Digital Appendix TRAIN$_4$Positivity – Development and Pilot Evaluation of a Mobile-Based Training of Positivity Bias at the Level of Action Tendencies

Appendix K1 Previous Research on Selective Information Processing (Bias) and CBM

Appendix K1.1

Examples of CBM Assessment Using Affective Stimuli at the Level of Attention, Interpretation, and Memory

Task	Task content
Attention	Simultaneous presentation of neutral and emotional material in filtering (e.g., emotional Stroop task), search paradigms (e.g., visual search task) and cueing tasks (e.g., visual probe task)
Visual probe task (Bar-Haim et al., 2007; MacLeod et al., 1986)	• Paradigm most often used; was demonstrated to be most sensitive to examine affective attentional bias • Pairs of cue stimuli (e.g., pictures, words) with different affective content (generally positive or negative cue, e.g., happy or fearful face vs. neutral cue, e.g., neutral face) are presented simultaneously and on opposite sides of a fixation cross (left and right or top and bottom) for a duration of 500 ms. • Immediately after the offset of the two cue stimuli, a neutral probe stimulus appears at the former location of one of the two cue stimuli. • Participants are instructed to respond as quickly as possible to the position or the identity of the probe by pressing a button. • In the assessment version of this task, the probe stimulus is presented equally often at the locations previously occupied by the affective (negative or positive) or the neutral cue stimuli. • Attention bias toward negative affective information, for example, is indicated by faster responses (i.e., shorter RTs) to probes that replace a negative cue stimulus compared to probes that appear at the previous location of a neutral cue.
Emotional spatial cueing task (e.g., Gibb et al., 2016)	• Presentation of an emotional (disorder-relevant) cue (e.g., negative word) in one of two possible locations • Target stimulus (e.g., dot) is presented at either the cued or the opposite location. • Participants have to respond as quickly as possible to its location by button press. • Negative attentional bias is indicated by faster responding to target that replaces disorder-relevant cue or by delayed target responding when target is presented at the opposite position of the disorder-relevant cue.
Interpretation	Participants are usually asked to indicate their interpretation of ambiguous stimulus material, such as ambiguous sentences/scenarios (e.g., Ambiguous Scenario Test; Berna et al., 2011), homophones (e.g., Mathews et al., 1989), or scrambled sentences (Scrambled Sentences Test [SST]; e.g., Sanchez et al., 2015)

Task	Task content
Ambiguous Scenario Test (e.g., Berna et al., 2011)	• Subjects are presented with ambiguous scenarios that are followed by ratings (e.g., "You are starting a new job that you very much want. You think about what it will be like."). • First, participants are instructed to form a mental image of each of the scenarios and to imagine each scenario as if it was happening to them personally. • Subsequently, they are asked to rate the pleasantness as well as the vividness of this image on Likert scales, respectively (1 = *extremely unpleasant*; 9 = *extremely pleasant*; 1 = *not vivid at all*; 7 = *extremely vivid*). • A negativity bias at the level of interpretation is indicated by a lower subjective pleasantness rating, whereas a higher rating indicates a positivity bias.
Word Sentence Association Task ([WSAT]; e.g., Beard & Amir, 2008)	• Presentation of a fixation cross • After fixation cross, a word representing either a negative (e.g., threat) interpretation (e.g., "embarrassing") or a benign interpretation (e.g., "funny") is shown. • Subsequently, an ambiguous sentence (e.g., "People laugh after something you said.") is presented and remains on the computer screen until participants indicate that they finished the sentence by pressing the space bar. • Subjects are instructed to press #1 if they think that the word and the sentence are related or to press #3 if they think that word and sentence are unrelated to each other.
Memory – explicit memory	
Free recall or recognition (Mitte, 2008)	• Participants are instructed to read a list of words in order to recall the respective words or recognize them in another word list.
Memory – implicit memory	
Completion of word stems after reading (Mitte, 2008)	• Participants receive no instructions concerning the conscious recall or recognition of words after the reading of a list. • Instead, they have to complement word stems or estimate the personal relevance of a certain word. • It is assumed that the presentation of the original list of words influences the response behavior in this task although the list did not have to be consciously remembered.

