Cognitive Bias Modification

A New Frontier in Cognition and Emotion Research

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It is now generally accepted that heightened vulnerability to negative emotions such as anxiety and depression and to clinical disorders involving emotional pathology is characterized by cognitive biases that favor the processing of negative information. For example, it is well established that for individuals who display such vulnerability or pathology, attention is selectively drawn to negative information, interpretation operates to selectively impose negative resolutions on ambiguity, and negative past events may be recalled with disproportionate ease. Such observations have given rise to cognitive theories of emotional dysfunction, according to which these low-level biases in selective information processing make a direct causal contribution to the etiology of dysfunction pathology (e.g., Beck & Clark, 1997; Eysenck, Derakshan, Santos, & Calvo, 2007; Williams, Watts, MacLeod, & Mathews, 1997).

However, despite the pervasive influence of these accounts, the finding that cognitive biases are *characteristic* of emotional dysfunction does not permit the conclusion that these patterns of processing selectivity functionally contribute to such dysfunction. This theoretical position could be adequately tested only if it were possible to directly modify the cognitive bias of inter-est, in order to test the prediction generated by this causal hypothesis: that emotional vulnerability and the symptoms of emotional pathology will be influenced by this cognitive bias modification. Such a finding not only would confirm that the processing bias in question does causally contribute to emotional dysfunction, but it would raise the exciting possibility that emotional vulnerability might be reduced, and the symptoms of emotional pathology therapeutically attenuated, through clinical interventions that directly modified this type of selective information processing.

The theoretical and applied importance of these potential outcomes helps explain the considerable interest in recently developed techniques designed to modify the low-level cognitive biases implicated in models of emotional vulnerability and dysfunction (cf. Bar-Haim, 2010; Hakamata et al., 2010; Hallion & Ruscio, 2012; Hertel & Mathews, 2011; MacLeod, 2012; MacLeod & Mathews, 2012; Mathews, 2012). Cognitive bias modification (CBM) research is still a young field, as evidenced by the observation that over 70% of CBM publications has appeared within only the past 3 or 4 years (MacLeod & Mathews, 2012). Most of the work to date has sought only to modify attentional or interpretive bias,

though new techniques are emerging that promise to extend the range of processing biases that can be targeted using the CBM approach. The present chapter provides an overview of this rapidly developing new field of clinical research. We begin by introducing the general principles that have been employed to transform tasks, previously used to assess cognitive bias, into training procedures designed instead to modify such bias. We then describe the CBM procedures that have been most widely used to induce change in interpretive and attentional bias. Thereafter we review experimental work that has examined the impact of interpretive and attentional bias modification on normal emotional experience, on subclinical manifestations of emotional dysfunction, and on the symptoms of emotional pathology. In the latter half of the chapter we review some of the emerging new directions in CBM research that are likely to prove increasingly influential in future work, including the extension of the bias modification approach to alternative forms of processing selectivity and other clinical conditions, and the use of CBM as a therapeutic tool in real-world clinical settings.

CBM Techniques: Transforming Bias Assessment Procedures into Bias Modification Procedures

As already noted, cognitive theories of emotional vulnerability implicate low-level information processing biases in the development and maintenance of emotional dysfunction. Because these biases commonly are inaccessible through introspection, they do not readily lend themselves to assessment via self-report. Consequently, a variety of cognitive-experimental methodologies have been developed to assess such patterns of processing selectivity. These assessment procedures have, in turn, been amended to transform them into techniques capable of systematically modifying the patterns of selective information processing they were initially designed to assess. This transformation has been accomplished by introducing specific contingencies into these tasks, designed such that they become easier to

perform if the participant adopts a target pattern of processing selectivity. It is anticipated that repeated practice of the tasks configured in this manner will foster a change in cognitive bias to favor the type of selectivity encouraged by the training contingency.

Two features are common to the majority of CBM methodologies (Koster, Fox, & MacLeod, 2009). First, the cognitive bias targeted for change represents a pattern of selective information processing that is known to characterize psychopathology. Second, this cognitive bias is altered in a manner that does not involve instructing the participant to intentionally change such information-processing selectivity. Rather, change in the cognitive bias is induced by introducing into tasks previously used to assess this processing selectivity a contingency designed such that successful task performance will be enhanced by adoption of a new pattern of selectivity. In the following sections we illustrate how these principles have been implemented, focusing first on interpretive bias modification procedures, then on procedures developed to modify attentional bias.

Emotionally Linked Interpretive Bias and Its Modification

Interpretive bias refers to the tendency to selectively impose negative resolutions on ambiguous information. This information-processing bias has a well-established association with clinical psychopathology, being evident in patients diagnosed with depressive and anxiety disorders, and also in individuals with subclinical levels of anxiety and depression (Mathews, 2012). A number of different tasks have been used to assess interpretive bias. Commonly, how the presentation of initial ambiguous prime information impacts on the processing of subsequent targets that are related to alternative negative or non-negative meanings of this preceding ambiguity has been examined. An interpretive bias is revealed by a processing advantage for target stimuli associated with one particular valence of the ambiguous prime. In one variant of this approach participants perform lexical decisions on target words following the presentation

of homograph primes that permit negative and non-negative interpretation (e.g., *arms*). These target words can be associated with either the negative meaning (e.g., *weapons*) or the non-negative meaning (e.g., *hands*) of the initial homograph (Richards & French, 1992). Other interpretive bias assessment tasks instead employ descriptions of ambiguous scenarios as the initial primes, then measure speed to process target stimuli related to either the negative or non-negative meanings of these scenarios (Hirsch & Mathews, 1997).

Transforming this interpretive bias assessment approach to yield interpretive bias modification procedures has involved introducing a contingency between the ambiguous prime material and the subsequent target, such that successful task performance will benefit from imposing resolutions on the ambiguous information that favors a single valence. Thus, whereas the interpretive bias assessment task involves presenting targets that are associated equally often with the negative and the non-negative meanings of the initial ambiguous prime, the interpretive bias training task involves consistently presenting targets associated with those meanings of the ambiguous material that share one particular emotional valence. Optimal performance on such a task is achieved by adopting a style of interpretation that favors resolving the ambiguous primes in a manner that yields meanings of this same emotional valence.

The two most common cognitive bias modification tasks used to modify interpretation (CBM-I) differ primarily in terms of whether the initial ambiguous prime information comprises words or sentences. Grey and Mathews (2000) developed a CBM-I variant employing homograph primes. This approach presents an initial homograph, which permits negative or benign interpretation, followed 750 milliseconds (ms) later by a word fragment that can be completed only to yield an associate of one of these two meanings. Participants are instructed to solve the word fragments using the initial word as a clue. In one condition, designed to encourage negative resolutions of ambiguous information (interpret negative condition), target word fragments can be completed only to yield words associ-

ated with the negative meanings of the preceding homographs. In another condition, designed to encourage benign interpretation of ambiguity, the fragments can yield only words associated with non-negative meanings of the ambiguous primes (interpret benign condition). For example: The initial homograph *choke* is presented. In the interpret negative CBM-I condition this homograph would be followed by the target fragment *t-ro-t (throat)*, whereas in the interpret benign CBM-I condition it would instead be followed by the target fragment *eng-n- (engine)*. Participants usually complete between 120 and 240 of these training trials in a CBM-I session. The impact of the CBM-I procedure on interpretive bias then can be determined using an interpretive bias assessment task. This assessment task might be similar to the CBM-I task, but with the training contingency removed to restore it to a bias assessment procedure. Alternatively, quite different task variants can be employed to measure interpretive selectivity following exposure to the CBM-I procedure. Across a series of studies, Grey and Mathews consistently observed that groups of participants exposed to a single session of this CBM-I task in each of these two training conditions came to differ in the patterns of interpretive selectivity they displayed on the subsequent interpretive bias assessment task. Specifically, as intended, participants given the interpret benign CBM-I condition came to exhibit a significantly lesser tendency to impose negative interpretations on ambiguous stimuli than was the case for participants given the interpret negative CBM-I condition.

