold for emotional Stroop because colors and fear meanings do not lie on the same dimension (see Algom, Chajut & Lev, 2004). The primary evidence for automaticity with emotional Stroop seems to come from experiments with ‘subliminal’ presentation (i.e., by short presentation and masking to prevent, or at least

reduce, conscious perception) of fear words. To avoid the notion of a consciousness threshold (i.e., ‘limen’), implying an identity position on conscious and nonconscious processing (e.g., see Mandler, 1996), we, however, prefer the terms ‘suboptimal’ and ‘optimal’ above ‘subliminal’ and ‘supraliminal’. In the automatic bias view, moreover, conscious processing may counteract automatic effects, so that interference by suboptimally presented threat words can even exceed interference in optimal conditions (MacLeod & Hagan, 1992; MacLeod & Rutherford, 1993; Fox, 1996).

Some pictures and sounds may have been evolutionary prepared, but can this also be the case for emotion words? Words from the same emotional category do not share obvious perceptual characteristics. Across different languages, words with the same emotional meaning may look quite differently. In view of the large number of different languages that exist, it is unlikely that particular emotion words share a large part of our species’ evolutionary history. Fast neural routes (e.g., LeDoux, 1996) are probably dedicated to processing evolutionary prepared stimuli. Electrophysiological studies, however, suggest that the emotional value of words is encoded relatively later in the brain than of facial expressions (for a review, see Compton, 2003). An evolutionary account for the automatic processing of emotion words, thus, seems implausible.

Automaticity in the emotional Stroop task may also arise through extended practice with emotion words (e.g., Phaf, Christoffels, Waldorp & den Dulk, 1998) or may be acquired during ontogeny in other ways (see Williams, Mathews & MacLeod, 1996). For the classic Stroop task, however, the evidence in favor of automatic processing through practice with the color words is also rather mixed (see MacLeod, 1991), and automaticity even appears to be contradicted by a number of experimental results (Besner, Stolz & Boutilier, 1997; Durgin, 2000). Williams et al. (1996), moreover, reject the practice hypothesis for the emotional Stroop task because interference appears to decrease after therapy, which constitutes

additional practice with threat-related material. They hypothesize instead that the gain of the neural centers involved in processing threat words has been selectively enhanced by past (fear-)tagging, through neuromodulators such as norepinephrine. This neuromodulatory enhancement should, however, also apply to optimal conditions and does not predict a special position for suboptimal Stroop conditions. Both the practice and the neuromodulatory tagging accounts for automaticity in emotional Stroop thus appear to run into difficulties.

In the automaticity view, all attentional selectivity, and all forms of distracter interference, is assumed to result from competition for resources from some limited capacity reservoir. Automatic processes do not require such resources and are capable of running concurrently with other processes without experiencing interference. Conversely, the automatic processes (e.g., word reading) would be able to draw resources away and thus interfere with other processes (e.g., color naming). Particularly the limited capacity aspect of automaticity has been forcefully criticized by a number of authors (e.g., Allport, 1989). With respect to emotional perception, a strong automaticity position has been falsified by the finding of top-down attentional modulation of the processing of suboptimally presented emotional stimuli (see Pessoa, 2005). At present, only a more diluted version of automaticity, involving stimulus-driven, fast, and nonconscious processing, but not total insensitivity to interference, appears to survive.

An interesting study by McKenna and Sharma (2004, for supporting findings, see Algom et al., 2004; Waters, Sayette, Franken & Schwartz, 2005) casts further doubt on the automaticity of emotional Stroop, and particularly on whether emotional Stroop interference constitutes a fast process. Card versions, when emotion words are blocked together (e.g., Richards, French, Johnson, Naparstek & Williams, 1992; Waters, Sayette & Wertz, 2003), generally yield larger effects than computer presentation when neutral and emotion words are mixed. McKenna and Sharma explained this by the effects of the emotion words carrying

over to subsequent trials, which they called a ‘slow’ emotional Stroop effect. Slow effects were contrasted to fast, presumably automatic, interference effects that should be observed in the trial itself. They measured interference in the target trial and for six consecutive trials with short inter-trial intervals. Both in the emotional and neutral target conditions all subsequent trials consisted of neutral words. Interference by threat words only occurred with color naming in the neutral trial following the fear trial. A slow effect, in the absence of fast emotional Stroop, cannot easily be explained in terms of automatic processing.

