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CLINICAL RESEARCH ARTICLE

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Information processing biases in posttraumatic stress disorder (PTSD): cross-sectional findings and exploratory investigation of bias changes following treatment

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ABSTRACT

Background: Information processing biases are ascribed an important role in the aetiology and maintenance of posttraumatic stress disorder (PTSD). While findings on attentional biases have been mixed, there are only a few studies that have used implicit measures to assess dysfunctional appraisals and their malleability over the course of treatment in PTSD.

Objective: The primary aim was to examine whether individuals with PTSD (1) show attentional biases towards trauma-related stimuli, (2) generate more implicitly assessed dysfunctional appraisals, and (3) more strongly associate the self as traumatized and vulnerable compared to traumatized individuals without PTSD and a healthy control group. The second and exploratory aim was to explore whether biases would be reduced after treatment.

Method: Participants included individuals with PTSD ($n = 50$), traumatized individuals without PTSD ($n = 54$), and healthy controls ($n = 57$). Attentional biases were measured with a Visual Search Task, dysfunctional appraisals with a scenario task, and trauma-related self-appraisals with two Implicit Association Tests (self-traumatized, self-vulnerability). In exploratory analyses, changes in these measures were examined across treatment.

Results: No significant differences were found in attention allocation to trauma-related stimuli between groups. However, participants with PTSD generated more dysfunctional appraisals and demonstrated stronger trauma-related associations than both control groups. Importantly, treatment significantly reduced dysfunctional appraisals and fostered more functional self-appraisals in the IAT.

Conclusions: Implicitly assessed dysfunctional (self-) appraisals differentiate individuals with PTSD from controls and appear responsive to treatment. Future research should clarify whether these implicit biases function as mechanisms of change and predict long-term clinical outcomes.

Sesgos de procesamiento de la información en el trastorno de estrés postraumático (TEPT): hallazgos transversales e investigación exploratoria de los cambios de sesgo después del tratamiento

Antecedentes: A los sesgos de procesamiento de la información se les atribuye un importante papel en la etiología y mantenimiento del trastorno de estrés postraumático (TEPT). Si bien los hallazgos sobre los sesgos atencionales han sido mixtos, hay solo pocos estudios que hayan utilizado mediciones implícitas para evaluar las valoraciones disfuncionales y su maleabilidad a lo largo del tratamiento del TEPT.

Objetivo: El objetivo primario fue examinar si los individuos con TEPT (1) muestran sesgos atencionales hacia los estímulos relacionados con trauma, (2) generan valoraciones disfuncionales evaluadas más implícitamente, y (3) asocian más fuertemente el yo como traumatizado y vulnerable en comparación con las personas traumatizadas sin TEPT y un grupo de control sano. El segundo objetivo, de carácter exploratorio, fue explorar si los sesgos se reducirían tras el tratamiento.

Método: Los participantes incluyeron personas con TEPT ($n = 50$), personas con trauma sin TEPT ($n = 54$) y controles sanos ($n = 57$). Los sesgos atencionales se midieron con la Tarea de Búsqueda Visual, las valoraciones disfuncionales con una tarea de escenario y las auto-valoraciones relacionadas con el trauma con dos Pruebas de Asociación Implícita (yo-

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PALABRAS CLAVE
TEPT; sesgos cognitivos; sesgo de atención; asociación de memoria; valoración disfuncional

HIGHLIGHTS

- A Visual Search Task revealed no evidence for biased attentional processing of trauma-related stimuli in PTSD.
- PTSD was associated with stronger implicit, dysfunctional appraisals and trauma-memory associations.
- Implicit, dysfunctional appraisals and trauma-memory associations were attenuated after treatment.