Mathews and Mackintosh (2000) extended this CBM-I approach by employing as primes ambiguous scenarios that each could be interpreted in either a negative or benign manner. On each trial of this task, participants read a textual description of such an ambiguous scenario, which concludes with an incomplete word fragment. They are then required to rapidly solve this word fragment to provide a meaningful ending to the scenario. In the interpret negative CBM-I condition the fragments yield words that provide such a meaningful ending only if the ambiguous scenario has been interpreted negatively. In the interpret benign

CBM-I condition the fragments yield words that provide meaningful completions to scenarios only if they have been interpreted in a non-negative manner. Across five studies, Mathews and Mackintosh (2000) confirmed that participants consistently exhibited the pattern of selective interpretation these experimental contingencies were designed to encourage. This seminal work has formed the foundation upon which subsequent CBM-I research has been built.

Emotionally Linked Attentional Bias and Its Modification

The development of cognitive bias modification techniques that target attentional bias (CBM-A) has followed a similar trajectory. Attentional bias toward negative information is strongly characteristic of clinically anxious patients and of nonclinical individuals with elevated levels of trait anxiety (cf. Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). This attentional bias has also been observed in clinically depressed patients and in nonclinical individuals who exhibit elevated levels of trait depression (Baert, De Raedt, Schacht, & Koster, 2010). The tasks employed to measure such attentional bias commonly involve the simultaneous presentation of information that differs in emotional valence, and they seek to assess the distribution of attention between these competing alternatives. Such attentional bias assessment tasks include interference paradigms such as the emotional Stroop (e.g., Rutherford, MacLeod, & Campbell, 2004). Selective attentional bias is revealed on interference paradigms by presenting negative and non-negative stimuli as task-irrelevant distracters and assessing the degree to which each valence of distracter impairs performance on the primary task. This bias can also be assessed using dichotic listening procedures to examine the distribution of attention between the two ears, when one ear is presented with negative and the other with non-negative information (e.g., Wenzel, 2006). Yet another method of assessing attentional bias involves having participants search for target information within arrays of stimuli, with the relative latency to detect targets of differing emotional valence being taken as an indication of the degree to which these targets selectively recruit attention (e.g., Rinck, Becker, Kellermann, & Roth, 2003).

Perhaps the most frequently used method of assessing biased attention has been the visual probe task (MacLeod, Mathews, & Tata, 1986). This task involves the simultaneous brief presentation of negative and non-negative stimuli to different areas of a visual display, before a small visual probe appears in the location vacated by one of the two stimuli. Relative speeding to discriminate the identity of probes appearing in the location of negative versus non-negative stimuli provides an indication of the degree to which attention is selectively drawn to negative information. Using this task, it has been demonstrated repeatedly that individuals with elevated emotional vulnerability and those suffering from emotional pathology display disproportionate speeding to discriminate probes appearing in the same location, as compared to the opposite location, as the negative stimuli, indicating an attentional bias that favors negative information (cf. Bar-Haim et al., 2007).

The development of CBM-A methodologies has involved the introduction of contingencies into these tasks, such that performance will be enhanced by consistently directing attention either toward, or away from, negative stimuli. By far the most frequently used CBM-A approach has been a training variant of the attentional probe task. In the assessment version of this task, probes are presented in the same and opposite location to the negative stimuli with equal frequency. However, the CBM-A variant introduces a contingency between the stimulus position and the probe position, such that probes always appear only in the location of neutral stimuli in the condition designed to encourage attentional avoidance of negative stimuli (avoid negative condition), or else appear only in the locus of negative stimuli in the condition designed to encourage attentional preference for negative stimuli (attend negative condition). In two separate studies MacLeod, Rutherford, Campbell, Ebsworthy, and Holker (2002) exposed participants to 576 attentional probe training trials delivered in either of these two training conditions, using word stimuli. Subse-

quent attentional bias assessment, using the original format of the attentional probe task, revealed that these participants came to display a pattern of induced attentional selectivity in line with the assigned training contingency. Those exposed to the attend negative CBM-A condition became faster at discriminating probes appearing in the location of negative words rather than neutral words, indicating an attentional bias toward negative information. Those exposed to the avoid negative CBM-A condition instead became faster at discriminating probes appearing in the location of the neutral words rather than the negative words, indicating an attentional bias away from negative information. Subsequent research has also demonstrated that versions of this probe CBM-A task, using negative and non-negative pictorial stimuli, can similarly serve to modify attentional bias (e.g., Eldar, Ricon, & Bar-Haim, 2008).

A great many attention training studies employing this probe CBM-A approach have verified its capacity to modify attentional bias (cf. Hakamata et al., 2010). Recent research also has demonstrated successful modification of attention using a visual search CBM-A methodology. Dandeneau and Baldwin (2004) developed such a task, designed to encourage attentional avoidance of negative stimuli and attentional preference for positive stimuli. This task requires participants to identify a single smiling face within arrays of angry faces. When compared to a control condition involving only nonemotional stimuli, this task has been shown to be effective in encouraging attentional avoidance of negative information, as subsequently assessed using the emotional Stroop task (Dandeneau & Baldwin, 2004; Dandeneau, Baldwin, Baccus, Sakellaropoulo, & Pruessner, 2007) or the attentional probe task (Dandeneau & Baldwin, 2009).

Using these types of CBM-I and CBM-A methodologies, researchers not only have been able to induce systematic change in patterns of interpretive and attentional selectivity, but have gone on to evaluate the impact of such bias change on measures of emotion. In the following sections we describe how such CBM studies have lent support to the hypothesis that these types of selective information processing make a causal contribution to emotional vulnerability and dysfunction.

The Impact of Cognitive Bias Modification on Normal and Abnormal Emotional Experience

Many CBM studies have sought to determine whether interpretive or attentional bias contributes to normal variance in emotional vulnerability, using participants unselected with respect to emotional dysfunction. Other CBM studies, either seeking to address the theoretical hypothesis that such types of processing bias also contribute to emotional pathology, and/or motivated by the possibility that CBM may contribute therapeutically to the treatment of such conditions, instead have been carried out on participants exhibiting subclinical or clinical manifestations of emotional dysfunction. In the following subsections we separately review CBM research conducted on these different populations, in each case covering first those studies that have investigated the impact of interpretive bias modification, before going on to consider those that have examined the impact of attentional bias modification.

Impact of CBM-I on Normal Emotional Experience

Using the fragment-completion CBM-I task with a sample of unselected student participants, Mathews and Mackintosh (2000) demonstrated that those who completed the interpret benign condition came to report significantly lower state anxiety than did those who instead completed the interpret negative condition. Although this finding suggests that the modification of interpretive bias may impact on emotional state, it does not warrant the conclusion that interpretive bias causally contributes to emotional vulnerability. Support for this premise has been strengthened, however, by the demonstration that participants exposed to a single session of these differing CBM-I conditions subsequently report differing levels of trait anxiety, in line with the training contingency, on a questionnaire measure of this emotional disposition (Salemink, van den Hout, & Kindt, 2007, 2009).