McKenna and Sharma (2004) even succeeded in showing negative interference, that is facilitation, by cleverly distributing threat and control trials. If a non-random order is created by always putting a control trial after a threat trial and vice versa, then, assuming only slow interference, reaction times are longer in control than in threat trials. Because subjectively random sequences tend to avoid repetitions (see McKenna & Sharma, 2004), such pseudo-random sequences of Stroop trials will generally yield smaller Stroop effects than genuinely random sequences. Slow Stroop, therefore, does not preclude an interference effect with mixed presentation. Well-randomized designs may reveal some interference, even when there is no fast Stroop effect.

In the dominant account for emotional Stroop (e.g., Fox, 1996; Mathews & Mackintosh, 1998; Mathews & MacLeod, 2002; Mogg & Bradley, 2005; Williams et al., 1988; Williams et al., 1996) general anxiety is accompanied by an automatic tendency to shift processing priorities to potentially threatening material, leading to interference in color naming. The automatic bias is considered an example of the information processing modes (Oatley & Johnson-Laird, 1987) activated by specific emotions (e.g., Mogg & Bradley, 2005). The hypothesis is, thus, embedded in general emotion theory, and would be expected to apply to both clinical and nonclinical individuals showing elevated levels of general anxiety. In their review on emotional Stroop and psychopathology, Williams et al. (1996) also noted that

hypervigilance to cues signaling impending danger is a central feature in many models of anxiety, and that individual differences in, both clinical and subclinical, anxiety play an important role in emotional Stroop.

A remarkable aspect of McKenna and Sharma's data was that slow emotional Stroop was obtained in an unselected group of subjects. No distinction was made between high- and low-anxious groups. A possible solution to the apparent discrepancy between this study and previous findings would be to assume that slow emotional Stroop occurs in all persons, irrespective of anxiety status, whereas fast Stroop can only be found for high-anxious persons and patients. Alternatively, there may have been a considerable number of high-anxious among the undergraduates participating in McKenna and Sharma's experiments causing the slow effects, and there may be no fast Stroop effect, even for high-anxious individuals.

A large number of emotional Stroop studies has been published by now, but it is unclear how fast and slow effects are distributed among them and how many actually reflect automatic processing. Initially, when the emotional Stroop effect was discovered, there may have been a strong bias towards publishing only significant results. This bias may have eased when the task became established and no longer was the main focus of a study but served as an additional control measure. Ten years after the major review by Williams et al. (1996), a meta-analysis including newer studies may provide a finer insight into which type of Stroop effect survives closer scrutiny. In order to investigate these issues, we conducted a meta-analysis on emotional Stroop findings with both clinical and nonclinical groups varying in trait-anxiety level when threat words either were presented very shortly (i.e., suboptimal) or were clearly visible (i.e., optimal) and when trials were either blocked or mixed. Because the automatic bias towards threat is considered a general emotional process, we focused on studies measuring general anxiety and presenting general threat words in the emotional Stroop task. Studies using specific threat words (e.g., phobia-related words) fell outside the

scope of the present meta-analysis. We calculated, according to the Hedges-Olkin (1985) method, effect sizes for interference in color naming times by the emotion words relative to the neutral words.

Meta-Analysis

An extensive literature review eventually yielded a total of 182 effect sizes provided by 70 studies (with results from 3574 different individuals) that were suitable for inclusion in the meta-analysis. The studies encountered initially in our search differed widely in quality. An unpublished study, for instance, presented words morphologically (e.g., “hatRED”) or semantically (e.g., “grass”) related to colors. The first line of defense against such methodological flaws is, of course, the review process of a scientific journal. Publication in a scientific journal served as the main inclusion criterion, because there are probably fewer methodological problems in the published literature than in research reports that may have been rejected for publication. The enormous variability in reporting precludes the use of further inclusion criteria with respect to methodological quality. The quantitative review of a meta-analysis should, moreover, be compared to a qualitative review which generally only analyzes published studies. Because automatic bias is the dominant account for emotional Stroop in the published literature, it should also follow from published results. If, however, the file-drawer problem applies to these studies (i.e., null results selectively remain unpublished), this leads to an over-estimation of effect sizes and we err in favor of the automaticity hypothesis. To correct for a possible file-drawer problem, we applied the trim-and-fill method (Duval & Tweedie, 2000), which was suggested by an anonymous reviewer. A publication bias generally results in an asymmetric ‘funnel plot’ (i.e., study size, or weight, plotted against effect size), which is subsequently made more symmetric in an iterative procedure. The method results in an estimate of the number of unpublished studies (i.e., the

Wilcoxon statistic minus 1: R_0, see Duval, 2005) and an adjustment of the effect-size estimates.