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traumatizado, yo-vulnerabilidad). En los análisis exploratorios, los cambios en estas medidas se examinaron a lo largo del tratamiento.
Resultados: No se encontraron diferencias significativas en la asignación de atención a los estímulos relacionados con trauma entre los grupos. Sin embargo, los participantes con TEPT generaron más valoraciones disfuncionales y mostraron asociaciones más sólidas relacionadas con el trauma que ambos grupos de control. Cabe destacar, que el tratamiento redujo significativamente las valoraciones disfuncionales y fomentó autovaloraciones más funcionales en la PAI.
Conclusiones: Las (auto)valoraciones disfuncionales evaluadas implícitamente diferencian a las personas con TEPT de los controles y parecen responder al tratamiento. Las investigaciones futuras deberían clarificar si estos sesgos implícitos funcionan como mecanismos de cambio y predicen los resultados clínicos a largo plazo.

1. Information processing biases in posttraumatic stress disorder

Posttraumatic Stress Disorder (PTSD) is a debilitating condition marked by persistent trauma-related memories, avoidance, negative thoughts and mood, and heightened arousal (American Psychiatric Association, 2013). Additionally, cognitive theories of PTSD (Brewin et al., 1996; Dalgleish, 2004; Ehlers & Clark, 2000; Foa et al., 1989) stress the central role of cognitive biases in attention, interpretation, and memory[1] (see Bomyea et al., 2017; Woud et al., 2017 for a review) for the aetiology and maintenance of PTSD. Specifically, it has been proposed that attention is selectively directed to trauma-related stimuli (attentional biases), partly explained by the high accessibility of the fear structure (Foa et al., 1989) and a lower perceptual threshold for trauma-related stimuli (Ehlers & Clark, 2000). Negative appraisals are highlighted in PTSD through their inclusion as a diagnostic criterion (American Psychiatric Association, 2013). According to cognitive models, chronic PTSD develops if the traumatic event and its sequelae are interpreted dysfunctionally (e.g. 'The symptoms mean that I am going crazy', Ehlers & Clark, 2000). These dysfunctional appraisals may create a sense of current threat, triggering PTSD symptoms and maladaptive coping, which maintain the disorder. Moreover, as a traumatic event is of monumental significance and disrupts basic assumptions of safety, it has been suggested that the self is often no longer regarded as safe, but rather as traumatized or defenseless (Janoff-Bulmann 1989; Foa & Rothbaum, 1998).

1.1. Empirical evidence for cognitive biases in PTSD

Attentional biases to trauma-related stimuli have mostly been assessed with emotional variants of the dot-probe (MacLeod et al., 1986) and the Stroop task (Williams et al., 1996). However, evidence for attentional biases in PTSD is inconsistent (Bomyea et al., 2017; Woud et al., 2017), which may be partly explained by the tasks' poor psychometric properties (Kappenman et al., 2014; Schmukle, 2005; Siegrist, 1997; Strauss et al., 2005; Waechter et al., 2014). A limitation of both paradigms is their inability to distinguish whether attentional biases reflect faster threat detection or difficulty disengaging from threat (attentional interference). The Visual Search Task (VST, Öhman et al., 2001) allows this differentiation and has shown satisfactory split-half reliability (e.g. Schmitz et al. 2023). However, it has been applied in only two studies on trauma-related stimuli (Pineles et al., 2007; Pineles et al., 2009), both finding that individuals with high PTSD symptoms struggle to disengage from trauma- or threat-related words, with no evidence of attentional facilitation.

Ample evidence supports negative appraisals as both a risk factor and correlate of PTSD (see Woud et al. 2017 for review). Although theoretical models of PTSD (Brewin et al., 1996; Ehlers & Clark, 2000) propose that negative appraisals are activated automatically and unintentionally, this hypothesis has received surprisingly little attention. Negative appraisals have mostly been assessed with self-report measures, e.g. the Posttraumatic Cognitions Inventory (PTCI, Foa et al. 1999), assessing the extent of agreement with given trauma-relevant statements and capturing information that is consciously accessible. To tap into the more associative and automatized processes, however, implicit measures are needed, assessing attitudes or cognitions that participants may be unaware of or cannot control (De Houwer 2006). Accordingly, implicit measures present a valuable complement to self-report measures. Two different implicit measures have been used to assess trauma-relevant appraisals. The first is a scenario-task (Woud et al., 2019), in which participants are presented with trauma-relevant, open-ended sentences and are instructed to complete each sentence with the first ending that comes to mind. Previous studies showed that a higher dysfunctional appraisal ratio was associated with more severe PTSD symptoms (Woud et al., 2019; Woud et al., 2021). The second task is the Implicit Association Test (IAT, Greenwald et al., 1998), intended to assess the associative strength