Although the finding that CBM-I can induce change in questionnaire measures of trait anxiety is consistent with the hypothesis that interpretive bias makes a causal

contribution to anxiety vulnerability, an alternative possibility is that CBM-I training contingencies may simply affect judgments made when responding on such questionnaire measures. Specifically, the modification of selective interpretation may influence individuals' perceptions of the frequency with which anxiety has been experienced in the past, rather than producing genuine change in current susceptibility to anxious mood. More compelling evidence that interpretive bias causally contributes to emotional vulnerability comes from studies that have assessed the impact of CBM-I on emotional reactions to a subsequently administered stressor task. For example, Wilson, MacLeod, Mathews, and Rutherford (2006) delivered 160 trials of Grey and Mathews' (2000) CBM-I task to participants with midrange trait anxiety. Following exposure to either the interpret benign or interpret negative training conditions, these participants viewed four brief video clips depicting emergency situations in which a victim is injured but ultimately rescued. Consistent with the hypothesis that interpretive bias causally underpins emotional vulnerability, participants exposed to the interpret benign and interpret negative CBM-I conditions came to exhibit differentially intense emotional responses to the subsequent stressor. Wilson and colleagues found that immediately following completion of the alternative CBM-I conditions, but prior to exposure to the video stressor, participants who had received the alternative CBM-I conditions did not differ in mood state. However, following the video stressor, those who had undergone the interpret negative CBM-I showed significant elevations on measures of state anxiety and depression, whereas those who had undergone the interpret benign CBM-I did not evidence significant elevations of either anxiety or depression in response to this stressor. Interpretive bias does, therefore, appear to causally contribute to emotional vulnerability, as revealed by emotional reactivity to current stressful events.

Several researchers have used CBM-I to modify patterns of interpretive selectivity in unselected samples of children. Muris, Huijding, Mayer, and Hameetman (2008) developed a CBM-I variant employing ambiguous scenarios designed to engage children's interest. These researchers had children ages 8–13 complete a single session of interpret benign or interpret negative CBM-I before rating how threatening they found new scenarios of a potentially stressful nature. Children who had received the interpret benign CBM-I were found to rate these new situations as significantly less threatening than those who had been given the interpret negative CBM-I. In subsequent research using a modified version of Mathews and Mackintosh's (2000) CBM-I procedure with a group of 13- to 17-year-olds, Lothmann, Holmes, Chan, and Lau (2011) obtained further evidence that interpretive bias modification exerts an emotional impact on young participants. Participants exposed to a single session of interpret benign CBM-I, compared to those given a session of interpret negative CBM-I, not only evidenced more positive interpretations of new scenarios but also displayed a reduction in negative affect.

Impact of CBM-A on Normal Emotional Experience

MacLeod and colleagues (2002) gave the probe CBM-A task to participants with midrange trait anxiety in a study designed to determine whether attentional bias causally contributes to emotional vulnerability. They observed that the attend threat and avoid threat versions of this CBM-A procedure induced differential attentional responses to negative stimuli, as intended. Moreover, although mood state assessed immediately following the CBM-A procedure did not differ between participants given these two CBM-A conditions, the degree to which a subsequent anagram stress task served to elevate anxiety and depression was attenuated for participants who had completed the avoid negative CBM-A, compared to those who had completed the attend negative CBM-A. These findings suggest that selective attentional response to negative information causally influences emotional reactivity to stressful events.

Variants of the attentional probe paradigm using pictorial rather than verbal stimuli have produced similar findings in children. Eldar and colleagues (2008) delivered attend negative or avoid negative CBM-A to unselected 7- to 12-year-olds. Participants given the attend negative CBM-A exhibited significantly more attention to negative pic-

tures than did those given the avoid negative CBM-A. Furthermore, subsequent exposure to a stressful puzzle task served to significantly elevate anxiety only in participants who had been given the attend negative condition, and did not induce a negative emotional response in those who had been given the avoid negative CBM-A. Eldar and colleagues also had independent raters blind to the experimental condition assess the children's behavioral signs of anxiety during the puzzle completion stress task. These raters reported that participants given the avoid negative CBM-A displayed lower levels of anxiety-related behavior than participants given the attend negative CBM-A. Such behavioral data provide verification that the CBM-A manipulation genuinely influenced anxiety reactivity, rather than only affecting self-report. Eldar and colleagues' findings therefore demonstrate that attentional bias functionally contributes to emotional vulnerability in children as well as adults.

Although most CBM-A research has been conducted using variants of the attentional probe paradigm, inducing differential attentional bias by using the visual search variant of CBM-A, described earlier, has also been found to influence emotional vulnerability. For example, Dandeneau and Baldwin (2009) had unselected participants from an adult education center complete 112 trials of this CBM-A task, either in the avoid negative condition or in a control condition containing no training contingency. Exposure to the avoid negative CBM-A, compared to the control condition, induced attentional avoidance of negative images and also served to reduce feelings of rejection subsequently experienced in response to a simulated social interaction. This observation—that the visual search CBM-A condition that reduced selective attention to negative information also ameliorated dysphoric response to a stressor—again supports the hypothesis that attentional bias causally contributes to emotional vulnerability.

Some studies that have examined the capacity of CBM-A to attenuate dysphoric emotional experience in participants unselected with respect to emotional vulnerability have investigated whether such attentional bias modification can attenuate emotional response to stressful life events. For example, Dandeneau and colleagues

(2007) examined the influence of the visual search task CBM-A on emotional response to the high-stress environment of telemarketing workers. They delivered this CBM-A in either the avoid negative condition or in a no-training control condition, each day for 1 week, to telemarketers. Only those who received the avoid negative CBM-A subsequently reported significant reductions in perceived stress and significant increases in self-esteem. Independent assessment of stress reactivity was provided by cortisol measures and by supervisor ratings. Again, only those in the avoid negative CBM-A condition showed reduced cortisol release and were rated by supervisors as becoming more self-confident with clients. These participants also showed a significant increase in their telemarketing sales.

See, MacLeod, and Bridle (2009) also examined the impact of CBM-A on emotional reactivity to a natural stressor in participants unselected with regard to their emotional vulnerability. Students emigrating from their home countries to commence tertiary studies abroad often experience heightened anxiety (Babiker, Cox, & Miller, 1980), and See and colleagues examined whether avoid negative CBM-A could attenuate the emotional impact of such a stressor in participants about to experience this event. In the 2 weeks prior to leaving their home country, participants completed the probe CBM-A procedure online, either in the avoid negative condition or a no-training control condition, on a daily basis. Assessment of attentional bias 1 day prior to departure confirmed that those who had been exposed to avoid negative CBM-A, but not those in the control condition, had come to show attentional avoidance of negative stimuli. When assessed following subsequent transition to the new country, both state anxiety and trait anxiety were found to be significantly attenuated in participants who had completed the avoid negative CBM-A procedure. Furthermore, this effect of avoid negative CBM-A on state and trait anxiety was mediated by its effect on attentional bias.

Such CBM studies, conducted on unselected samples, have provided convincing evidence that attentional and interpretive biases can causally contribute to variations in emotional vulnerability. However,

this does not mean that these cognitive biases necessarily contribute to the elevated levels of emotional vulnerability associated with subclinical emotional dysfunction or with emotional pathology. To determine whether this is the case, it becomes necessary to examine whether CBM, designed to modify such processing selectivity, can attenuate this emotional vulnerability in these populations. In the following subsections we review studies that have taken this approach by evaluating the impact of CBM-I and CBM-A on the emotional symptomatology observed in participants selected on the basis of displaying subclinical levels of emotional dysfunction.