From a number of different sources, such as databases and review articles, we collected all published studies that reported sufficient details to calculate the effect size. We approached a number of authors for additional data, but these attempts were often unsuccessful. We started with the studies cited in Williams et al. (1996) and subsequently searched computerized databases (i.e., PsychINFO, ScienceDirect, Web of Science, and Google Scholar) with combinations of the keywords “subliminal”, “masked” “emotional Stroop”, “modified Stroop”, “anxiety”, and the various acronyms for general anxiety measures. We also performed a forward search in Web of Science to find studies that cited core publications on subliminal emotional Stroop (i.e., MacLeod & Hagan, 1992; MacLeod &Rutherford, 1993; Williams et al., 1996). Studies with children as participants, or with patients receiving medication, and studies with explicit mood inductions were excluded from the meta-analysis (control conditions in these studies without inductions, or medication, were included, however). The studies also needed to measure general anxiety and had to separate groups differing in general anxiety level. Many Stroop studies investigating specific patient groups do not explicitly measure general anxiety of patients or controls. Particularly the control groups, may then contain an unknown number of subclinically anxious participants. The studies included in the meta-analysis covered a time span of twenty years; from the first studies reporting emotional Stroop in the mid eighties of the previous century until 2005 (the latest study included was Jansson, Lundh & Oldenburg, 2005).

The foregoing theoretical discussion suggests a number of dimensions along which the studies should be classified in order to reduce variability in methodology. Moderator variables were the level of anxiety of the participant groups, whether presentation was blocked (e.g., the classic card format) or mixed, and whether presentation of the emotion word was optimal

or suboptimal. Three groups were compared: low-anxious control participants, high-anxious nonclinical participants, and high-anxious patients. High-anxious patients were suffering from an anxiety disorder, such as General Anxiety Disorder (GAD), Post-Traumatic Stress Disorder (PTSD), Obsessive Compulsive Disorder (OCD), Panic Disorder (PD), Body Dysmorphic Disorder (see Buhlmann, McNally, Wilhelm & Florin, 2002) and phobias. Patients with depression as the primary diagnosis were not included. STAI trait (Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983) was the most frequently used general anxiety measure. In the studies explicitly reporting averages, high anxiety was defined as an average STAI trait score above 40 for the group. If average anxiety scores were not reported but efforts were made to select extreme scorers, the group classification from the study was followed (e.g., Dawkins & Furnham, 1989). Other general anxiety measures were the Anxiety Sensitivity Index (ASI; Reiss, Peterson, Gursky & McNally, 1986), the Mood and Anxiety Symptom Questionnaire (MASQ; e.g., Yovel & Mineka, 2004), the Beck Anxiety Inventory (BAI; e.g., Stewart, Westra, Thompson & Conrad, 2000), and the Karolinska Scales of Personality (KSP, see Jansson et al., 2005). In some studies a number of anxiety measures were combined. Because we assume that anxiety and depression may modulate information processing differently (see also Williams et al., 1988), we excluded studies that made a group distinction only on the basis of a depression measure.

To investigate Stroop interference associated with the general emotion anxiety, the emotion words should be general fear words (i.e., related to GAD or PTSD), but not specific to, for instance, a phobia, eating disorder, or OCD. Studies employing only words that were related to particular concerns of the patients were excluded from the meta-analysis. Because, moreover, the nonclinical groups presumably do not share these concerns, inclusion of these studies would not allow for a comparison between groups. If studies investigated both social and physical threat words (e.g., Lang & Sarmiento, 2004), the Stroop effects of both words

types were averaged and considered representative for general fear words. Only studies with word type (i.e., general fear vs. neutral) as a within-subjects manipulation were included.