between automatically activated concepts in memory. During the IAT, participants are instructed to categorize stimuli belonging to one of four categories using two response keys. Two categories represent target concepts (e.g. me vs. other), and two represent attribute categories. In the context of PTSD, attribute categories such as traumatized (e.g. damaged, broken) versus healthy (e.g. adjustable, whole, Lindgren et al., 2013), or vulnerable (e.g. weak, helpless) versus invulnerable (e.g. strong, tough, Engelhard et al., 2007) have been used to assess automatic self-appraisals. Each target category is paired with each attribute category, such that faster responses during congruent pairings (e.g. me + traumatized/vulnerable) indicate stronger trauma-or vulnerability-related associations. Engelhard et al. (2007) were the first to apply the IAT in the context of PTSD (i.e. in soldiers deployed to Iraq), finding that stronger self-vulnerable associations post-deployment correlated with PTSD symptoms but did not predict later symptoms. Further, Lindgren et al. (2013) showed that stronger self-traumatized associations correlated with more PTSD symptoms and were a unique predictor of PTSD symptoms. Finally, Blackwell et al. (2023) administered a self-vulnerable IAT in addition to the self-traumatized IAT and found that stronger trauma IAT scores were related to more PTSD symptoms.

To conclude, while findings on attentional biases are inconsistent, studies of implicit appraisals consistently link stronger dysfunctional appraisals to greater PTSD symptom severity.

1.2. Limitations of previous research

A significant limitation of previous research on attentional biases in PTSD is that these biases have mostly been assessed using tasks that have been criticized for their low reliability (e.g. Dotprobe, Stroop, Kappenman et al., 2014; Schmukle, 2005; Siegrist, 1997; Strauss et al., 2005; Waechter et al., 2014). Moreover, these tasks are unable to disentangle whether attentional biases result from faster orienting to, or difficulties disengaging from, disorder-specific stimuli. Studies that have implicitly assessed dysfunctional appraisals have mostly been conducted in non-clinical samples, leaving open whether these effects can be replicated in clinical populations and whether such biases are associated with trauma exposure per se or specifically with PTSD. Another key limitation of prior research is its focus on individual cognitive biases in isolation, leaving unclear whether they co-occur. Moreover, only few studies examined whether cognitive biases are reduced following treatment, with findings on attentional bias changes being inconsistent (Devineni et al., 2004; El Khoury-Malhame et al., 2011). As an exception, Lindgren et al. (2013) examined whether self-traumatized associations changed following Cognitive Processing Therapy in a military PTSD sample but found no association with symptom severity and no treatment-related reduction. In contrast, Woud et al. (2019) reported that Cognitive Bias Modification-Appraisal training, as an adjunct to treatment as usual (TAU) in an inpatient PTSD sample, reduced implicitly assessed dysfunctional appraisals, with symptom improvement mediated by changes in these cognitions.

1.3. The present study

To advance our understanding of implicit cognitive biases, their association, and malleability in PTSD, the study pursued two overarching goals. The primary goal was to compare cognitive biases in attention and appraisals between a diagnosed PTSD sample, a traumatized non-PTSD group, and a non-traumatized, healthy control group using a cross-sectional design. The second aim was to examine, in an exploratory manner, whether cognitive biases changed following routine clinical treatment, including trauma-focused interventions, in a subgroup of treatment-seeking participants with PTSD. We hypothesized that patients with PTSD (compared to both control groups) would show more difficulties disengaging from trauma-related stimuli (Hypothesis 1), exhibit more implicitly assessed dysfunctional appraisals (Hypothesis 2), and stronger trauma-memory associations (Hypothesis 3). In addition, we expected that cognitive biases would be reduced after treatment (Hypothesis 4).