Impact of CBM-I on Subclinical Emotional Dysfunction

Using an auditory version of Mathews and Mackintosh's (2000) CBM-I task, Murphy, Hirsch, Mathews, Smith, and Clark (2007) delivered either interpret benign CBM-I or a control condition to participants selected because of their atypically high levels of social anxiety. Participants given the interpret benign CBM-I displayed a reduced tendency to impose negative interpretations on ambiguity, generating significantly more benign interpretations of new ambiguous social situations than did those who had been given the no-training control condition. The participants exposed to the interpret benign CBM-I also subsequently predicted that they would experience less anxiety in response to a future social situation than was the case for those who had received the control condition, suggesting that negative interpretive bias causally contributes to the type of anticipatory anxiety commonly experienced by socially anxious individuals.

Steinman and Teachman (2010) also selected participants on the basis of elevated anxiety vulnerability, specifically recruiting those who reported abnormally high scores on the Anxiety Sensitivity Index (ASI; Reiss, Peterson, Gursky, & McNally, 1986). These participants completed a variant of Mathews and Mackintosh's (2000) CBM-I task. Compared to participants who were exposed to a nontraining control version of the task, those exposed to interpret benign CBM-I made more positive interpretations of ambiguity and also evidenced a reduction

in ASI scores. These individuals also showed a marginally significant attenuation of fear symptoms in response to a subsequent interoceptive exposure task.

Additional evidence that interpretive bias causally contributes to dysfunctional emotional experience comes from CBM-I research using highly worry-prone individuals. Hirsch, Hayes, and Mathews (2009) recruited participants who showed elevated scores on the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) and had them complete a single session of CBM-I in the interpret benign condition or in a no-training control version of the task. The former group of participants reported fewer negative thought intrusions and reduced levels of state anxiety during the completion of a subsequent breathing focus task than did those in the control condition. Given that worry and intrusive thinking are key features of generalized anxiety disorder (GAD), the finding that CBM-I can attenuate such dysfunctional symptoms suggests not only that interpretive bias may functionally contribute to the symptomatology of GAD, but also that interpret benign CBM-I may be of therapeutic value to GAD patients.

Research utilizing single-session administration of CBM-I has confirmed that selective interpretation contributes to variation in emotional reactions to contrived lab-based stressors. In order to determine whether interpretive bias contributes to elevated emotional vulnerability in real-world settings, it becomes necessary to induce more enduring change in interpretive bias by delivering multiple CBM-I sessions across more extended time periods. A number of studies have now adopted this approach, using participants selected on the basis of heightened emotional vulnerability. Mathews, Ridgeway, Cook, and Yiend (2007) delivered four sessions of interpret benign CBM-I over a 2-week period to individuals selected on the basis of their high-trait anxiety scores. Compared to participants in a test–retest control condition, those who completed the interpret benign CBM-I sessions subsequently demonstrated fewer negative interpretations of novel ambiguous scenarios. Critically, measures taken a full week after this CBM-I program revealed that these individuals also now displayed lower trait anxiety scores

than did participants who received the control condition.

Salemink and colleagues (2009) have corroborated these findings using a similar research design. These investigators gave high-trait anxious individuals eight daily sessions of interpret benign CBM-I, or a nontraining control condition, delivered via the Internet. Following completion of the program, those who received the interpret benign CBM-I, compared to those in the control condition, demonstrated more benign interpretations of ambiguous scenarios and reported lower levels of both state and trait anxiety. They also evidenced less general psychopathology according to scores on the Symptom Checklist–90 (SCL-90; Arrindell & Ettema, 1986). Together, these studies suggest that negative interpretive bias does causally contribute to elevated anxiety vulnerability within the real-world setting, and they highlight the potential therapeutic value of CBM-I techniques in attenuating such heighted anxiety vulnerability.

In addition to influencing general anxiety vulnerability, CBM-I has also proven capable of reducing the symptoms of elevated social anxiety. Beard and Amir (2008) delivered eight sessions of interpret benign CBM-I or a nontraining control condition across a 4-week period to individuals selected on the basis of scoring above the 75th percentile on the Social Phobia Scale (SPS; Turner, Beidel, Dancu, & Stanley, 1989). Assessment conducted at the end of this period confirmed that the interpret benign CBM-I was successful in reducing negative interpretive bias, and scores on the SPS revealed that these individuals also showed reduced social anxiety symptoms compared to participants who received the control condition. Of particular interest, the magnitude of the reduction in negative interpretive bias induced by the CBM-I procedure directly accounted for the degree of improvement in social anxiety symptoms.

This finding has since been replicated in children exhibiting heightened social anxiety symptoms. Vassilopoulos, Banerjee, and Prantzalou (2009) recruited 10- and 11-year-old children scoring in the top 25% of the Social Anxiety Scale for Children—Revised (SASC-R; la Greca & Stone, 1993). These participants completed three sessions of CBM-I over 7 days, with posttraining measures gathered 3 to 4 days following the final CBM-I session. Consistent with expectations, participants completing the interpret benign CBM-I procedure evidenced a significant reduction in negative interpretations of ambiguity, whereas those in a control condition revealed no change. Social anxiety symptoms also decreased in the former group, as measured by the SASC-R. Consistent with the findings of Beard and Amir (2008), the magnitude of the CBM-I-induced reduction in the tendency to impose negative interpretations significantly predicted the reduction in SASC-R scores. The results from these CBM-I studies strongly suggest that interpretive bias does make a causal contribution to subclinical levels of emotional dysfunction, and they indicate that CBM-I may yield benefits for nonclinical individuals experiencing elevated levels of emotional vulnerability.

Impact of CBM-A on Subclinical Emotional Dysfunction

Many researchers have sought to determine whether CBM-A also can serve to reduce emotional symptomatology in individuals displaying heightened emotional vulnerability. Amir, Weber, Beard, Bomyea, and Taylor (2008) examined the effects of CBM-A on anxiety responses to a public speaking challenge in participants recruited because of their high levels of social anxiety. Using a pictorial version of the attentional probe task, Amir and colleagues successfully reduced attention to negative information using an avoid negative CBM-A. Participants who received this CBM-A condition also reported significantly lower levels of anxiety in response to a subsequent public speaking challenge than were reported by participants who completed a control condition that contained no attentional training contingency. The impact of the avoid negative CBM-A was corroborated by independent raters, blind to the experimental condition, who assessed the quality of participants' speeches. The speeches presented by individuals who had been exposed to the avoid negative CBM-A were judged to be of a higher quality that those given by participants in the control condition. Furthermore, the degree of reduction in anxiety and the impact of the avoid negative CBM-A on

speech performance were statistically mediated by the degree to which they avoid negative CBM-A served to reduce selective attention to social threat stimuli. Li, Tan, Qian, and Liu (2008) delivered a more extended probe CBM-A to undergraduates recruited on the basis of elevated social anxiety symptoms. These participants received either avoid negative CBM-A or a control condition without any training contingency, across 7 consecutive days. Only those exposed to the former condition evidenced reduced selective attention to negative information at the end of this period, and these participants also displayed a significant reduction in scores on the Social Interaction Anxiety Scale.