The first step in the calculations involved computing the effect size estimate (the product-moment correlation coefficient *r,* see Rosenthal, 1991) for each level of the moderator variables investigated in each study. The effect size *(r*) indicates the degree of association between word type (i.e., threat vs. neutral) and color naming times. If a study yielded multiple effect size estimates for a level of the moderator variables, these effect sizes were combined into one estimate, to achieve within-level statistical independence. The next step was to determine composite effect sizes across studies by weighting individual studies according to their sample size minus three (n-3). These average effect sizes were calculated (see Rosenthal, 1991) by converting each *r* into a Fisher's *z* coefficient, multiplying each *z* by n-3 (i.e., the inverse of the variance of the correlation), summing the weighted *z*s, dividing this sum by the total weight, and transforming the resulting *z* back to *r*. A z-value was then calculated by dividing the mean effect size by its standard error (see Lipsey & Wilson, 2001). The one-tailed probability (p) of this *z* served as an estimate of the significance level of the composite effect size.

We computed the effect sizes either from the means and standard deviations, if reported, or otherwise from the statistics (e.g., *t, F*). Because word valence constitutes a within-subjects manipulation, the latter statistics do not represent independent tests, which may lead to an overestimation of effect size (Dunlap, Cortina, Vaslow & Burke, 1996). For this reason we also conducted a trimmed meta-analysis without the estimates based on the test statistics. When a test of emotional Stroop was reported as not significant, but no statistics or means were cited, the conservative procedure (Rosenthal, 1991) of entering a zero effect size was followed. These studies were also omitted in the trimmed meta-analysis, which eventually included 146 effect sizes.

There are generally two approaches (i.e., fixed-effects vs. random effects models) to meta-analysis. The fixed-effects case assumes that studies are taken from populations with the same effect size, whereas the random-effects case assumes that populations have varying effect sizes. In the random-effects model the weights are computed using a variance component that incorporates between-study variance in addition to the within-study variance used in the fixed-effect model. A heterogeneity test may be used to decide between the models (Field, 2001). In the homogeneous case the estimate of the between-study variance equals zero. To test the heterogeneity of effect sizes across studies, we calculated the Q statistic which is based on the sum of squared errors of the mean effect size (Lipsey & Wilson, 2001). In the present meta-analysis, not only did the random and fixed effects models yield the same results, but also all heterogeneity tests were not significant.

Results

The main results of the meta-analysis are the effect size estimates in terms of *r*, which are presented in Table 1, together with the study characteristics, test statistics, and the results of the trim-and-fill method. The largest Stroop effect was obtained for anxious patients and with blocked optimal presentation. All constituent effects were larger than zero in this condition. The correction for publication bias somewhat reduced the effect size, but it still remained at medium levels. The second largest, but more modest, effect was also with blocked optimal presentation but now for high-anxious nonclinical participants. All effects here were larger than, or equal to, zero, with the exception of the facilitation effect in Experiments 1 and 2 of Martin, Williams and Clark (1991). The control words in this study (see also Mathews & Macleod, 1985), however, had a positive emotional connotation which may have hidden the interference by threat words. These facilitation effects may have corrected for the asymmetry in the funnel plot caused by publication bias, so that the trim-and-fill method yielded the same

effect size. Interestingly, also the small interference effect in the optimal blocked condition with low-anxious controls reached marginal significance. This may be due to the relatively large number of studies in this condition, but may also indicate that even with low-anxious participants some slow Stroop can be found. (e.g., see McKenna & Sharma, 2004).

[Insert Table 1 about here]

With mixed presentation there were also some indications of an interference effect, but effect sizes were less than half as large as with blocked presentation. Only for the patients, moreover, was emotional Stroop significant with mixed (optimal) presentation. Here, only three out of 22 studies yielded effects smaller than zero. The effect size was, however, considerably reduced by the correction for publication bias. Though this effect was no longer significant for the high-anxious nonclinical participants, only three out of 20 studies revealed a negative effect size here. For low-anxious individuals there were about as many interference and facilitation effects with mixed presentation and the combined effect size was even slightly negative. Emotional Stroop interference, thus, seems considerably reduced by mixed presentation relative to blocked presentation, but a small effect may remain, particularly with high-anxious patients, even when fear and neutral words are randomly mixed. A dependence upon anxiety level, moreover, can be observed both with blocked and mixed optimal presentation.