2. Methods

2.1. Participants and recruitment

Between October 2019 and July 2023, 163 participants took part in the study (pre-registration: https://aspredicted.org/jy5nb.pdf; amendment: https://aspredicted.org/dg7st.pdf). One participant discontinued and data of one participant was missing due to a technical error during data transfer, resulting in a final sample of 161 participants. Inclusion criteria for all groups were: (1) age 18–60, (2) sufficient knowledge of the German language, and (3) capability of giving consent. General exclusion criteria were: (1) lifetime psychotic disorder, (2) substance use disorder within the last month (if the criteria were met within the past 12 months, we additionally assessed whether they had been met during the past month), (3) primary depressive, bipolar, or borderline personality disorders, and (4) acute suicidality. Additionally, group-specific inclusion criteria were applied: PTSD group: participants had to fulfil DSM-5 criteria for PTSD (American Psychiatric Association, 2013) and had to have experienced a traumatic event falling

into one of three categories (sexual assault, physical assault, severe accident). The latter categories were chosen because trauma-related stimuli can comprise a broad range of traumatic events (e.g. accidents, assaults, sudden deaths) and using generic trauma-related words may lack sufficient specificity for participants with PTSD. As it would be practically challenging to develop Visual Search Tasks (VSTs) that include stimuli tailored to every type of traumatic event, we decided instead to construct three VSTs, each containing stimuli specific to one of the three traumatic events described above, in order to enhance specificity. Traumatized non-PTSD group[2]: (1) experience of any traumatic event according to DSM-5 criteria (if participants experienced a traumatic event that did not fall into one of the trauma categories described above, the VST was not administered [n = 15 for the non-PTSD group]), (2) no diagnosis of a psychological/psychiatric disorder within the last 12 months (except substance use disorder [see general exclusion criteria]), (3) no lifetime diagnosis of PTSD, (4) no current use of psychotropic drugs, and (5) no psychological/psychiatric treatment within the last 12 months. Non-traumatized healthy controls: (1) no DSM-5 traumatic event, (2) no lifetime diagnosis of any psychological/psychiatric disorder, (3) no current use of psychotropic drugs, and (4) no lifetime psychological/psychiatric treatment.

PTSD patients were recruited through clinical facilities, self-help and crisis centres, online ads, newspapers, flyers, and resident registration addresses. The study was advertised as an investigation of cognitive processes in individuals with trauma exposure. During the description of the study procedures, participants were informed that those currently receiving trauma treatment could take part in a follow-up assessment. Accordingly, the study was not presented as a clinical trial. Participants received financial compensation and students of the LMU could receive course credit instead. The study was approved by the LMU Munich ethics committee (14_Wittekind_b).

2.2. Sample size

The power analysis was conducted a priori using G-Power® (Faul et al., 2007). Based on a medium effect of f = 0.25 for all analyses, an α = .05 and a power of .80, it was estimated that a total sample size of N = 159 participants was needed (i.e. 53 participants per group) for a one-way ANOVA comparing group differences cross-sectionally (PTSD vs. non-PTSD vs. non-traumatized controls). For our exploratory analyses examining whether trauma-focused treatment (PTSD group only) was associated with changes pre- to post-intervention, a sample of N = 34 participants was required (paired sample t-test or ANOVA, repeated measures, within factors, one group, two time points with α = .05, 1-β = .80, and f = 0.25).