CBM-A has also been shown to reduce the incidence of negative thought intrusions in individuals predisposed to experience high levels of worry. Hayes, Hirsch, and Mathews (2010) delivered a single session of 480 probe CBM-A trials, in addition to a novel dichotic listening CBM-A variant, to participants selected on the basis of their elevated worry symptoms. The avoid negative CBM-A condition successfully induced attentional avoidance of negative information, compared to a control condition that contained no attentional training contingency. Completion of this avoid negative CBM-A condition also resulted in fewer negative thought intrusions during a subsequent breathing focus task, compared to the control condition. Hazen, Vasey, and Schmidt (2009) also examined the influence of CBM-A on a sample of undergraduates identified as extreme worriers according to the PSWQ (Meyer et al., 1990). Five sessions, each comprising 216 trials of the probe CBM-A procedure, were given to participants across an average of 34 days. When delivered in the avoid negative condition, this series of training sessions was observed to successfully induce attentional avoidance of negative stimuli, an effect that remained evident 7 days after the final attentional training session had been completed. Hazen and colleagues also found that participants exposed to this avoid negative CBM-A also exhibited a significant decrease in a composite index of anxiety, worry, and depression scores, as compared to those who completed the no-training control version of the task.

Najmi and Amir (2010) have reported beneficial effects of CBM-A in a rather different sample of participants exhibiting subclinical symptoms of emotional pathology. They recruited undergraduates reporting high levels of contamination fear, and had them complete a variant of the probe CBM-A task either configured to encourage attentional avoidance of contamination-related stimuli or in a control condition containing no training contingency. The results confirmed that the former condition alone served to reduce attention to contamination related information. During completion of a subsequent exposure-based stress task, it was observed that participants who had received this CBM-A condition were able to approach feared objects more closely than was the case for participants in the control condition. The proximity to which participants were able to approach the feared contaminants was statistically mediated by the degree to which this CBM-A induced attentional avoidance of contamination-related information.

In a follow-up to Eldar and colleagues' (2008) earlier study examining emotional reactivity in unselected children, Bar-Haim, Morag, and Glickman (2011) used a similar design to assess whether inducing attentional avoidance of negative information can also reduce emotional reactions to stressful events in children with heightened anxiety vulnerability. They selected children who showed elevated scores on the Screen for Child Anxiety Related Emotional Disorders (SCARED; Birmaher et al., 1999) and were able to replicate Eldar and colleagues' findings with this sample. Avoid negative CBM-A did serve to induce attentional avoidance of negative information in the anxious children and also attenuated the intensity of their anxiety reactions to a subsequent puzzle stressor task.

Most CBM-A work carried out on emotionally vulnerable participants has examined the capacity of attentional bias modification procedures to reduce elevated levels of anxiety. However, Wells and Beevers (2010) investigated whether CBM-A could reduce depression levels in undergraduate students reporting mild to moderate depression. These individuals were exposed to the probe CBM-A procedure in either the avoid negative or a no-training control condition in four sessions spread across 2 weeks. The avoid negative CBM-A procedure produced

a decline in attentional bias to negative information and a significant reduction in depression scores on the Beck Depression Inventory (Beck & Steer, 1993), which was not evident for participants receiving the control condition. Further support for the premise that attentional bias contributes to elevated depression comes from the observation that this reduction in depressive symptoms was mediated by the degree to which the CBM-A induced attentional avoidance of negative information.

Taken together, these CBM studies, carried out on participants selected on the basis of their elevated emotional vulnerability, provide good evidence that interpretive and attentional bias contribute not just to normal variability in emotional disposition, but also to problematic levels of emotional vulnerability. The findings also suggest the possibility that CBM techniques may have potential therapeutic utility in the treatment of emotional pathology. In the following sections, we review more direct evidence that the modification of selective information processing can indeed reduce the symptoms experienced by patients with diagnosed emotional disorders.

Impact of CBM-I on Symptoms of Emotional Pathology

Few studies have yet examined the influence of prolonged CBM-I on clinical psychopathology. However, in an extension of their study on high-worry-prone individuals (Hirsch et al., 2009), Hayes, Hirsch, Krebs, and Mathews (2010) examined the effect of a single CBM-I session on individuals diagnosed with GAD. These clinically anxious participants were exposed to the same CBM-I procedure employed by Hirsch and colleagues (2009), and this was followed by an assessment of negative thought intrusions when performing a breathing focus task both before and after a 5-minute period of instructed worry. It was revealed that the CBM-I condition significantly impacted on the frequency of negative thought intrusions during the breathing focus task, particularly following instructed worry. The patients with GAD who had received the interpret benign CBM-I experienced fewer negative thought intrusions during the breathing task

than did those who received the no-training control condition.

In a small series of A-B design single case studies, Blackwell and Holmes (2010) investigated the impact of interpret benign CBM-I on the symptoms of clinical depression. Seven individuals meeting diagnostic criteria for a major depressive episode had their interpretive bias and their mood state assessed daily for 15 days. Across each of the final 7 days they received 64 trials of CBM-I in the interpret benign condition. Comparison of these baseline and intervention phases led to four of the seven participants being classified as responders, and three of these individuals displayed clinically significant improvement in depression symptomatology across the intervention phase of the study. As the authors acknowledge, there are limitations to the conclusions that can be drawn from this pilot investigation. However, we concur that these findings justify more rigorous testing, within a controlled trial, of the potential contribution CBM-I may make to symptom reduction in clinical depression.

The limited number of CBM-I research studies using clinical samples highlights the need for further research of this nature. Although these early findings certainly are encouraging, they will need further corroboration before it will be possible to confidently conclude that negative interpretive bias causally contributes to emotional pathology, and that CBM-I can make a meaningful therapeutic contribution to the treatment of such pathology.

Impact of CBM-A on Symptoms of Emotional Pathology

There is more compelling evidence that attentional bias causally contributes to emotional pathology, and that CBM-A can exert a therapeutic influence on such clinical dysfunction. Amir, Beard, Burns, and Bomyea (2009) delivered eight, 160-trial sessions of probe CBM-A across a 4-week period to patients diagnosed with GAD. Whereas patients who received a no-training control condition did not evidence improvement in clinical symptoms, those who received avoid negative CBM-A showed a substantial reduction in worry, state anxiety, trait anxiety, social anxiety, and depression.

Indeed, diagnostic interviews revealed that only 50% of those who received avoid negative CBM-A continued to meet diagnostic criteria for GAD at the end of the 4-week intervention, as compared to 87% of those who received the control condition. These findings provide direct evidence that negative attentional bias causally contributes to GAD symptomatology, and they indicate that avoid negative CBM-A may be of value in the treatment of this disorder.

The effectiveness of CBM-A in reducing anxiety pathology is not limited to patients with GAD. Several studies have demonstrated the capacity of avoid negative CBM-A to alleviate the symptoms of social anxiety disorder (SAD). Using a pictorial version of the probe CBM-A procedure, Schmidt, Richey, Buckner, and Timpano (2009) delivered multiple sessions of CBM-A to patients diagnosed with SAD. Across 4 weeks, these patients completed eight sessions of 160 trials in either an avoid negative CBM-A condition or a control condition with no training contingency. Those given the avoid negative CBM-A demonstrated significantly greater reductions in self-reported social anxiety and trait anxiety than did those given the control condition. Furthermore, clinical interviews conducted at completion revealed that 72% of patients given this active CBM-A condition no longer met diagnostic criteria for SAD, compared to only 11% of those given the control condition. Follow-up assessment indicated that these treatment gains were maintained 4 months later.

Schmidt and colleagues (2009) did not assess change in attentional bias. However, measures of attentional selectivity were included in a similar study carried out by Amir, Beard, Taylor, and colleagues (2009), which also delivered eight sessions of either avoid negative CBM-A or a no-training control condition across 4 weeks to patients diagnosed with SAD. Attentional bias assessed posttreatment revealed that patients given the avoid negative CBM-A attended less to negative stimuli than did those who received the control condition. Fifty percent of the former group no longer met diagnostic criteria for SAD postintervention, compared to only 14% of those in the control group. Again, a 4-month follow-up confirmed maintenance of these gains.