Rather surprisingly, the effect sizes for suboptimal presentation- we only had sufficient studies with mixed presentation- were all close to zero and no effect even approached significance. After correction for publication bias, the effect sizes mostly moved closer to zero. The number of positive effects about equaled the number of negative effects in all three groups. The absence of significant heterogeneity, moreover, suggests that no study

obtained convincing evidence for emotional Stroop at suboptimal presentation conditions. The finding that provides the strongest support for automaticity in emotional Stroop (i.e., suboptimal interference) is thus not confirmed by the meta-analysis.

[Insert Table 2 about here]

A concern may be that the studies reporting nonsignificant emotional Stroop, without sufficient data to calculate the actual effect sizes, may have led to an under-estimation of the effect sizes. On the other hand, the effect sizes that were derived from within-subjects test statistics may have led to an over-estimation. We also conducted a trimmed meta-analysis after excluding both types of effect sizes (see Table 2). Only slight changes in results could be observed. The two significant effects with blocked optimal presentation in the first analysis stayed significant, and all effects in the suboptimal conditions remained close to zero. Only the effect for patients with mixed optimal presentation was reduced and moved even closer to zero after further correction for publication bias. The combined influence of neglecting finite, but nonsignificant, effects, and of overestimating effect sizes from repeated measures statistics, thus, appears to be very limited.

Discussion

Automaticity can show up in the meta-analysis in two different ways. Direct, nonconscious, processing should lead to a fast interference effect (i.e., in the trial of the emotion word) with optimal word presentation, but, conversely, fast interference is not necessarily indicative of automaticity. An interference effect with suboptimal presentation would constitute stronger evidence for automaticity. Even with clinically anxious patient groups, however, the effect size of suboptimal emotional Stroop was virtually zero and remained negligibly small in the

other suboptimal conditions. A larger suboptimal-than-optimal effect (e.g., Rotteveel et al., 2001) for emotional Stroop with emotion words, as has been suggested by Fox (1996), can be dismissed on the basis of these results. The significant interference effect for patients with mixed optimal presentation, which proved rather vulnerable to corrections for statistical dependence and publication bias, could still be taken as evidence for fast Stroop and indirectly for automaticity, but probably requires another explanation. In contrast to pseudo-random presentation orders, genuinely random orders entail some repetitions of emotion and control trials (e.g., McKenna & Sharma, 2004). Slow interference in these ‘mini-blocks’ may be responsible for the effect with mixed random presentation. Interference due to slow Stroop in mixed optimal conditions may further be strengthened by unequal numbers of threat and neutral words, and by the inclusion of ineffective (i.e., effectively neutral) words in the threat list. Particularly, when ineffective threat words separate effective threat words from subsequent neutral words, slow Stroop enhances interference in mixed designs. In any case, the effect sizes doubled in all groups with fully blocked presentation. Even if there is evidence for a fast emotional Stroop effect in these results, it disappears with suboptimal presentation of the fear word. The present meta-analysis, therefore, suggests no role for automaticity in a modified Stroop task with emotion words.

It could be argued that, for suboptimal interference effects to occur, the words should match the particular concerns of the participants even more closely than in optimal conditions (c.f., Dalgleish, 1995, who obtained optimal Stroop effects of bird names with ornithologists). Automaticity may then only be a characteristic of suboptimal Stroop with concern-specific words. The first study that investigated suboptimal Stroop conditions (MacLeod & Hagan, 1992) found that masked Stroop interference from threat words, of which many were disease-related, was associated with higher anxiety, depression, and dysphoric reaction scores after a diagnosis of cervical pathology. Correlations of difference scores (i.e., the color naming

latency with control words subtracted from the latency with threat words) with other variables may, however, be spurious (e.g., Peter, Churchill & Brown, 1993), and should be treated with caution. We cannot tell whether emotional interference occurred in this study because only correlations but not the actual Stroop results (i.e., reaction times) were reported. For this reason the study could not be included in the meta-analysis. The suboptimal studies that were included also did not provide evidence for such concern-specific interference. If the words matched individual concerns better in some studies than in others, there should be considerable heterogeneity in the effect sizes, which was not the case. Similarly, when presentation times were too short for any processing of emotion words to take place at all in some suboptimal studies, but not in others, this should show up in the heterogeneity Q-value. Very short presentation could amount to virtual nonpresentation of the words and could be a factor contributing to smaller suboptimal-than-optimal effects. In fact, the suboptimal effect sizes were all quite homogeneous, or at least not significantly heterogeneous.

