# Chapter 11
# Cognitive Bias Modification Training to Change Interpretation Biases


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## 11.1 Cognitive Bias Modification – Interpretation (CBM-I) Training

According to cognitive models of psychopathology, many psychological disorders are characterized by interpretation biases and a great body of research has provided empirical support for this claim (Harvey et al., 2004; Schoth & Liossi, 2017). This assumption has been especially influential with respect to emotional disorders (Hirsch et al., 2016; Mathews & Macleod, 2005). To illustrate, depressed or anxious individuals are, compared to non-anxious individuals, more likely to interpret disorder-relevant ambiguity in a negative or threatening manner (Hirsch et al., 2016); individuals suffering from Posttraumatic Stress Disorder (PTSD) will appraise the experienced traumatic event and its consequences in a dysfunctional manner (Brown et al., 2019; McNally & Woud, 2019), and interpreting normal intrusive thoughts (e.g., "I will jump in front of the train") as threatening is a core problem in Obsessive Compulsive Disorder (OCD) (Salkovskis, 1985).

Cognitive models not only argue that psychopathology is associated with biased interpretations, but that these biases play a critical role in the etiology and maintenance of emotional psychopathology (Beck, 1976; Beck et al., 1985; Williams et al., 1997; (for an overview of the role of interpretation biases in the etiology of

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emotional psychopathology, see Chap. 12 by Woud and Hofmann). Put differently, they argue that biased interpretations play a *causal* role in pathological emotions and behaviors. Despite the great body of research emphasizing the strong and robust association between interpretation biases and symptoms of emotional psychopathology, up to 2000, the causal role of biases remained largely unstudied. To examine whether a factor (i.e., interpretation bias) is a causal risk factor, it should not only be shown that the factor is a correlate of and precedes psychopathology, but, importantly, it should also be demonstrated that the factor can be manipulated (variable risk factor) and that such a manipulation results in an increase or decrease in levels of psychopathology (framework by Kraemer et al., 1997). Applied to the present context of interpretation biases, this implies that if the biases' manipulation is indeed followed by a congruent change in levels of psychopathology, the variable risk factor should then be regarded as a causal risk factor. A similar line of argumentation has been adopted by Grafton et al. (2017). To test the hypothesized causal role of interpretation biases on psychopathology symptoms, researchers started to design computerized procedures manipulating interpretation biases from about 2000 onwards to examine whether this manipulation has an effect on symptoms of emotional psychopathology. This approach is called Cognitive Bias Modification (CBM) (Koster et al., 2009; MacLeod & Mathews, 2012) and the specific training procedure central for the present chapter is called Cognitive Bias Modification-Interpretation[1] (CBM-I).

The past two decades have witnessed a surge of interest in CBM-I. Originally, CBM-I was applied primarily with a theoretical aim to probe the potential causal role of interpretation biases in psychopathology. As those initial studies provided evidence consistent with a causal role of interpretation biases (see, for example, Mathews & Mackintosh, 2000; Salemink et al., 2007), a subsequent more clinically oriented line of research investigated the potential clinical utility of CBM-I, aiming to reduce symptoms of emotional psychopathology. Based on the rationale that if there is a training that can systematically reduce interpretation biases, such a training might have therapeutic effects given the expected impact upon emotions and behaviors.

In this chapter, we will provide an overview of (a) CBM-I paradigms that are often used to modify emotional interpretation biases; (b) results from recent meta-analyses regarding the effects of CBM-I training; and (c) mediators and moderators of CBM-I training effects. This summary will include studies in which CBM-I has been applied in both an experimental and clinical research context. We will round off the chapter with some concluding remarks and a discussion of future directions.

[1] This term will be used as an umbrella term for all procedures that target interpretive biases and related processes, i.e., procedures that all target the manipulation of interpretive, evaluative, and appraisal-related processes.

## 11.2 Overview CBM-I Training Paradigms

During the past two decades, different CBM-I training paradigms have been developed. However, all of them have a common aim, that is, modifying interpretation biases and by doing so affecting symptoms of emotional psychopathology. Generally, existing interpretation bias *assessment* tasks were adapted to training tasks to modify the biases. Specifically, these *training* tasks include an experimentally established contingency between the presented cue and a certain response, expecting that participants' biases can be manipulated via learning the contingency (cf. Koster et al., 2009). So how does this work in the context of CBM-I? A commonality across CBM-I paradigms is that participants are presented with ambiguous materials and repeatedly trained to interpret this material in a certain way (e.g., positively or negatively, depending on the training's conditions). Across many training trials, participants therefore learn to anticipate positive/negative outcomes for the ambiguous information, and, in turn, acquire a bias to interpret ambiguous information accordingly. The types of ambiguous stimuli vary across training paradigms, and can include for example words, short stories, and images. Trainings also vary in *content* given the disorder-specificity in interpretations. Thus, the stimuli presented in the training need to capture the salient cognitions of the respective psychological disorder (e.g., anxious- vs. depression-related cognitions). In the next paragraphs, we will present a chronological overview of training approaches in the context of CBM-I. We will provide examples of CBM-I training for different types of symptoms and psychopathology, to illustrate the match between training stimuli/content and salient cognitions of psychological disorders.