More recent research suggests that CBM-A procedures may also be capable of attenuating emotional symptomatology in youth suffering anxiety-related mental health problems. Rozenman, Weersing, and Amir (2011) delivered three avoid negative CBM-A sessions per week, for 4 weeks, to children ages 10–17 with a diagnosis of clinical anxiety (separation anxiety disorder, social phobia, or GAD). Only 25% of the children continued to meet diagnostic criteria at the conclusion of the 4-week CBM-A intervention. These participants also reported a consistent reduction in symptoms of depression, highlighting the potential that depressive symptoms may be responsive to attentional bias modification. As no studies have, to date, examined the impact of CBM-A on the symptoms of patients suffering from clinical depression, this remains an interesting avenue for future research.

Current Issues and Future Directions in CBM Research

The work reviewed in the preceding sections demonstrates that the CBM approach holds considerable promise, both as an investigative methodology capable of illuminating the functional contribution of selective information processing to emotional symptoms of interest, and as a therapeutic technique that may contribute to the alleviation of emotional vulnerability and pathology. The full realization of this promise will depend on investigators now working successfully (1) to broaden the focus of CBM research; (2) to increase understanding of the mechanisms that govern bias modification; and (3) to better exploit the capacity of CBM to yield therapeutic benefits in real-world clinical settings. In this section we consider how work is progressing with respect to each of these three important objectives.

Broadening the Focus of CBM Research

Most CBM studies have sought to modify only selective attention or selective interpretation in participants with heightened emotional vulnerability or dysfunction. However, the types of processing selectivity associated with psychopathology extend

beyond attention and interpretation. Hence, it would be appropriate to now broaden the focus of CBM studies by developing tasks capable of modifying other facets of selectivity. Already, as we review in the following sections, such steps are being taken, with encouraging results.

Modification of Other Processing Biases

The range of available CBM techniques is beginning to expand as investigators seek ways of modifying more diverse forms of processing selectivity. Although much of this work is still in its infancy, we briefly consider some of these newer CBM approaches to illustrate their diversity and to communicate the likely flavor of things to come.

CBM Targeting Memory. Given the importance theorists have placed on memory bias in the etiology of psychopathology, value could be gained from CBM procedures capable of directly modifying selective memory retrieval. Joormann and her colleagues have worked to develop a method of training depressed participants to forget negative information. Their approach is based on Anderson and Green's (2001) work, showing that when participants repeatedly encounter cues previously associated with a target memory item, while following the instruction not to think of this target, the representation of the target information thereafter remains suppressed below baseline. Joormann, Hertel, Brozovich, and Gotlib (2005) have employed this approach to induce selective forgetting of negative information in clinically depressed participants. They also have shown that trained forgetting of negative memories is rendered more effective if clinically depressed individuals focus on distracting information during exposure to the cues (Joormann, Hertel, LeMoult, & Gotlib, 2009). It will require further research to determine whether the application of this memory modification procedure will prove effective in attenuating clinically depressed individuals' preferential recollection of negative memories and in reducing their dysphoric emotional symptoms.

CBM Targeting Imagery. The observation that negative mental imagery is a common characteristic of psychological dysfunction (cf. Hackmann & Holmes, 2004) has led Holmes and Mathews (2005) to contend that such imagery makes a particularly strong contribution to emotional vulnerability. If negative imagery exerts an especially potent impact on emotion, then CBM-I designed to modify the degree to which such selective imagery is evoked by ambiguous scenarios should be particularly effective in altering emotion. Holmes, Mathews, Dalgleish, and Mackintosh (2006) have found support for this prediction, using a single-session auditory CBM-I procedure. This procedure was designed to increase benign resolutions of ambiguous scenarios, but in one condition participants were instructed to form mental images of these scenarios during the CBM-I procedure, whereas in the other they were told to process the scenarios in a verbal form. Benign interpretive bias was most strongly induced by the imagery condition, and this imagery version of the CBM-I procedure proved most effective in attenuating negative emotion. This finding has since been replicated by Holmes, Lang, and Shah (2009), who also demonstrated that the imagery version of the CBM-I procedure was more effective than the verbal version in attenuating dysphoric responses to a subsequent mood induction procedure. Hence, it seems likely that the therapeutic benefits of CBM procedures may be augmented when they are designed to alter emotional imagery.

CBM Targeting Appraisal. A central premise underpinning cognitive accounts of psychopathology is that dysfunctional psychological symptoms can reflect the tendency to appraise events in a maladaptive manner (cf. Power & Dalgleish, 2008). Hence researchers are now beginning to investigate whether the use of CBM procedures to modify appraisal style can attenuate such symptoms. In some task variants, participants have been directly instructed to practice appraising scenarios in a particular way. For example, to address the hypothesis that abstract and overgeneral thinking contributes to rumination and dysphoria, Watkins, Baeyens, and Read (2009) presented participants, who had scored high on a measure of depression, with short auditory scenarios and instructed them to practice processing these in a concrete and specific manner.

Across seven daily sessions, these participants reported greater decreases in depressive symptoms than were shown by participants in a no-practice control condition. In a more recent follow-up study, Watkins and colleagues (2012) employed a randomized controlled design to investigate whether the efficacy of a guided self-help intervention for people with a current diagnosis of major depression could be enhanced by the inclusion of this concreteness training. They found that this form of CBM significantly improved symptoms posttreatment and at 3- and 6-month follow-ups. Taking a similar instructional approach, Schartau, Dalgeish, and Dunn (2009) exposed unselected volunteers to potentially distressing film clips and directed them to practice employing a positive appraisal style. This procedure led to a reduction in the distress evoked by the clips, as revealed by self-report and skin conductance measures.

In other cases, researchers have adapted previously used CBM-I methodologies, but have refined their focus to target particular types of negative appraisal. This was the approach taken by Lang, Moulds, and Holmes (2009) in a study designed to test the hypothesis that maladaptive appraisal of negative intrusive memories increases the frequency of such intrusions. On each trial of this CBM procedure, participants were exposed to text describing appraisal of a negative intrusive memory, in which one word was an incomplete fragment and the nature of the communicated appraisal depended on the identity of this word. Participants were instructed to quickly complete the word fragment. In the appraise negative CBM condition, the only words capable of completing the fragments communicated negative appraisal of memory intrusions, whereas in the appraise benign condition these words communicated non-negative appraisal of such intrusions. Following exposure to this CBM procedure in either condition, participants were shown a distressing film designed to elicit negative memory intrusions. This film evoked less negative memory intrusions across the next 7 days in the participants previously exposed to the appraise benign CBM procedure, compared to those given the appraise negative CBM procedure. In view of recent evidence that the attenuation of intrusive memories can alleviate the symptoms of clinical depression (Kandris & Moulds, 2008), this CBM approach may have practical value in clinical settings.