2.3. Measures

2.3.1. Clinical Interviews and Questionnaires

PTSD was verified either with the Structured Clinical Interview for DSM-5 (SCID-5-CV, First et al., 2016) or with the Clinician Administered PTSD Scale (CAPS, Weathers et al. 2018). Traumatic events were assessed with the Life Events Checklist for DSM-5 (LEC-5, Weathers et al. 2018), severity of PTSD symptoms with the PTSD Checklist for DSM-5 (PCL-5, Blevins et al., 2015), whereby items were rephrased for the non-traumatized control (i.e. traumatic event was replaced by distressing event). Internal consistency of the PCL-5 was Cronbach´s α = .974. The Posttraumatic Cognitions Inventory (PTCI, Foa et al. 1999) assessed dysfunctional appraisals with 33 items across self, world, and self-blame subscales (Cronbach´s α = .974). Early adverse events were captured with the Childhood Trauma Questionnaire (CTQ, Bernstein et al., 2011) (Cronbach´s α = .897), and depressive symptoms with the Inventory of Depressive Symptoms (IDS, Rush et al., 1986) (Cronbach´s α = .944).

2.3.2. Visual search task

To assess attentional biases and to disentangle facilitation versus difficulties disengaging from trauma-related stimuli, a visual search task (VST, Öhman et al., 2001), adapted from Pineles et al. (2009) was administered, with one version for each trauma category (sexual assault, physical assault, accident, stimuli selection is described in detail in the Supplementary Material) and two conditions (interference first vs. facilitation first). In both conditions (see Figure 1), a discrepant stimulus was presented in an array of seven identical letter strings, with the same word length as the discrepant stimulus. Stimuli were arranged in a rectangle, written in black ink on a white background (Arial, size 20). Each trial started with the presentation of a fixation cross (700 ms) in the middle of the screen, followed by the letter array which remained on the screen until the participants made a response (inter-trial interval: 1000 ms). Participants had to indicate via key-press whether the discrepant stimulus was a word ('Y', German keyboard) or a non-word ('N'). In the interference condition, experimental trials included a non-word (discrepant stimulus) in an array of seven experimental words (distractors; trauma-related, negative or neutral). In the facilitation condition, the experimental trials consisted of one experimental word (discrepant stimulus; trauma-related, negative or neutral) embedded in an array of seven identical non-words (distractors). Additionally, catch trials were presented, in which