### *11.2.1 Scenario-Based CBM-I*

The scenario-based CBM-I training procedure was one of the first developed paradigms and has been used most in subsequent research. In this scenario-based training developed by Mathews and Mackintosh (2000), participants are presented with ambiguous, open-ended scenarios. Participants are instructed to imagine themselves in the scenario, as if they are part of the described situation. Each scenario ends with a word fragment (i.e., a word with missing letters) such that the meaning of the scenario remains ambiguous until the word fragment is completed. It is the participants' task to finish each scenario by completing the word fragment. The word fragments are designed such that only one possible solution completes the scenarios' meaning. Completing the word fragment then produces a valenced outcome consistent with the training condition (e.g., a positive or negative interpretation of the ambiguous scenario). An example for a scenario in the context of social anxiety is as follows (see Mathews & Mackintosh, 2000, p. 604): "Your partner asks you to go to an anniversary dinner that their company is holding. You have not met any of their work colleagues before. Getting ready to go, you think that the new people you will

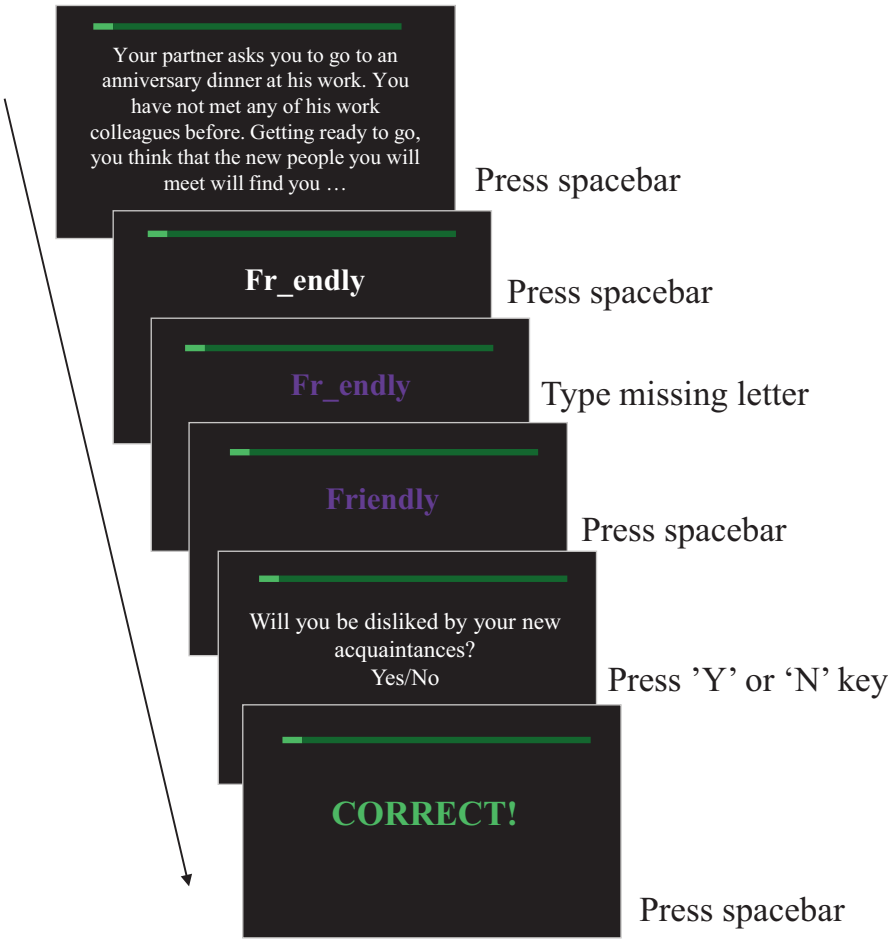


**Fig. 11.1** Example of a positive scenario-based CBM-I training for social anxiety

meet will find you …", "fri-ndly" (*friendly* in the positive training condition) or "b-ring" (*boring* in the negative training condition). To encourage participants to thoroughly process the scenario's meaning, scenarios are followed by a yes/no comprehension question. For the previous example this might be: "Will you be disliked by your new acquaintances?", and participants receive feedback for (in)correct responses (see Fig. 11.1 for an illustration).

The scenarios in Mathews and Mackintosh's (2000) experiments described ambiguous social situations as they aimed to modify interpretations in the context of social anxiety. In the following paragraphs, we will provide some examples of this scenario-based training applied to other emotional disorders (anxiety, depression, PTSD, and OCD), to illustrate how this paradigm can be tailored to modify

disorder-specific interpretations. Teachman and Addison (2008), for example, trained positive interpretations of spiders in individuals high in spider fear using the scenario-based training. An example trial in the positive condition is: "You wake up in the middle of the night and see something on your alarm clock. You realize it is a spider. You think that it is …", "h-rmless" (*harmless* in the positive training condition) (p. 451). Post-training, while the positive training group interpreted novel spider-relevant scenarios more positively and less negatively, there were no group differences on spider fear. This scenario-based training has also been applied in other areas of anxiety, for example to height phobia (see, for example, Steinman & Teachman, 2014) or anxiety sensitivity (Steinman & Teachman, 2010). In the context of anxiety sensitivity, the training aimed to reduce negative interpretations in individuals with high anxiety sensitivity using scenarios such as: "You are jogging. Your heart starts to beat quickly. This is …", "in-igorating" (*invigorating* in the positive training condition) (p. 73). Compared to two control conditions (neutral vs. no training), the positive training group had lower scores on a self-report measure of anxiety sensitivity symptoms post-training.

The scenario-based CBM-I training has also been frequently applied to depression. For example, Lang et al. (2009) designed a scenario-based CBM-I training to target maladaptive appraisals of intrusive memories that are associated with depression. Stimuli in the positive condition utilized adaptive appraisals/interpretations such as "Having an intrusive memory means nothing is wrong with me" (p. 141). Healthy participants who underwent the positive CBM-I training (compared to the negative training) showed a more positive appraisal bias and reported fewer intrusions of a depressive film 1 week later. Joormann et al. (2015) showed that two sessions of this type of positive training in individuals diagnosed with major depressive disorder resulted in participants reporting more positive interpretations, more positive memory intrusions, and showed a smaller increase in heart rate in response to a stressor. Another example in the context of depression is the CBM-I training by Yiend et al. (2014). This training targets the full range of depression-related cognitive errors including interpretation biases, thus broadening the scope of the training.