Note. RT = reaction time.

Appendix K1.2

Previous Meta-Analyses on CBM Training (Not Systematically Identified)

Meta-analysis	Focus	Studies (partic.)	Study design	Effect sizes
Beard et al. (2012)[a]	CBM-A	37 (2135)	Randomized trials	*Attention bias (pre-post effect sizes):* - Neutral versus control condition: g = 0.80* - Positive versus control condition: g = 0.24* o high symptomatology: g = 0.48* o healthy subjects: g = –0.02 - Neutral versus disorder-relevant: g = 1.19* *Subjective experiences (e.g., depression, anxiety; pre-post treatment effect sizes; after multi-session CBM-A treatment):* - Neutral versus control condition: g = 0.41* o high symptomatology: g = 0.51 o healthy subjects: g = –0.15 - Positive versus control condition: g = 0.09 - Neutral versus disorder-relevant: n.a. (no multi-session treatment)
Cristea et al. (2015)[a]	CBM-A; CBM-I; others	49 (total *N* n.a.)	RCTs	*All samples:* - anxiety[b] (n_{comp} = 37): g = 0.23* - social anxiety[b] (n_{comp} = 9): g = 0.23 - generalized anxiety (n_{comp} = 3): g = 0.68* - panic symptoms (n_{comp} = 4): g = 0.02 - depression[b] (n_{comp} = 15): g = 0.33* *Clinical samples:* - anxiety[b] (n_{comp} = 12): g = 0.16 - social anxiety[b] (n_{comp} = 6)): g = 0.11 - generalized anxiety[b] (n_{comp} = 7): g = –0.01 - depression[b] (n_{comp} = 9): g = 0.24*
Hakamata et al. (2010)[a]	CBM-A (only dot probe)	10 with 12 datasets (467)	RCTs	*Attention bias* (all within-study effect sizes averaged; k = 7, n = 207): d = 1.16* *Anxiety:* d = 0.61* - clinical samples (k = 3; n = 113): d = 0.78* - healthy subjects (k = 9; n = 384): d = 0.48*
Hallion and Ruscio (2011)[a]	CBM-A; CBM-I	45 (2591)	Controlled trials	*Cognitive biases* in total: g = 0.49* *Attention bias* (k = 15): g = 0.29* - posttest (k = 20): g = 0.08 - after stressor (k = 11): g = 0.25* *Interpretation bias* (k = 25): g = 0.81* - posttest (k = 22): g = 0.19* - after stressor (k = 9): g = 0.21* *Depression:* - posttest (k = 23): g = 0.06 - after stressor (k = 10): g = 0.12 *Anxiety:* - posttest (k = 41): g = 0.13* - after stressor (k = 18): g = 0.28* *Effect sizes on symptoms depending on sample:* - clinical sample (posttest; k = 3): g = 0.39* - healthy/unselected subjects (posttest; k = 24): g = 0.09 - elevated symptoms/analogue (posttest; k = 15): g = 0.17*