CBM Targeting Attributional Style. The hopelessness theory of depression proposes that a key causal factor underpinning depressive vulnerability is the tendency to attribute negative events to stable internal causes, whereas resilience to depression results from the tendency to instead attribute them to external transient causes (Abramson, Metalsky, & Alloy, 1989). Peters, Constans, and Mathews (2011) recently developed a CBM task variant specifically designed to modify such attributional style. Each trial in this CBM procedure first described a positive or negative event, with the subsequent completion serving to resolve the initially uncertain cause of this event. In one condition, designed to induce depressogenic attributional style, the resolutions consistently implicated internal stable factors as the causes of negative events and external transient factors as the causes of positive events. In the other condition, designed to induce resilient attributional style, these contingencies were reversed. Following a single CBM session comprising 120 trials of this task, a questionnaire measure confirmed that the groups exposed to these different CBM conditions differed in attributional style, as intended. Furthermore, subsequent exposure to a failure experience served to elevate dysphoria to a significantly lesser extent in those participants who had received the CBM procedure that induced resilient attributional style, compared to those who had received the procedure that induced depressogenic attributional style. These findings provide empirical support for the causal role of attributional style in the moderation of emotional vulnerability, and they suggest that CBM designed to directly alter this attributional style may yield therapeutic benefits.

Illuminating the Mechanisms That Underpin CBM

If we are to optimize the capacity of future CBM interventions to modify cognitive bias, then we must develop a good understand-

ing of the mechanisms through which CBM procedures change such patterns of processing selectivity. Of course, we must be confident that the changes in both the processing bias and symptomatology are genuine and do not represent only a demand effect, reflecting participants' compliance with what they perceive to be the experimenter's expectation. MacLeod and Mathews (2012) offer the following six reasons to doubt the plausibility of demand-effect explanations for CBM-induced change: (1) the patterns of altered task performance that serve to confirm occurrence of the intended cognitive change commonly are not readily evident to participants; (2) simulating this pattern of task performance often would be exceptionally difficult; (3) neurocognitive measures have provided concurrent evidence of CBM-induced cognitive change (e.g., Browning, Holmes, Murphy, Goodwin, & Harmer, 2010; Eldar & Bar-Haim, 2010); (4) CBM-induced symptom change commonly is more highly specific than would be expected if it resulted from demand; (5) such symptom change has also been observed on psychophysiological measures that are not amenable to voluntary control; and (6) direct assessment of participant expectancies has shown that these cannot account for the observed effects of CBM. Hence, it appears that CBM does produce genuine change in processing selectivity.

But through what mechanism is this change produced? It could be argued that CBM-induced change in processing bias might be mediated by mood, given that CBM procedures commonly expose participants to emotional information that could potentially serve to directly influence their mood state. However, the weight of evidence is against this account. The induction of differential mood state does not elicit the cognitive changes produced by CBM (Standage, Ashwin, & Fox, 2010), and these cognitive changes are produced by CBM even when the bias modification procedure itself has no effect on mood (Hoppitt, Mathews, Yiend, & Mackintosh, 2010; Wilson et al., 2006). When CBM does exert an impact on mood, this effect does not statistically account for its impact on cognitive bias (Amir et al., 2008; Hirsch, Mathews, & Clark, 2007), and CBM-induced cognitive changes remain evident for periods of time that far exceed the

duration of any such transient mood effects (Hazen et al., 2009; Mackintosh, Mathews, Yiend, Ridgeway, & Cook, 2006). Neither does the evidence support the idea that CBM may bring about observed changes in cognitive task performance through general affective priming, whereby increased exposure to information of one particular emotional valence during training generally facilitates the processing of subsequent information that shares this same emotional tone. Observed training effects are often more specific than would be predicted by such a semantic priming account, and these effects endure across time periods that greatly exceed the temporal scope of semantic priming (MacLeod & Mathews, 2012).

The most plausible account of CBM-induced cognitive change, articulated in some detail by Hertel and Mathews (2011), is that this change results from transfer of training (Blaxton, 1989). According to this account, after participants have been required to continuously "practice" a specific pattern of selectivity while engaging in the particular cognitive process invoked by the CBM training procedure, this pattern of selectivity then transfers to other tasks that require participants to again employ this same cognitive process. If this is so, then the most effective CBM tasks should be those that generate the most pronounced transfer-of-training effects. Thus, ensuring that CBM-induced change in information processing generalizes beyond the constraints of the CBM training procedure is of paramount importance. One widely adopted method of verifying that CBM training effects generalize beyond the specific stimulus sets used in training involves the inclusion within assessment tasks of new stimulus materials, not previously exposed during the preceding training procedures. To maximize transfer of training to new stimulus materials, it may be prudent to vary the stimuli used across different CBM sessions, such that participants acquire an altered cognitive response to a broad class of stimuli, as opposed to a single subset of stimuli (See et al., 2009).

In addition to the transfer of CBM training across stimuli, it is also desirable that such training transfers across different tasks designed to assess bias in the cognitive process targeted by the CBM procedure. Hence

it is appropriate to measure this cognitive process, post CBM, using assessment tasks that differ substantially from those employed to deliver the bias modification. Again, the likelihood that training will transfer across a wide variety of tasks designed to assess the target cognitive process may be maximized by using a broad range of different CBM procedures to induce the desired cognitive change. Thus, for example, rather than restricting CBM-I to a single interpretive training task delivered repeatedly, a battery of interpretive training tasks that share the inclusion of a contingency designed to encourage the same pattern of interpretive selectivity, but that differ in terms of other task parameters and procedures, may produce better generalization of training effects across a wider variety of subsequent bias assessment tasks.

Another issue related to transfer of training concerns the transfer of the CBM-induced change in a targeted cognitive process to other types of information operations. There has been growing experimental interest in evaluating the degree to which the cognitive training effects produced by alternative CBM procedures transfer across different cognitive processes. Recent findings suggest that effective CBM procedures may operate to change processing selectivity at a fundamental level within the cognitive system that spans attentional, interpretive, and memorial processing. Thus, for example, it has been shown that the probe CBM-A training task affects not only selective attention but also exerts an impact on selective interpretation (White, Suway, Pine, Bar-Haim, & Fox, 2011), and that Mathews and Mackintosh's (2000) CBM-I training task influences attentional bias (Amir, Bomyea, & Beard, 2010) and memory bias (Tran, Hertel, & Joormann, 2011) in addition to interpretive bias. As noted by MacLeod and Mathews (2012), the systematic investigation of such CBM transfer-of-training effects should assist future researchers to categorize and fractionate the cognitive mechanisms that underpin the spectrum of psychological disorders. Moreover, it should enable them to identify the CBM variants that exert the most pervasive influence on selective information processing, and so promise to yield the most widespread therapeutic benefits.

Exploiting the Applied Benefits of CBM in Real-World Settings

Our capacity to extract maximum real-world clinical benefits from CBM-based research will be further enhanced by two developments. First, it will be necessary to refine CBM technologies in ways that bolster the magnitude and stability of the changes they induce in their target cognitive biases. Second, these CBM interventions must be packaged in a manner that not only is therapeutically beneficial to patients, but that patients find acceptable within the clinical setting. We conclude by briefly considering how such goals might be pursued and by reviewing recent progress toward these objectives.