In the context of PTSD, an appraisal-based CBM-I training was designed to train both functional and dysfunctional trauma-related reappraisals or interpretations of self-efficacy and secondary emotions (e.g., De Kleine et al., 2019; Woud et al., 2012, 2013, 2018c). For example, "In a crisis, I predict my responses will be …", "h-lpf-l" (*helpful* in the positive training condition) or "u-el-ss" (*useless* in the negative training condition) (Woud et al., 2012, p. 780). Compared to the negative training, the positive training induced more functional appraisals and resulted in fewer intrusions and lower levels of posttraumatic stress symptoms post-training, and these results were replicated in a clinical sample of PTSD (Woud et al., 2021). In OCD, CBM-I training targets the misinterpretations (as threatening) of (normal) intrusive thoughts/obsessions (Clerkin & Teachman, 2011; Williams & Grisham, 2013; Wolters et al., 2021). In adolescents with OCD, a CBM-I scenario could be the following: "You bought some roses for your mum and accidently got pricked by a thorn. You are bleeding and ask your mum to put a band-aid on it. It is … unli-ely

(*unlikely* in the positive training condition) that this would make your mother sick. If you are bleeding, is there a great risk of making somebody else sick?" (Salemink et al., 2015, p. 114). Results indicated that the positive CBM-I training, compared to a placebo version of the training, resulted in lower levels of self-reported and clinician-rated OCD symptoms.

Application of this scenario-based CBM-I training has also been applied beyond the emotional domain. For example, it has been applied to the field of alcohol consumption. In an alcohol-related CBM-I training (Salemink et al., 2019) that focused on alcohol consumption in negative affective situations, an example scenario is the following: "I am worrying about the presentation I gave. To relax, I'll take a …", "n-p" versus "b-er" (respectively *nap* or *beer*) (Salemink et al., 2019, p. 108, see also Woud et al., 2015). The training has also been applied to aggression. In that domain, CBM-I training tends to target hostile attribution/interpretation biases (the tendency to interpret others' motives and intentions in ambiguous situations as hostile) (Van Bockstaele et al., 2020b). An example of such a CBM-I-scenario in the context of hostile attributions is the following: "You're at the tennis court. A player hits the ball hard against your head. It hurts a lot. The player is …", "inexp-rienc-d" (*inexperienced*) (p. 4).

### *11.2.2 Homograph CBM-I Training*

In the homograph training developed by Grey and Mathews (2000), participants are presented with a cue word, followed by a word fragment. Participants are told that the cue word helps them to resolve the word fragment, and they are instructed to complete the word fragment by pressing its first missing letter. Unbeknown to the participants, the cue words are homographs (i.e., words with multiple meanings), and the word fragments are constructed in such a way that they either represent a neutral/positive or negative interpretation of the previously presented homograph, depending on the participant's training condition. Some examples of homographs with a negative and neutral/positive meaning in the context of anxiety: "choke": "throat" versus "engine"; "patient": "sick" versus "kind"; "parting": "leaving" versus "center". In a series of proof of principle experiments, Grey and Mathews (2000) showed that this homograph CBM-I training was indeed capable of changing interpretation biases. In a later study, it was examined whether the homograph CBM-I training would also impact on anxiety reactivity to a stressor (Wilson et al., 2006). Participants were randomly allocated to either a positive or a negative training condition using Grey and Mathews' (2000) homograph paradigm. After the training, participants watched stressful videos (i.e., a stress task) with state anxiety measurements before and after. Results indicated that interpretation biases were changed and that they affected stress reactivity accordingly. That is, only participants who were trained to interpret the homographs in a negative manner (compared to the