Meta-analysis	Focus	Studies (partic.)	Study design	Effect sizes
Menne-Lothmann et al. (2014)[g]	CBMI-I	42 (total *N* n.a.)	RCTs	*Difference between positive and negative interpretation bias after training[c]:* - Benign training (k = 35): d = 1.33* - Negative training (k = 28): d = –0.05 - Neutral training (k = 6): d = 0.49* - No training (k = 6): d = 0.28 *Pre-post training change in positive interpretation bias[d]:* - Benign training (k = 20): d = 0.43* - Negative training (k = 5): d = –0.22 - Neutral training (k = 6): d = 0.12 - No training (k = 3): d = 0.32 *Pre-post training change in negative mood[e]:* - Benign training (k = 47): d = 0.25* - Negative training (k = 25): d = –0.20* - Neutral training (k = 14): d = 0.22* - No training (k = 4): d = –0.03 *Pre-post training change in negative mood after emotional challenge[f]:* - Benign training (k = 18): d = –0.79* - Negative training (k = 10): d = –0.80* - Neutral training (k = 6): d = –1.03* - No training (k = 1): d = –0.77*
Mogoaşe et al. (2014)[a]	CBM-A	43 (2268)	RCTs	*Attention bias*[a] (n_{comp} = 38; n = 1685): g = 0.312* *Overall change in symptoms*[b,h] (n_{comp} = 42; n = 1979): g = 0.160* *Anxiety:* - posttest (k = 22): g = 0.26* - after stressor (k = 11): g = 0.337* *Depression:* - posttest (k = 7): g = –0.106* - after stressor (k = 0): n.a.

Note. For all meta-analyses reported in this Table except for Beard et al. (2012) and Menne-Lothmann et al. (2014): posttest effect sizes.

partic. = participants; CBM-A = Cognitive Bias Modification Attention; CBM-I = Cognitive Bias Modification Interpretation; g = Hedge's g (effect size); n.a. = not available; n_{comp} = number of comparisons; d = Cohen's d (effect size); k = number of studies; n = number of participants.

[a] Higher (positive) values of Hedge's g indicate greater improvement of respective outcomes in the CBM compared to the control group.

[b] outliers removed.

[c] positive values reflect higher positive than negative bias.

[d] positive values reflect increase in positive bias.

[e] positive values reflect decrease in negative mood.

[f] negative values reflect increase in negative mood.

[g] pre-post (within) effect sizes within four different trainings conditions reported; for differences between conditions, see Table 3 in Menne-Lothmann et al. (2014).

[h] additional assessment of distress (healthy participants), pain, and substance use; not reported here

Appendix K1.3 Optimism as Resilience Factor

Based on the available literature – mostly cross-sectional and retrospective studies – optimism is as relatively well-evidenced resilience factor (Carver et al., 2010; Helmreich et al., 2017). In general, two components of the construct are differentiated. On the one hand, optimism describes a stable tendency to have positive expectations for situations and the future, which in turn has an impact on behavior and an individual's coping strategies (Scheier & Carver, 1985). Optimists' anticipation of positive things to happen is associated with more persistence in pursuing personal goals, active coping with stressors (e.g., more problem-solving coping in case of controllable stressors), and positive emotions (Scheier & Carver, 1992). Dispositional optimism has been positively associated to mental health in individuals exposed to stressors (e.g., Brissette et al., 2002; Grote et al., 2007; Kleiman et al., 2017; Scheier & Carver, 1992).

Second, a positive attributional or explanatory style is seen as component of optimism. In general, attributions refer to inferences of an individual about the causes of events. According to Seligman (1990), optimistic individuals tend to attribute negative events to external (i.e., cause is located in other people or situational circumstances), specific (i.e., cause does only apply to the respective situation), and variable causes (i.e., cause is modifiable over time). Positive events, however, are (rather) attributed to internal (i.e., personal factors as reason), stable (i.e., cause is stable over time), and global causes (i.e., cause does apply to many different situations; Poppe et al., 2005; Seligman, 1990). In different populations exposed to stressors (e.g., physical disease), a positive attributional style was shown to be related with better mental health (e.g., Fresco et al., 2006; Johnson et al., 2017; Jowsey et al., 2012; Kleiman et al., 2012; Segovia et al., 2012).