If larger effects could be found in optimal conditions when the words match the individuals' specific concerns than when general fear words are used, this suggests that an additional process not related to the general emotion fear contributes to emotional Stroop. Contrasting findings of fast Stroop effects with concern-specific words and slow effects with general fear words would further strengthen this idea. A specific phobia (e.g., of spiders) is not necessarily accompanied by a high general anxiety and might, for instance, show fast effects with spider words but no fast or slow effects with general fear words. In fact, the additional process does not need to be related to emotion at all. Storbeck and Robinson (2004), for instance, argued on the basis of their lexical decision and evaluation tasks with short duration priming that semantic priming was more robust than affective priming and that indeed encoding stimuli with respect to their semantic category appeared to be the more obligatory operation. The present meta-analysis only allows conclusions for emotional Stroop

with general anxiety and general fear words. The conclusion that semantic priming also plays a role in suboptimal emotional Stroop would require a further meta-analysis with word category and type of disorder as moderator variables.

Clear evidence was obtained in favor of a slow emotional Stroop effect. Recently, Waters et al. (2005) also emphasized the role of slow effects in the Stroop task, which they called carry-over effects. They concluded that it generalized over a wide range of domains (e.g., addiction Stroop studies) and depended, for instance, on stress level and whether participants were patients or normals. In the present meta-analysis, interference depended on level of anxiety both with blocked and with mixed presentation, but the former conditions yielded much larger effects overall than the latter. In unselected samples of participants, as used by McKenna and Sharma (2004; see also Algom et al., 2004), different levels of trait anxiety may be mixed, so that only an appreciable effect remains for blocked conditions.

The presence of slow emotional Stroop and the absence of suboptimal emotional Stroop suggest that other processes than an automatic bias cause the effect. Mathews and MacLeod (2002) argued that anxiety-prone individuals have greater difficulty in disengaging attention from threatening information. Disengagement stems from the spatial attention literature and can, for instance, account for performance in the dot-probe task (e.g., Yiend & Mathews, 2001), in which attention has to be shifted from the location of a fear stimulus to the location of a dot probe that is presented subsequently to the fear stimulus. To explain slow Stroop the concept needs to be transferred to the domain of color naming. In our opinion, two types of disengagement should be distinguished. In the classic Stroop task attention has to be disengaged from the color word in order to respond to the color. Color and word also constitute one stimulus object from which attention has to be disengaged in order to attend to the next stimulus object. In the emotional Stroop task there is no need for the former type of disengagement because color and fear word do not lie on the same dimension (Algom et al.,

2004). High anxious individuals, in particular, seem to experience a difficulty in disengaging from a stimulus object containing a fear stimulus, and, therefore, show slow emotional interference, but little or no fast interference.

In contrast to what MacLeod and Hagan (1992; e.g., see also Fox, 1996; Mathews & Macleod, 2002) initially claimed, we have not found in the present meta-analysis any evidence of emotional interference under suboptimal conditions, at least on an intra-trial basis. It remains possible, but seems rather unlikely, that a slow, inter-trial, effect occurs with suboptimal presentation. Unfortunately, only very few studies were available that blocked the suboptimal presentation of fear words, but the available studies suggested a null effect. Instead, we found clear support for the slower carry-over effect in optimal conditions that was first hypothesized by McKenna and Sharma (2004). The above disengagement account predicts that the slow effect should extend to classic Stroop, as has indeed been found by Mathews (2003, unpublished results cited in Dalgleish, 2005). Also in our laboratory (Phaf, 2005, unpublished results), moreover, with a set-up similar to McKenna and Sharma (2004), we obtained slow effects in both classic and emotional Stroop tasks, but only a fast interference effect with classic Stroop. This suggests that emotional and classic Stroop are related phenomena only with respect to the slow disengagement process (see Algom et al., 2004). Even after more than half a century of research (MacLeod, 1991), the Stroop effect, thus, still seems capable of sending us in unexpected new directions.

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Table 1. Emotional Stroop effects in the full meta-analysis over 70 studies.