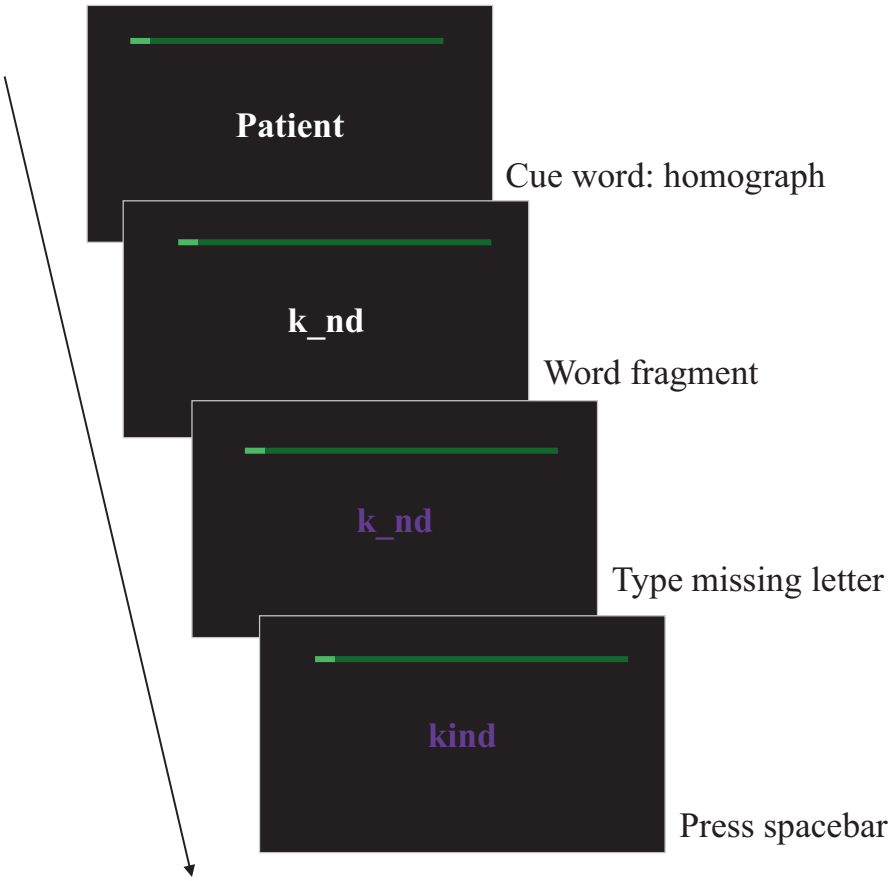


**Fig. 11.2** Example of a positive homograph-based CBM-I training for anxiety

positive training) experienced an increase in state anxiety in response to the stressful videos. See Fig. 11.2 for an illustration.

There have only been a limited number of studies that have used this homograph CBM-I training. This low number is especially apparent when comparing it to the large number of studies that have used the scenario-based CBM-I training as both paradigms were introduced in a publication in the year 2000. The requirement of having enough homographs with two meanings of opposing valence or content might have hindered the application to use in multi-session training and to other domains of psychopathology. Also, translation from the English homographs (Grey & Mathews, 2000) to other languages has been difficult as there is no 1-to-1 translation.

### *11.2.3 Interpretation Modification Program (IMP): Word Sentence Association Paradigm (WSAP)*

During the Interpretation Modification Program: Word Sentence Association Paradigm (IMP-WSAP) developed by Beard and Amir (2008), participants are presented with ambiguous disorder-relevant sentences. Every sentence is presented twice; once with a word prime that corresponds to a disorder-relevant interpretation, and once with a word prime that corresponds to a disorder-irrelevant interpretation. An example in the context of social anxiety: "criticize" versus "praise" – "Your boss wants to meet with you". It is the participants' task to decide as quickly as possible whether the word prime is related to the ambiguous sentence. This is followed by feedback, depending on the participants' training condition: Participants in the positive condition receive reinforcing feedback during trials where they accept word-sentence combinations with a positive word prime and reject word-sentence combinations with a negative word prime. Participants in the negative condition receive the opposite feedback. An eight-session training completed over 2 weeks by socially anxious individuals revealed that the IMP-WSAP successfully decreased threat interpretations, increased benign interpretations, and decreased social anxiety symptoms compared to a control condition (Beard & Amir, 2008). See Fig. 11.3 for an illustration.

Steinman and Teachman (2014) adapted the IMP-WSAP for the context of fear of heights by associating positive words with ambiguous, height-relevant sentences. For example, the presented word "risky" or "stable" was followed by the sentence "As you stand on a stepladder, you feel it rock slightly beneath you" (Steinman & Teachman, 2014, p. 408). This training was combined with the scenario-based CBM-I training. Extremely height-fearful individuals completed two training sessions and compared to a control condition, had lower negative interpretation biases and less fear of heights. These IMP-WSAP results were comparable to the effects of an exposure condition. Möbius et al. (2015) adapted the IMP-WSAP to allow for modifying depression-related interpretations. In their training, the following sentence "Your supervisor is surprised by your work" was for example presented with a benign word (e.g., "competent") or a negative word (e.g., "incompetent") (Möbius et al., 2015, p. 39). In a sample of healthy participants, the IMP-WSAP training enhanced a healthy bias favoring benign interpretations, however, it did not attenuate emotional vulnerability during a stressful task. Also, Conley and Wu (2018) examined the effectiveness of the IMP-WSAP training in the context of OCD by combining, for example, the word "disease" with "You visit someone who is ill" (Conley & Wu, 2018, p. 58). Participants with elevated contamination concerns who completed the training, compared to a control condition, showed a decrease in interpretation biases for threat cues and when ceiling effects were accounted for, completed more steps when approaching contaminants in a behavioral approach task. Additionally, beyond the emotional psychopathology domain, this IMP-WSAP training has, for example, also been applied to body dissatisfaction where appearance-related interpretations were re-trained (Dietel et al., 2020).