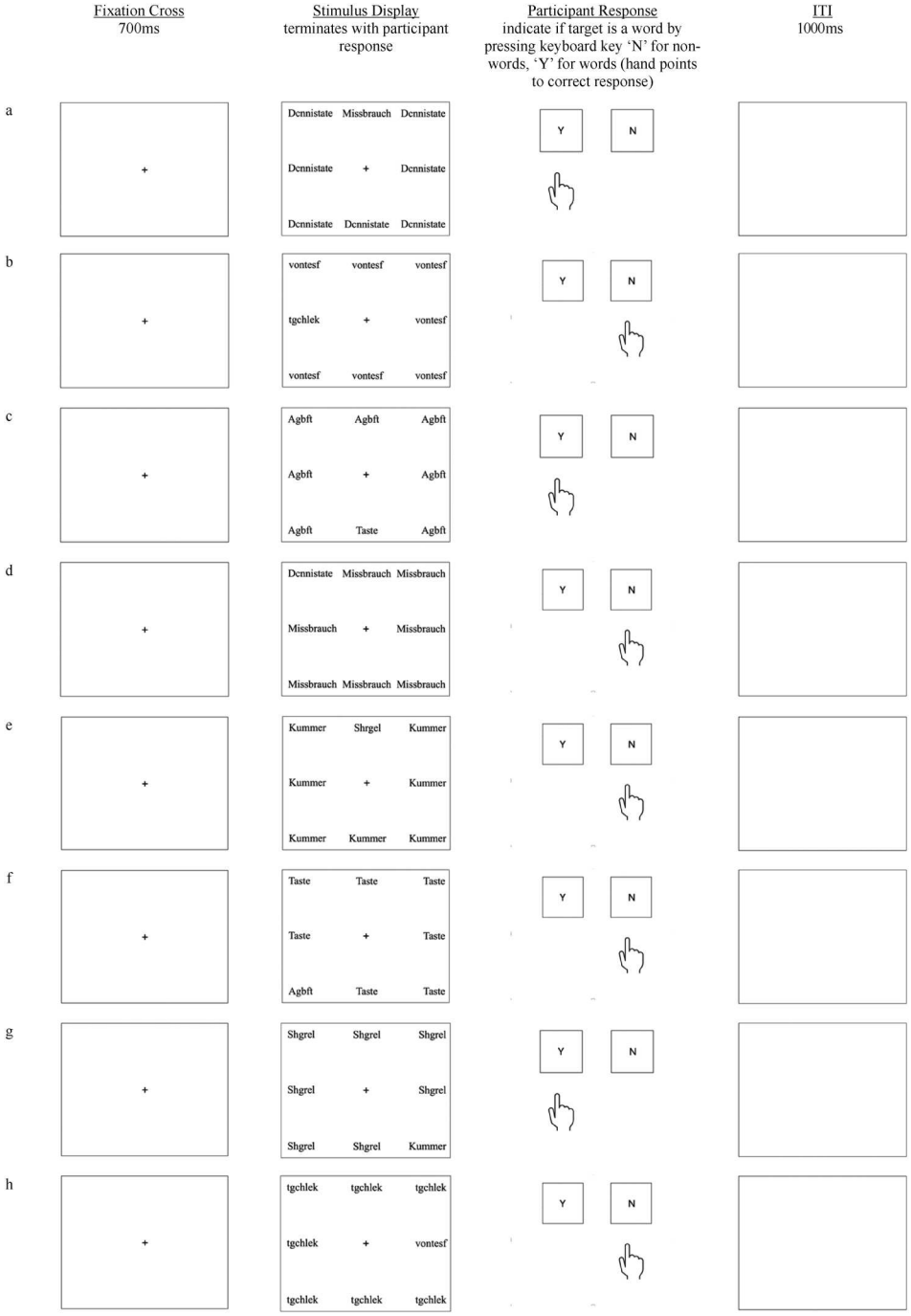

Figure 1. Example of trial sequences from the visual search task. (a) Facilitation condition, experimental trial, trauma-related target ('Missbrauch' [abuse]) and non-word distractors (b) Facilitation condition, catch trial, non-word target and non-word distractors (c) Facilitation condition, experimental trial, neutral target ('Taste' [button]) and non-word distractors (d) Inference condition, experimental trial, non-word target and trauma-related distractors ('Missbrauch' [abuse]) (e) Inference condition, experimental trial, non-word target and negative distractors ('Kummer' [sorrow]) (f) Inference condition, experimental trial, non-word target and neutral distractors ('Taste' [button]) (g) Facilitation condition, experimental trial, negative target ('Kummer' [sorrow]) and non-word distractors (h) Inference condition, catch trial, non-word target and non-word distractors.

the discrepant stimulus belonged to the same category as the distractors (words/non-words). In the interference condition, catch trials consisted of seven identical neutral words (distractors) and another neutral word (discrepant stimulus); in the facilitation condition, catch trials contained one non-word (discrepant stimulus) embedded in an array of seven identical non-words (distractors). The task consisted of 10 practice trials, including error feedback to familiarize participants with the task, and four experimental blocks (2 interference, 2 facilitation), with each block containing 40 stimuli (10 trauma-related, 10 negative, 10 neutral, 10 catch trials; i.e. 160 experimental trials in total). The order of trials within one block was fully randomized, and there was a 30s break after each block. The position of the discrepant stimulus varied systematically across trials, so that the discrepant stimulus was presented exactly five times in

each of the eight positions per block. The VST lasted approximately 10 min.