Appendix K1.4

Examples of CBM Positivity Training at the Level of Attention, Interpretation, and Memory

Level of training and paradigm	Training details and results
Attention – Modified visual probe task (Johnson, 2009)	Training • During dot-probe task, face pairs consisting of a happy and an angry expression of the same person were presented. • A dot-probe appeared at the former position of one of the faces and subjects had to react as fast as possible by indicating whether one or two dots were presented. • Participants were randomly assigned to goal (*n* = 54) or no goal group (*n* = 55): Whereas subjects in the no goal condition were only instructed how to perform the dot-probe task, participants in the goal condition were instructed to focus their attention on happy faces and to avoid focusing their attention on angry faces. • In addition, participants in the goal group were informed that the position of the probe (i.e., behind a happy or angry face) was completely random and that they should keep their attention focused on the happy faces independent of the position of the probe. Results • Subjects in the goal condition reported nearly three times less frustration reactivity during a stressful anagram task compared to participants without any attention goal. Furthermore, individual differences in the ability to focus or deploy attention on happy faces and away from angry faces predicted longer persistence on the stressful anagram task. • Goal-directed attentional deployment toward positive stimuli and away from negative stimuli was assumed as mechanism of emotion regulation.
Attention – Modified visual probe task (Wadlinger & Isaacowitz, 2008)	Training • While performing probe detection paradigm (i.e., presentation of one positive and one neutral word), visual target either appeared consistently in the location of the positive words (train-positive group) or neutral words (train-neutral or control group). • Participants (healthy undergraduates) had to discriminate the target's identity as precisely and fast as possible by pressing a key. • Subsequently a visual stressor task was performed by presenting negative emotional images and eye-tracking of the attention toward negative components of images. Results • After the attention training, visual fixation time (i.e., proxy for emotional reactivity) significantly differed between conditions. • Participants in the condition that induced a selective attention toward positive (emotional) information, viewed negative components for less time than the attend-neutral group (*d* = 0.62). • The authors suggested that the positive attentional training had trained a certain gaze pattern by teaching participants an aversion to negative emotional stimuli, thereby facilitating effective emotion regulation.

Level of training and paradigm	Training details and results
Attention – Modified visual probe task (Taylor et al., 2011)	Training • Based on the same probe detection task described above, the probe in the "Attention Toward Positive" (ATP) condition always replaced the positive word and no specific instructions to direct attention toward the positive word were provided. • In the "Attention Control Condition" (ACC), however, the probe appeared with equal frequency at the previous location of the positive and neutral word. Results • In contrast with Wadlinger and Isaacowitz (2008), Taylor et al. (2011) also measured the effect of the experimental manipulation on the attentional bias for positive information (i.e., Positive Attentional Bias Index). • Participants who showed the greatest change in attentional allocation toward positive stimuli following the CBM paradigm displayed the least anxiety reactivity to the laboratory stressor.
Attention – Modified visual probe task using eye-tracking (ET-ABM task; Ferrari et al., 2016)	Training • A positive training (PT; *n* = 44) was compared with a negative training condition (NT; *n* = 42) in an unselected study sample. • On each trial, a white fixation cross was shown in the middle of one of four grid quadrants. After fixation of the cross (500 ms), it disappeared and four pictures appeared. • two sorts of trials: positive and negative - Positive training (PT): Participants had to disengage attention from negative pictures, shift it to positive ones, and maintain attention to positive pictures. - Negative (PT: disengagement) trials: One of two negative pictures replaced fixation cross and participants had to look away from it and fixate one of the two positive pictures for 1000 ms. After a positive picture was fixated for sufficient duration, all pictures disappeared and a probe replaced the previous fixated positive picture. Participants had to respond to probe (direction of arrow) by pressing a computer key; the probe then disappeared. - Positive (PT: maintained attention) trials: Positive picture replaced the fixation cross and the trial continued only if participants kept looking at this picture for 1000 ms or if they fixated the other positive picture (1000 ms). - Negative training (NT): The opposite pattern is trained. • In both (PT, NT) conditions, the participants' gaze pattern controlled the appearance of the probe: As soon as a positive (PT) versus negative (NT) picture was fixated for 1000 ms, the probe replaced the fixated picture. However, participants were not told that their viewing patterns would influence the continuation of trials or the location of the probes. Results • Supporting the hypothesis, the PT group exhibited longer fixations on positive, and faster disengagement from negative images, whereas no attentional changes were found for the NT. • No group differences with respect to mood changes to a stressor (video-recorded speech) were found.
Attention – Visual search paradigms[1] (Dandeneau &	Training • A positive condition using visual search ("find the smile": tapping on a smiling/accepting face among many negative/frowning faces as quickly