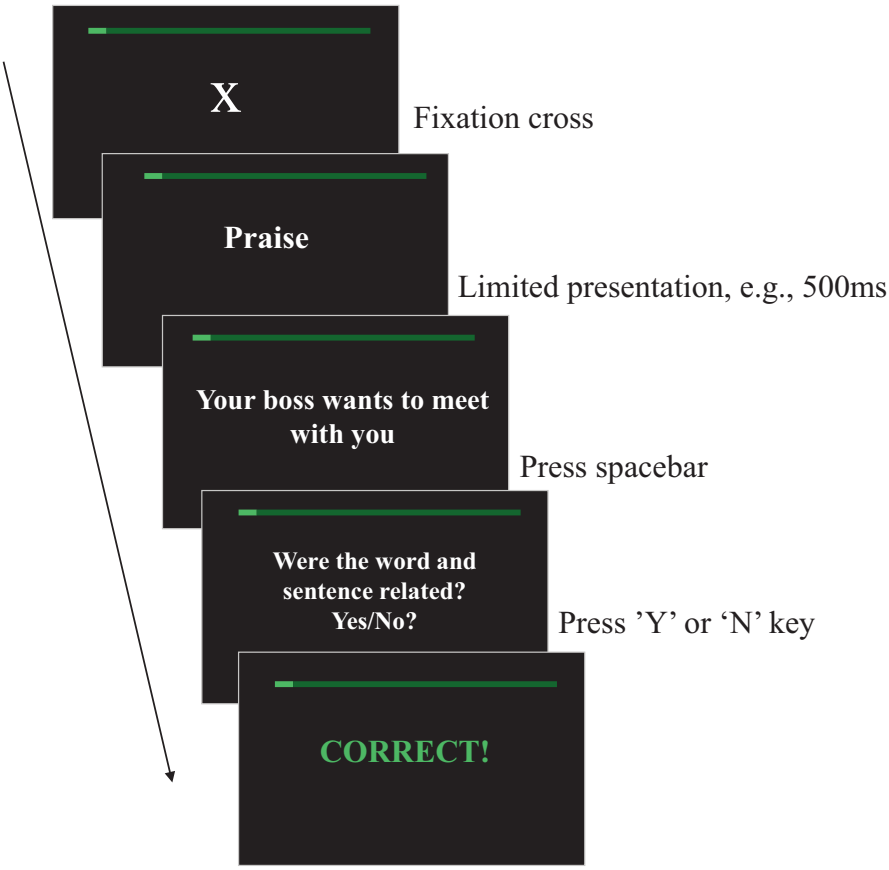


**Fig. 11.3** Example of a positive Word-Sentence Association Paradigm CBM-I training for anxiety

### *11.2.4 CBM-I Training Paradigms with Images or Imagery*

Given the importance of mental images in emotions and affect (Holmes & Mathews, 2005; Holmes et al., 2016), CBM-I training paradigms have been developed that use images and pictures instead of words and sentences as stimuli (with the latter used as the comparison training condition). These training paradigms focus more on visual/imagery processing given the hypothesized stronger link to emotions (for an overview of imagery-based training paradigms to reduce interpretation biases, see Chap. 6 by Blackwell). One such paradigm is the picture-word training (Holmes et al., 2008). During this training, participants are presented with colored, ambiguous photographs of mostly neutral, ambiguous, everyday scenes: e.g., people sitting in a park, a bus, or a classroom (Holmes et al., 2008). Each picture is combined with a word or short phrase, providing potential positive or negative interpretations of the

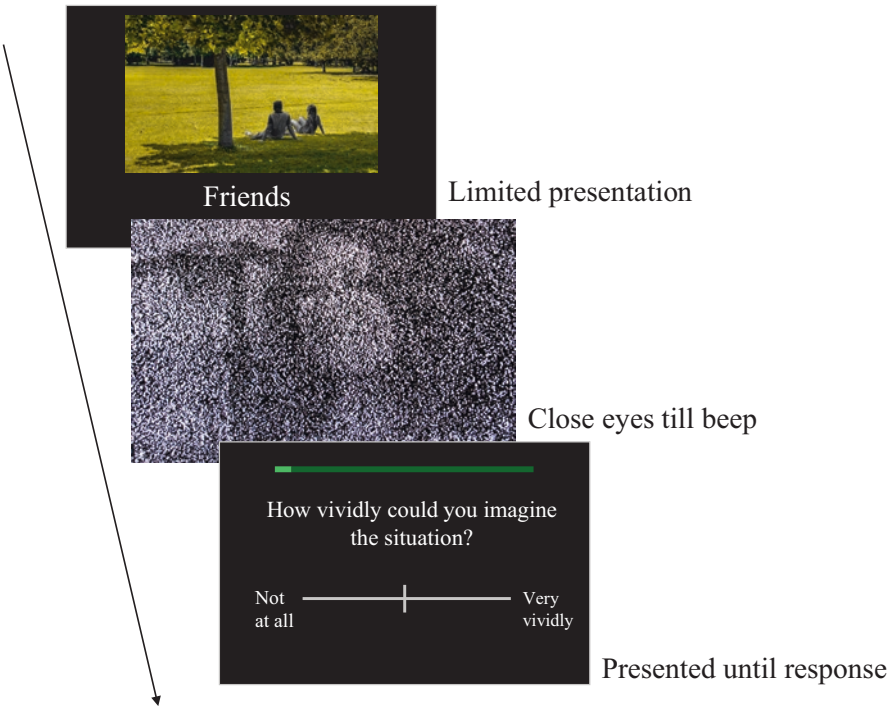


**Fig. 11.4** Example of a positive picture-word CBM-I training for anxiety

picture. An example in a social context is a picture of a person sitting in the park accompanied by the word "friends" for a positive interpretation, or by the word "excluded" for a negative interpretation. Participants are instructed to form a mental image of the picture-word combination. Participants in both the positive and negative training conditions receive the same pictures. However, during the positive training, participants are repeatedly presented with positive interpretations, whereas participants of the negative condition are repeatedly presented with negative interpretations. Using this picture-word training, Holmes et al. (2008) compared an imagery task instruction (i.e., imagine the combination of the picture and word) with a verbal task instruction (i.e., create a grammatically correct sentence using the picture and word) (see Fig. 11.4 for an illustration). It was shown that the imagery training condition had a greater impact on state anxiety than the verbal training condition, which is consistent with the hypothesis that imagery, compared to verbal processing, evokes stronger affective responses.