For CBM to be a maximally effective therapeutic tool, it is necessary to optimize the emotional impact of CBM-induced change in information processing. In some ways it might be considered paradoxical that CBM procedures designed to induce avoidance of negative information have been shown to be emotionally beneficial, given the evidence that intentional efforts to avoid information and situations that elicit anxiety may be implicated in the development and maintenance of emotional pathology, particularly anxiety-related problems (cf. Barlow, 2002). The resolution to this apparent paradox may lie in the difference between the type of avoidance encouraged by CBM and the type of avoidance that instead characterizes (and possibly contributes to) emotional dysfunction. In the latter case, individuals commonly adopt the explicit goal of intentionally avoiding processing threatening information in an active effort to suppress anxiogenic thoughts. As is well documented from the extensive work of Wegner and colleagues, effortful attempts at suppression frequently evoke the "ironic" effect of increasing the very patterns of thinking they are intended to attenuate (Wegner, Schneider, Carter, & White, 1987). Hence, deliberate efforts to avoid processing negative information might contribute to emotional dysfunction simply because this avoidance intention does not effectively translate into the successful cognitive avoidance of such information, but instead ironically elicits the pattern of cognitive vigilance for negative information typically evidenced by people suffering

from such conditions. In contrast, CBM is designed to induce cognitive avoidance of negative information in a manner that does not involve effort or intention at all. Rather, this pattern of cognitive selectivity is encouraged by exposure to a task contingency that generally is not communicated explicitly to participants, but instead is intended to implicitly evoke the desired change in selective information processing. Assessment tasks confirm that CBM is effective in successfully inducing cognitive avoidance of negative information, which contrasts with the widely reported finding that attempts to avoid negative processing through effortful and intentional suppression commonly fail (Wenzlaff & Wegner, 2000). It is plausible, therefore, that the successful cognitive avoidance of negative information, as is induced by CBM, yields emotional benefits, whereas the counterproductive emotional consequences of more effortful attempts to avoid negative information reflect the fact that such efforts can paradoxically induce vigilance for such information.

Although necessarily speculative at the this stage, the above discussion bears upon a potentially important methodological issue concerning whether or not the efficacy of CBM would be impaired or enhanced by making participants explicitly aware of the training contingency and encouraging effortful practice in the desired pattern of processing selectivity. Very few researchers have yet sought to systematically examine whether the adoption of more explicit learning instructions in CBM procedures would serve to impair or to enhance their emotional impact, and early findings are mixed. MacLeod, Mackintosh, and Vujic (2009) have reported that the introduction of explicit learning instructions to their CBM-A procedure increased the magnitude of the attentional training effect on the training task itself, but eliminated transfer of this training to a different measure of attentional selectivity. It also eliminated the impact of the CBM-A procedure on emotional reactivity to a subsequent stressor. In contrast, however, Krebs, Hirsch, and Mathews (2010) found that their CBM-A manipulation had a more powerful impact on worry symptomatology when participants were given explicit learning instructions. Thus, further research is clearly needed to establish whether it is preferable to design CBM procedures in ways that maximize the contributions of implicit or explicit learning to the underlying cognitive change process.

Not uncommonly, it has been observed that the degree to which a CBM intervention attenuates the dysfunctional symptoms of interest is a direct function of the degree to which it changes the target cognitive bias. Hence the use of CBM approaches that induce cognitive changes of greater magnitude might reasonably be expected to result in more pronounced therapeutic benefits than those that exert a lesser impact on cognitive bias. Few studies have systematically compared alternative variants of CBM approaches to determine which produce the greatest cognitive change, but the field is now at the stage where meta-analysis can serve to usefully inform investigators about such matters (Hakamata et al., 2010; Hallion & Ruscio, 2012). Some of the findings from recent meta-analyses are perhaps unsurprising, such as the observation that the use of more CBM training sessions results in greater cognitive change. However, other factors found to affect the magnitude of cognitive bias modification effects are less self-evident. For example, from their meta-analysis, Hakamata and colleagues (2010) were able to show that probe CBM-A tasks that have separated the valenced stimuli vertically rather than horizontally, and those that have employed verbal rather than pictorial stimuli, produce the most pronounced change in attentional bias. The reasons for this are presently not clear, but candidate explanations, such as the possibility that verbal stimuli may permit participants to generate more personalized mental imagery than do pictorial stimuli, are amendable to future experimental investigation. We anticipate that the refinement of CBM methodologies to maximize cognitive change will be a cyclic process in which meta-analyses play a major role. Meta-analyses can identify which CBM task parameters have been associated with the magnitude of induced cognitive change in previous studies, leading to research designed to illuminate the mechanisms that underpin the enhanced efficacy of particular CBM variations, resulting in a range of more powerful CBM variants, the relative efficacy of which can be contrasted in subsequent meta-analyses.

Even a large change in cognitive bias will have limited therapeutic value if it does not endure across time. Reassuringly, the evidence suggests that a single CBM session can produce surprisingly robust cognitive bias change, particularly in the case of CBM-I. For example, it has been shown that one session of Mathews and Mackintosh's (2000) CBM-I procedure exerts an impact on selective interpretation that endures for at least 24 hours (Yiend, Mackintosh, & Mathews, 2005) and continues to influence emotional vulnerability even after such a delay (Mackintosh et al., 2006). Nevertheless, most researchers concur that the use of multiple CBM sessions will be required to produce truly lasting change in processing selectivity, raising the question of how best to schedule such sessions to yield the most enduring effect. See and colleagues (2009) note that previous work contrasting the persistence of learning acquired through either massed or spaced practice (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006) suggests that increasing the temporal separation of CBM sessions should increase the stability of the resulting bias change. It also has been proposed that the use of occasional booster CBM sessions, following completion of an initially intensive program of CBM, may contribute to the maintenance of such cognitive change (MacLeod, Koster, & Fox, 2009). Future studies designed to directly test such ideas may serve to enhance the longevity of CBM induced change in cognitive bias.

The continuing accrual of positive findings from small-scale randomized control trials provides good grounds for optimism that CBM will prove to be of value in the clinical context (Beard, Weisberg, & Amir, 2011; Brosan, Hoppitt, Shelfer, Sillence, & Mackintosh, 2011). Indeed, in their meta-analysis Hakamata and colleagues (2010) report that, when delivered to clinically anxious participants, CBM-A yields treatment effect sizes similar to those associated with CBT or selective serotonin reuptake inhibitors (SSRIs). Furthermore, client acceptability studies have confirmed that patients with emotional dysfunction express subjective satisfaction with multisession CBM-A and CBM-I delivered as part of their regular treatment (Beard, Weisberg, Perry, Schofield, & Amir, 2010). There is agreement among most researchers that the time is now ripe for large-scale trials, designed to comply fully with the Consolidated Standards of Reporting Trials guidelines (CONSORT), in order to demonstrate the capacity of CBM to yield meaningful therapeutic benefits for clinical patients in real-world settings (Beard, 2011; MacLeod, 2012).

Closing Comments

As we noted at the outset of this chapter, this is a young field of research. The range of presently available CBM techniques is limited, and almost certainly these do not yet represent the most effective possible means of inducing enduring change in the patterns of processing selectivity they target. In the fullness of time, we can expect to see CBM approaches broaden in terms of methodology, diversify in terms of the biases they target, and strengthen in terms of their capacity to modify these biases in an enduring manner. Nevertheless, on the basis of the seminal work reviewed in this chapter, we can already conclude that the advent of CBM has brought us to an exciting new juncture in our efforts to understand the cognitive basis of psychopathology and to exploit this understanding for therapeutic gain. Researchers seeking to determine whether particular forms of selective attention or selective interpretation contribute to symptoms of interest now can do so by drawing upon newly established techniques with a proven capacity to directly modify such aspects of information processing. When such causal influence is demonstrated, clinical investigators now can incorporate these same bias modification procedures into intervention approaches designed to attenuate such symptoms. The CBM studies reviewed in this chapter provide compelling evidence that attentional bias to negative information, and interpretive bias favoring negative resolutions of ambiguity, do both causally contribute to emotional vulnerability and pathology. Furthermore, CBM interventions designed to alleviate clinical symptoms by directly training target patterns of attentional and interpretive selectivity now have passed the proof of concept stage. These finding amply justify the larger-scale clinical trials that we can expect to see appear in the near future, and

we look forward with excitement, anticipation, and no small measure of optimism to this next stage of the CBM journey.

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