[1] visual search paradigms: participants repeatedly requested to identify a positive target stimulus (e.g., happy approving face) in a grid of distracting negative stimuli (e.g., frowning faces) as quickly as possible

Level of training and paradigm	Training details and results
Baldwin, 2009; Dandeneau et al., 2007)	as possible) with a neutral control condition (“find the flower”: identify one five-petaled flower as quickly as possible in a matrix of seven-petaled flowers). Results • Amongst other results, participants in the positive attentional training showed less feelings of rejection a after rejection threat procedure, less willingness to persevere in an unsolvable anagram task (performance threat), and higher self-esteem after having been rejected and experiencing failure in the two tasks.
Interpretation – Ambiguous Scenario Training (Beadel et al., 2016)[a]	Training • Resilience-enhancing interpretation bias modification (CBM-I) • Participants with increased fear of anxiety symptoms (i.e., anxiety sensitivity) were randomly assigned to CBM-I or a control (sham) condition. • Participants were presented with ambiguous scenarios that were potentially threatening to individuals with high anxiety sensitivity (e.g., “You are at an amusement park and decide to ride a roller coaster with your friends. After you get off the ride, you are a bit dizzy and your legs feel weak. Although this makes you anxious, you can still l_ugh with the rest of your friends about how fun the ride was.”). • In order to train interpretations associated with resilience, the word fragment that subjects had to complete by selecting the missing letter (only one solution to fragments) resolved a scenario’s ambiguity in a resilience-congruent (i.e., healthy) sense. • Resilience-fostering resolutions of the scenarios referred to greater flexibility in responding, greater self-efficacy, finding meaning or hope in a stressor, or the experience of positive emotions despite a stressor. Results • An increase of resilience-congruent interpretations, a trend for reduced anxiety sensitivity at 2-month follow-up, and less intense cognitive panic symptoms during a panic stressor (carbon dioxide [CO2] breathing challenge) were found, thereby providing first evidence for the efficacy of a positivity bias training at the level of interpretations.
Interpretation – Modified scenario task (Peters et al., 2011)	Training • Aims to modify attributional style and influence stress vulnerability • Participants were assigned to one of two conditions that either fostered the use of a positive (“resilience” group) or a negative attributional style (“vulnerability” group). • In both groups, participants imagined 120 event descriptions of positive and negative events, and subsequently completed word fragments. • In the resilience condition, the completion of the word fragment promoted self-worthy, stable causal attributions for descriptions of positive events and unstable attributions, unrelated to self-worth, concerning negative event descriptions (e.g., positive event: “I can solve the most difficult math problem on the test.”; “This success shows that my math abilities must be strong.”). • However, in the vulnerability group, completing the word fragment aimed to promote unstable attributions, unrelated to self-worth, for positive events, and stable, self-deficient attributions for negative events (e.g., “I can solve the most difficult math problem on the test.”; “This must be because the test was easy.”). Results

Level of training and paradigm	Training details and results
	• In a subsequent stress anagram test, individuals in the resilience group exhibited a greater tendency to attribute their poor performance to causes unrelated to the self and reported less depressed mood compared to the vulnerability condition.
Memory – Memory bias modification smartphone application (Visser et al., 2020)	Training • Memory bias modification using smartphone app movisensXS • Unselected participants were randomly assigned to one of three conditions (positive, negative or sham memory training) conducted over three days, respectively. - Participants were prompted a total of ten times a day - Positive condition: participants prompted to think of a recent positive event (most pleasant or positive event that happened since the last prompt) - Negative condition: participants prompted to think of a recent negative event (most unpleasant or negative event that happened since last prompt) - Sham condition: participants prompted to think of event related to work or study that occurred since last prompt - In each condition, event has to be described in three words and is rated on a 100-point slider (extremely unpleasant [-50] to extremely pleasant [+50]) • Assessment of autobiographical memory bias and depressive scores at pre- and posttest; recent event recall and explicit self-referent memory bias assessed post-training Results • The positive memory bias increased in the positive training condition, although memory bias did not differ between three conditions post-training. Positive autobiographical events were recalled more often in the positive condition compared to the other groups. Other outcomes, including depressive symptoms, did not differ between the conditions.