Another approach has been to present the scenario-based training auditorily via headphones with participants being instructed to imagine the situation and presented interpretation (see, for example, Hirsch et al., 2009, for an application in worry). In the context of depression, Blackwell and Holmes (2010) examined the effectiveness of this imagery version with scenarios such as: "You ask a friend to look over some work you have done. They come back with some comments, which

are *all very positive*" (resolution in italics) (Blackwell & Holmes, 2010, p. 341). In a case-series design, seven individuals experiencing a major depressive episode completed daily CBM-I training sessions for a week and four of them demonstrated improvements in mood, bias, and/or mental health. In 2015, Blackwell and colleagues examined the effectiveness of the picture-word training (six sessions) combined with the auditory scenario-based training (six sessions) as a treatment for individuals with a major depression. Unexpectedly, there was no significant advantage for the combined CBM-I trainings compared with a control condition on depression symptoms. However, when exploring subgroups, imagery CBM-I training significantly improved anhedonia and improved depression symptoms (compared with the control condition) for those participants with fewer than five episodes of depression and those who imagined the scenarios more vividly.

In the context of aggression, a different type of pictorial training has been developed (Penton-Voak et al., 2013). Aggressive individuals tend to interpret ambiguous social cues as hostile and angry (Nasby et al., 1980). In the training, images of ambiguous faces are used to encourage the perception of happiness over anger (Penton-Voak et al., 2013). Stimuli consisted of a morphed continuum of images ranging from an unambiguously happy face to an unambiguously angry face with emotionally ambiguous images in the middle. During the training, participants indicate whether the face is happy or angry. The subsequently provided feedback (correct versus incorrect) aims to shift the decision towards happier interpretations. Youth being at risk for committing a crime completed four of these training sessions (Penton-Voak et al., 2013; Experiment 2). Results indicated that, compared to a control condition, participants in the training condition shifted their interpretations which resulted in a decrease in self-reported aggression and clinician-rated aggressive behavior.

### *11.2.5 Assessing Effects on Interpretation Bias*

The aim of all described CBM-I paradigms is to change interpretation biases and an important step is to test whether a CBM-I training was successful in modifying those biases. Various tasks have been used to measure interpretation biases and two will be described as an illustration (for an overview of measures to assess interpretation biases, see Chap. 3 by Würtz and Sanchez-Lopez). A recognition test (Mathews & Mackintosh, 2000; Salemink & van den Hout, 2010) is often used. It consists of an encoding phase where participants are presented with novel ambiguous scenarios that have an identifying title. In the subsequent recognition phase, the titles are presented again, each followed by a set of four related sentences. Participants have to rate how close in meaning each new sentence seems to the original scenario the title belongs to on a 4-point Likert scale. Two sentences represent a possible positive and a negative interpretation of the original scenario (target items). The other two sentences have a general positive/negative meaning, but do not provide an actual resolution of the scenario's ambiguity (foil items). Generally, it is expected that those

participants that were trained positively give higher similarity ratings for positive compared to negative target items, and vice versa for those trained negatively. This recognition task is often used to evaluate the scenario-based CBM-I training effects on interpretation biases.

Another task to assess interpretation biases is the Word Sentence Association Paradigm-assessment task (Beard & Amir, 2008). Sentences are presented two times: once with a word prime that corresponds to a disorder-relevant interpretation, and once with a word prime that corresponds to a disorder-irrelevant interpretation. Contrary to the set-up in the IMP-WSAP training, in the assessment task, there is no feedback provided after participants indicated whether a word and sentence are related. The decision time and the endorsement rates of the relatedness between word and sentence are recorded. Here, one would expect that those trained positively, compared to those trained negatively, are faster to accept than to reject positive interpretations and endorse more positive than negative interpretations.

## 11.3 Overview Empirical Findings CBM-I Effects

From 2000 onwards, there have been an increasing number of studies examining the effects of CBM-I training. Here we would like to provide a summary of the main findings using results from various reviews and meta-analyses. Remarkably, the conclusions drawn by authors from such reviews and meta-analyses have been quite different. For example, the conclusions drawn by the first meta-analyses (Hallion & Ruscio, 2011; Menne-Lothmann et al., 2014) were quite positive, while a later meta-analysis by Cristea et al. (2015) was more critical. Differences between these meta-analyses could be related to inclusion of combinations of other types of cognitive bias modification training, experimental and more clinically oriented studies and outcomes, different disorders, and including assessment of mechanisms of change (see below Sect. 11.4). Here we will try to focus exclusively on CBM-I and effects on anxiety and depressive symptoms. We will discuss findings from the more recent meta-analyses, as these publications contain the largest number of individual studies.

In a review of multiple meta-analyses, Jones and Sharpe (2017) showed that CBM-I training has a significant effect on changes in interpretation biases, and thus conclude that CBM-I training can reliably modify interpretation biases. With respect to transfer effects on anxiety symptoms, Jones and Sharpe (2017) concluded that CBM training (combining the findings for CBM-I training with the findings for Attentional Bias Modification, -ABM-, trainings designed to change attentional biases) consistently reduced anxiety symptoms. Also, with respect to differences between attention and interpretation training, they concluded that "CBM-I training may have more power as a paradigm in symptom reduction compared with ABM" (Jones & Sharpe, 2017, p. 179). These effects on anxiety are consistent with the conclusions drawn in a recent network meta-analysis (Fodor et al., 2020) where CBM-I training outperformed both waitlist and sham-training control conditions in

reducing anxiety symptoms. While there is variability in the effects of CBM-I training on anxiety in individual studies, across all studies, there seems to be a promising effect on anxiety. The CBM-I effects on depressive symptoms seem less compelling as Fodor et al. (2020) concluded that CBM-I only outperformed waitlist control conditions (and not sham-training) in reducing depressive symptoms. Similarly, Jones and Sharpe (2017) indicated that CBM effects (again ABM and CBM-I combined) on depressive symptoms are less robust and smaller than the effects on anxiety. When taking together the recent meta-analyses, the findings for CBM-I have been quite positive and underscore the conclusion formulated by Fodor et al. (2020): "CBM-I emerged as a promising treatment" (p. 507).