Presentation	Order	Number of Studies	Number of Participants	Effect Size r (Standard Error)	z (p-value)	Q (p-value)	Minimum r	Maximum r	Estimated Missing Studies	Estimated Effect Size
Low Anxious	Nonclinical									
Optimal	Blocked	29	836	0.048 (0.037)	1.309 (0.095)	4.991 (1.000)	-0.092	0.365	2	0.038
Optimal	Mixed	32	839	-0.011 (0.037)	-0.294 (0.616)	2.168 (1.000)	-0.225	0.106	1	-0.008
Suboptimal	Blocked	2	44	0.026 (0.162)	0.158 (0.437)	0.028 (0.868)	0.000	0.054	0	0.026
Suboptimal	Mixed	16	380	-0.017 (0.055)	-0.318 (0.625)	1.176 (1.000)	-0.164	0.071	1	-0.005
High Anxious	Nonclinical									
Optimal	Blocked	19	447	0.135 (0.051)	2.673 (0.004)	7.157 (0.988)	-0.254	0.408	0	0.135
Optimal	Mixed	20	531	0.056 (0.046)	1.221 (0.111)	3.153 (1.000)	-0.032	0.229	3	0.018
Suboptimal	Blocked	3	159	0.021 (0.082)	0.260 (0.398)	0.023 (0.989)	-0.001	0.028	1	-0.017
Suboptimal	Mixed	11	300	0.037 (0.061)	0.608 (0.272)	1.401 (0.999)	-0.055	0.158	0	0.037
High Anxious	Clinical									
Optimal	Blocked	16	408	0.242 (0.053)	4.594 (0.000)	5.497 (0.987)	0.037	0.496	1	0.197
Optimal	Mixed	22	597	0.095(0.043)	2.180 (0.015)	7.208 (0.999)	-0.047	0.440	2	0.057
Suboptimal	Blocked	1	39	-0.012 (-)	-0.075 (0.529)	-	-	-	-	-
Suboptimal	Mixed	11	346	0.014 (0.057)	0.245 (0.403)	0.256 (1.000)	-0.038	0.097	0	0.014

Table 2. Emotional Stroop effects in the trimmed meta-analysis over 50 studies.

Presentation	Order	Number of Studies	Number of Participants	Effect Size r (Standard Error)	z (p-value)	Q (p-value)	Minimum r	Maximum r	Estimated Missing Studies	Estimated Effect Size
Low Anxious	Nonclinical									
Optimal	Blocked	26	777	0.051 (0.038)	1.355 (0.088)	4.871 (1.000)	-0.092	0.365	2	0.041
Optimal	Mixed	25	628	-0.015 (0.043)	-0.341 (0.633)	2.138 (1.000)	-0.225	0.106	1	-0.010
Suboptimal	Blocked	1	21	0.054 (-)	0.230 (0.409)	-	-	-	-	-
Suboptimal	Mixed	12	290	-0.023 (0.063)	-0.363 (0.642)	1.145 (1.000)	-0.164	0.071	1	-0.008
High Anxious	Nonclinical									
Optimal	Blocked	16	388	0.167 (0.054)	3.083 (0.001)	4.048 (0.998)	-0.005	0.408	2	0.114
Optimal	Mixed	15	356	0.068 (0.057)	1.199 (0.115)	1.998 (1.000)	-0.032	0.201	1	0.047
Suboptimal	Blocked	2	136	0.025 (0.088)	0.279 (0.390)	0.0121 (0.913)	-0.001	0.028	0	0.025
Suboptimal	Mixed	9	250	0.045 (0.067)	0.665 (0.253)	1.329 (0.995)	-0.055	0.158	0	0.045
High Anxious	Clinical									
Optimal	Blocked	12	330	0.198 (0.058)	3.401 (0.001)	2.079 (0.998)	0.037	0.329	1	0.210
Optimal	Mixed	18	468	0.068 (0.049)	1.374 (0.085)	3.144 (1.000)	-0.047	0.325	3	0.030
Suboptimal	Blocked	1	39	-0.012 (-)	-0.075 (0.529)	-	-	-	-	-
Suboptimal	Mixed	9	269	0.018 (0.064)	0.279 (0.390)	0.239 (1.000)	-0.038	0.097	0	0.018