Note. *d* = Cohen’s *d* (effect size); CBM-I = Cognitive Bias Modification Interpretation.

[a] Assessment of panic vulnerability and interpretation bias; resilience (Connor-Davidson Resilience Scale) was only measured at baseline.

Appendix K1.5 Action Tendencies and Information Processing – Further Information

Temporary Aspects of the Association of Action Tendencies and Information Processing

With respect to the *time point* when approach/avoidance behaviors may affect information processing, Neumann and Strack (2000) suggested that motivational systems of approach and avoidance (activated through respective behaviors) directly affect the categorization of affective concepts in *early* stages of processing. However, this mechanism could also affect *memory* processes. For instance, approach and avoidance behaviors (nodding vs. head-shaking) during encoding of valenced words were associated with contrasting memory performances. Subjects, who nodded while encoding positive and negative adjectives, were better at recognizing positive words compared with participants who performed horizontal head movements, who were more likely to recognize negative words (Förster & Strack, 1996). Other studies provided similar results (e.g., Förster & Strack, 1997; Förster & Strack, 1998).

Neural Structures Potentially Associated With the Approach and Avoidance System

According to several research groups, the approach and avoidance (motivational) systems are two separate (self-regulatory) systems with different *neural structures* involved, respectively (e.g., Carver, 2006; Davidson et al., 1990; Hecht, 2013; Trew, 2011). For example, from a number of neuropsychological studies, there is some, though not unanimous, evidence for anterior activation asymmetry (Davidson, 1995; Feldman Barrett & Wager, 2006; Trew, 2011). Greater activity in the *left* (pre)frontal cortex was associated with approach motivation and positive affect, while greater activity in the *right* (pre)frontal cortex was related with avoidance motivation and negative affect (Davidson, 1995; Feldman Barrett & Wager, 2006). These results are consistent with the findings for neural structures involved in optimism and pessimism. For example, high self-esteem, the tendency to look at positive aspects of a situation, and an optimistic outlook for the future were shown to be associated with physiological activity in the *left* cerebral hemisphere (Hecht, 2013). On the other hand, low self-esteem, the tendency to focus on negative aspects and exaggerate its significance, as well as a pessimistic outlook for the future were linked with physiological processes in the *right* hemisphere (Hecht, 2013).

Such research findings also shaped the distinction of *two neural systems*, the “behavioral activation system (BAS)” and the “behavioral inhibition system” (BIS; Gray, 1981), that are partly termed differently in the literature (e.g., "behavioral facilitation system"; see Carver, 2006). The BAS, that was shown to be lateralized in the left hemisphere (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), is responsible for appetitive motivation and elicits approach behaviors toward potentially rewarding stimuli (Hecht, 2013). The BIS, however, that is lateralized in the right hemisphere (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), is sensitive to negative cues and regulates avoidance behaviors from potentially harmful stimuli (Hecht, 2013). On the basis of approach deficits (e.g., reward insensitivity) and negative cognitive biases in depression, Trew (2011) described further potential neurobiological substrates for approach and avoidance. For the approach system, the basal ganglia, ventral striatum, medical thalamus, caudate and nucleus accumbens, as well as areas linked to motor planning and incentive motivation were also found to be relevant. The avoidance system, on the other hand, was associated with the amygdala and related paralimbic regions, as well as the hippocampus.

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