## 11.4 Mediators and Moderators of CBM-I Training Effects

Various studies have examined mediators and moderators of CBM-I training effects and those will be discussed here.

### *11.4.1 Mediators of CBM-I Training Effects*

With respect to mediators, based on theoretical models and the designed CBM-I paradigms, change in interpretation biases is a clear hypothesized mediator of CBM-I training. As summarized above, Jones and Sharpe (2017) concluded in their review of multiple meta-analyses, that CBM-I training can indeed reliably modify interpretation biases. As a crucial next step, there are empirical studies that have shown that symptom change was indeed *mediated by* the change in interpretation biases. For example, Steinman and Teachman (2014) demonstrated that change in interpretation biases was a mediator of CBM-I's effects on fear of heights. Further, Woud et al. (2021) showed that reductions in PTSD-related appraisals were correlated with reductions in PTSD symptoms from pre- to post-training, and that the differential impact of CBM-I versus sham training on PTSD symptoms was mediated by reductions in dysfunctional appraisals.

In the past, there has been some debate about the effectiveness of CBM-I training as not all CBM-I studies resulted in the intended symptom change. Some meta-analyses (e.g., Cristea et al., 2015) have exclusively focused on symptom change while not taking into account whether the CBM-I studies actually changed the hypothesized mechanism/mediator, i.e., interpretation biases. Theoretically, one would only expect change in symptoms, when the CBM-I training was capable of changing the targeted bias. If the training was not successful in changing interpretation biases (the mediator), then effects on symptoms are not to be expected. The implication is that when using CBM-I training to examine the causal role of interpretation biases in for example anxiety, and the training did not impact interpretation biases, the study cannot be used to evaluate the causal impact of those biases on

anxiety (cf. Grafton et al., 2017; Kraemer et al., 1997). Similarly, when evaluating the clinical utility of CBM-I training for reducing symptoms, a differentiation should be made between studies that did and did not successfully modify the bias. Grafton et al. (2017) not only provided an eloquent description of this issue, but also re-analyzed a previous meta-analysis (Cristea et al., 2015). Grafton et al.'s results indicated that not all CBM training paradigms successfully elicited a cognitive bias change, but that when the bias was successfully changed, reliable influences on emotional vulnerability were observed.

Various mechanisms have been proposed to explain how CBM-I works. While it has been shown that priming effects, demand effects, and response bias effects are unlikely mechanisms (e.g., Clarke et al., 2014; Hoppitt et al., 2010a, b; Macleod & Mathews, 2012; Mathews & Mackintosh, 2000), the *production rule* mechanism seem more likely. It has been proposed that CBM-I training could be understood as a procedure that modifies an implicit production rule concerning the resolution of ambiguity (Clarke et al., 2014; Hoppitt et al., 2010a, b; Wilson et al., 2006). In CBM-I training, participants are repeatedly exposed to ambiguous material that activates competing alternative meanings (Richards, 2004). As already described, the training guides the participant in resolving the ambiguity by consistently providing a positive interpretation of that ambiguity. With repeated practice, this could result in an implicit production rule on how to resolve ambiguity and to generate and select positive meanings. Consequently, after training, participants, unintentionally continue to do so when later encountering new and potentially threatening events (see Hoppitt et al., 2010a, b). The development of a production rule has been put forward as a mechanism of CBM-I effects, however, it remains unclear what exactly a production rule is (association between ambiguity and a positive resolution, or a proposition that if I encounter ambiguity, I can interpret it positively), and how it is acquired (which learning mechanisms play a role).

In sum, the findings with respect to mediators are promising. Across studies, CBM-I paradigms tend to be capable of modifying interpretation biases (Jones and Sharpe, 2017) and generally, changes in such biases tend to translate to effects on symptoms (Grafton et al., 2017). With respect to the underlying mechanism, a production rule explanation has been put forward, though there are many remaining questions to be answered.

#### 11.4.1.1 Moderators of CBM-I Training Effects

Different moderators of CBM-I training effects have been investigated, with some inconsistency in the findings. With respect to moderators related to the sample characteristics, there is generally no strong evidence for demographic variables such as age and gender moderating training effects (Jones & Sharpe, 2017). There is some evidence suggesting that sample type and associated baseline symptom level play a role in the effectiveness of CBM-I training effects on cognitive bias. That is, sample type was a significant moderator in two out of six meta-analyses with larger effect sizes in high symptomatology samples compared to healthy samples (Jones &

Sharpe, 2017). This is a promising finding when considering the potential application of CBM-I training as a psychological treatment in clinical samples. Whether CBM-I training might also be a preventative intervention in relatively healthy samples is less clear. CBM-I training may, for example, provide a *cognitive vaccine* against low mood (Holmes et al., 2009) or the development of symptoms of post-traumatic stress (Woud et al., 2013).

With respect to the number of training sessions; a meta-analysis that exclusively focused on CBM-I training (Menne-Lothmann et al., 2014) concluded that more CBM-I training sessions were related to stronger effects on interpretation biases and mood. However, more recently, Jones and Sharpe (2017) concluded that the evidence for a moderating role of a number of sessions is inconsistent, and it was not significant in Fodor et al.'s (2020) meta-analysis.