Using 5000 random splits, the Spearman-Brown corrected reliability estimates for mean RTs for each word category and condition were excellent (interference trauma: .92; interference negative: .92; interference neutral: .90; facilitation trauma: .87; facilitation negative: .88; facilitation neutral: .87). However, Spearman-Brown corrected split-half reliability estimates of difference scores were unsatisfactory (RT_{trauma} – $RT_{neutral}$ interference: – .04; RT_{trauma} – $RT_{neutral}$ facilitation: – .07; $RT_{negative}$ – $RT_{neutral}$ interference: – .28; $RT_{negative}$ – $RT_{neutral}$ facilitation: .10).

2.3.3. Scenario task

The trauma-related scenario task was developed by Woud et al. (2019). In the present study, the same six booklets as in the study of Woud et al. (2021) were used. All participants completed three booklets at baseline; only PTSD participants completed three additional booklets post-treatment. Each paper-and-pencil booklet consisted of 10 ambiguous, open-ended, trauma-related scenarios (e.g. 'My reactions to the traumatic event clearly show that … ') and four ambiguous, open-ended neutral scenarios (e.g. 'I cook myself something to eat. It tastes … '). Booklets for the non-traumatized control group were adapted by replacing the term 'trauma-related event' with 'distressing event'. Participants were told the booklets contained 14 unfinished stories and instructed to write the first ending that came to mind related to their traumatic/distressing event. Given the high correlation between dysfunctional appraisals in the scenario task and the PTCI (Woud et al., 2019), the procedure of the Scrambled Sentence Task (Rude et al., 2002; Wenzlaff & Bates, 1998) was adopted to promote the retrieval of the more automatic appraisals, i.e. participants were put under time pressure and were informed that they had to complete one booklet within 6.5 min. Additionally, participants were instructed at the beginning of each booklet to memorize a six-digit number, which would have to be recalled upon completion of the booklet (see Supplement Table S5 for the ratio of correctly recalled digits). The Spearman-Brown corrected average split-half reliability of the dysfunctionality score was $r = .93$ at baseline and $r = .95$ post-intervention ($n = 22$).

2.3.4. Implicit association tests

Participants completed two IATs (Greenwald et al., 1998), one *self-traumatized* IAT and one *self-vulnerable* IAT (Blackwell et al., 2023), with the order of IATs counterbalanced across participants. Both IATs consisted of seven blocks: (1) target practice (24 trials), (2) attribute practice (24 trials), (3) combined congruent practice (24 trials), (4) combined congruent test (48 trials), (5) target reversed practice (24 trials), (6) combined incongruent practice (24 trials), and (7) combined incongruent test (48 trials). Words were printed in white ink and presented in the middle of a black screen. Participants had to categorize the word by means of two response keys ('E' and 'I'). When participants responded incorrectly, a red cross was displayed for 200 ms, and participants had to correct their response to proceed with the task. The key assignment was the same for all participants, with the target concept *Self* presented in the upper-left corner ('E') and the target concept *Others* in the upper-right corner ('I') for the congruent blocks. For incongruent blocks, the assignment switched for the target concepts. All participants were given the same order (congruent–incongruent). Both IATs were adapted from Blackwell et al. (2023).

Self-traumatized IAT. The self-traumatized IAT aimed to assess the strength of the association between the target concepts *Self* vs. *Others* and the attribute concepts *traumatized* vs. *healthy* (for stimuli see Supplementary Material). As we hypothesized that participants with PTSD would show stronger associations between the self and concepts of traumatized, words of the target category *Self* and the attribute category *Traumatized* shared the response key ('E'), words of the concepts *Others* and *Healthy* shared the other response key ('I') in the congruent combined blocks. The assignment was reversed in incongruent combined blocks so that the concepts *Others* and *Traumatized* shared the response key ('I'), and *Self* and *Healthy* the response key ('E'). Faster reaction times in the combined congruent blocks would be indicative of the postulated stronger association between the self and concepts of traumatized. Split-half reliabilities were good (baseline: .90; post-intervention: .74).