There is variability in the setting where CBM-I training is delivered; some studies provided the training in the laboratory, while others have provided it online with participants often completing the training at home. While in Fodor et al. (2020) delivery setting (lab versus others) was not related to outcome, delivery setting was related to outcome in Jones and Sharpe (2017), where CBM-I training was most effective when delivered in the laboratory. It is an open question of why training might work better in the lab. Many CBM-I studies have been conducted in the context of social anxiety and performing a lab-based CBM-I training requires participants to travel to the lab and interact with others. This might actually be an exposure exercise for individuals with social anxiety and the CBM-I training might inadvertently been combined with an element from Cognitive Behavior Therapy (see also Sect. 11.5 below). The social nature of the lab-based training might also have increased state anxiety and arousal, which might have played a role in the effectiveness of CBM-I training (for their role in Attentional Bias Modification, see Kuckertz et al., 2014; Nuijs et al., 2020). Finally, there is some evidence that imagining the CBM-I training materials increased the effectiveness of the training (Jones & Sharpe, 2017; Menne-Lothmann et al., 2014). In the next section, some other, novel moderators are described as part of more recent studies that were designed to improve CBM-I training.

## 11.5 Concluding Comments and Avenues for Future Directions

CBM-I training was initially developed to examine the causal role of interpretation biases in emotional psychopathology. Given the evidence consistent with such a role, more recent studies have examined the curative and preventative possibilities of the training. In this chapter, we have described the many different types of CBM-I paradigms that have been designed to modify interpretation biases. Based on meta-analyses, we described that, in general, those paradigms are capable of changing the targeted interpretation biases and subsequent anxiety. The effects of depression are

less consistent. As such, CBM-I training is a valuable and promising approach, though there is also room for improvement and there is still uncertainty about how training paradigms exactly work. Here we will highlight a few areas that could be improved and offer novel approaches that seem successful in achieving the desired improvement. As such, they represent encouraging avenues for future directions.

At the moment, some basic, mechanistic questions regarding CBM-I training have received minimal attention. For example, it is not yet clear what the optimal dose of the training is; with respect to number of training trials per session, total number of sessions, and the distribution of sessions across days (is it better to space out training across days?). In addition, most outcome measures have been self-report measures and the field would benefit from studies including measures that are less susceptible to demand characteristic. Some promising steps have been taken though with, for example, examining effects on clinician-rated symptoms (e.g., Wolters et al., 2021) and on heart rate responses (Joormann et al., 2015; Van Bockstaele et al., 2020a).

Across studies, the CBM-I effects on interpretations biases seem more robust than its effects on symptoms. This might suggest that the transfer from the successfully changed interpretations to emotional symptoms is sub-optimal. Given that symptom change tends to be the goal when considering clinical application of the training, the observation that changed interpretations do not always result in changes in emotions poses a challenge for such clinical applications. Future research might need to focus on improving the transfer from changed interpretations to changes in emotions. There have been some recent studies that aimed to improve CBM-I training, for example by adding d-cycloserine (Woud et al., 2018a), cognitive load (Van Bockstaele et al., 2020a), or napping (Woud et al., 2018b), or by developing a fMRI-based neurofeedback training to boost cognitive reappraisal ability (Lisk et al., 2020). Another approach has been to increase engagement with the training. Participants often consider the training monotonous and boring (Beard et al., 2012; de Voogd et al., 2017) and this might have a negative impact on training engagement and learning of new interpretations. It might also result in drop-out during multi-session training. To increase engagement, there have been attempts to gamify CBM-I training. Recently, the scenario-based CBM-I training was changed into a shooting game with sound effects, visual feedback, and adaptive speed (Salemink et al., 2022). Another approach has been to use Virtual Reality (VR) technology. Otkhmezuri et al. (2019), for example, developed a mobile VR-based CBM-I training that contained simulated real-life environments that matched the scenarios and where individuals could fully immerse themselves and explore the environment by head movements. The promising finding was that this VR-based training not only resulted in higher enjoyment compared to the standard scenario-based training, but also in stronger reductions in state anxiety. To conclude, there is some inconsistency in CBM-I training effects on symptoms and future research should be dedicated to improving such effects. Recently, different approaches have been examined with some having promising effects.

A final point concerns translation from experimental studies to clinical trials (for a guide, see Blackwell & Woud, 2022). Given the causal role of interpretation biases

in emotional psychopathology and the advantages of computerized CBM-I training that can be easily offered online with 24/7 access, there seems great potential for CBM-I training as a treatment possibility for anxiety and depressive symptomatology. There have been some studies investigating the effectiveness of CBM-I training as a stand-alone treatment with inconsistent findings across studies (e.g., Bowler et al., 2012; Salemink et al., 2014). The question is whether the training is potent enough to change psychopathology in patients. Psychological disorders tend to be multifactorial; many factors and processes play a role in the etiology and maintenance of a disorder. As CBM-I training targets one specific process (interpretation biases), it remains an open question whether it is powerful enough as a curative intervention and/or might be better suited as a prevention program. Another approach has been to combine CBM-I training with evidence-based psychological treatments such as Cognitive Behavioral Therapy (CBT) and some promising findings have been obtained (e.g., Butler et al., 2015; Williams et al., 2015; Wolters et al., 2021; Woud et al., 2021). There are several ways to combine CBM-I with CBT; CBM-I might be used as a pre-treatment training completed for example during the time an individual is on a waitlist for treatment, or training could be offered in parallel to CBT treatment as an adjunct or be offered after treatment to prevent the return of fear and depression (for a related discussion about the interplay of scientific research and clinical practice, see Chap. 1 by Holmes). There is clearly room and need for exciting CBM-I studies that examine mechanistic questions in experimental, lab-based studies as well as examine the applied value of CBM-I for patients with various types of psychopathology.

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