Self-vulnerable IAT. The self-vulnerable IAT was used to assess the associative strength between the concepts *Self* vs. *Others* and the attribute categories *vulnerable* vs. *invulnerable*. In combined congruent blocks, the concepts *Self* and *Vulnerable* share the response key 'E', *Others* and *Invulnerable* shared the response key 'I' (the assignment was reversed for the combined incongruent blocks). Split-half reliabilities can be considered excellent (baseline: .89; post-intervention: .91).

2.4. Ratings

Subsequent to the reaction time tasks, participants completed a computerized rating of the presented stimuli (see Supplementary Material for details and results).

2.5. Treatment

Treatment was part of routine clinical care. Given that the second aim – examining whether treatment

had any effect on implicit biases at all – was exploratory, we chose a naturalistic setting without any requirements regarding the type and duration of trauma-focused interventions. Participants were included in the longitudinal analyses if they received in- or outpatient treatment that included trauma-focused interventions. Patients either received Eye Movement Desensitization and Reprocessing (EMDR) Therapy, Imagery Rescripting or Reprocessing Therapy (IRRT), or exposure. If participants indicated during the first assessment that they were receiving treatment and agreed to be re-assessed after its completion, they were re-contacted at regular intervals, and Session 3 was scheduled upon treatment completion. The average duration between Session 2 and 3 was 381.40 days for patients receiving outpatient ($n = 5$) and 105.41 days for patients receiving inpatient treatment ($n = 17$).

2.6. Design and procedure

Interested individuals completed a telephone interview explaining all relevant study details and scheduling the first session. At Session 1, written informed consent and a sociodemographic interview were obtained (age, sex, highest level of school education, a lifetime or current diagnosis of a psychological or psychotic disorder, lifetime psychological treatment, primary reason for current treatment [PTSD group only], suicidality, current medication, and current treatment [control groups only]). Subsequently, the Borderline Personality Disorder section of the Structured Clinical Interview for Personality Disorders (SCID-5-PD, First et al., 2015) was administered. Next, the final decision about in- or exclusion was made. Eligible participants returned within seven days for Session 2, completing questionnaires (see Section Measures), a measure of verbal intelligence (Multiple choice vocabulary test [MWT = Mehrfachwahl-Wortschatz-Test], Lehrl et al., 1995) as well as the Visual Search Task (VST), the scenario task, and two Implicit Association Tests (IAT). Finally, stimuli presented during the VST and both IATs were rated. If participants of the PTSD group underwent trauma-focused treatment, Session 3 followed post-treatment, including PCL-5, PTCI, and implicit measures. All participants were thanked for their participation and reimbursed.

2.7. Statistical analysis

Data preparation, pre-processing, and the operationalization of cognitive biases are described in the Supplementary Material (Section Data Pre-Processing). Based on our pre-registered criteria, participants with more than 35% missing trials in any experimental task were excluded from analyses (Wiers et al., 2011), which led to the exclusion of six participants in the VST for the baseline and two participants with post-intervention data (for statistical analyses of accuracy see Supplementary Material).

Data analyses were conducted with SPSS29 and R software version 4.3.1 (R Core Team, 2023). Assumptions of parametric data (e.g. normal distribution, homogeneity of variances) were examined. If the assumption of sphericity was violated for the repeated-measures ANOVAs, the Greenhouse correction was applied. If the assumptions were violated for *t*-tests and one-way ANOVAs, analyses were repeated with non-parametric tests and more robust measures are reported (e.g. Welch *F* statistic and Games-Howell corrected post-hoc tests).

To analyse RTs in the VST, a repeated-measures ANOVA was conducted with Group (PTSD, non-PTSD, non-Trauma) as a between-subject factor and Word Category (trauma, negative, neutral) and Condition (interference, facilitation) as within-subject factors.[3] Group differences regarding IAT scores and the ratio of dysfunctional appraisals were examined with two separate omnibus one-way ANOVAs. When analysing the baseline characteristics, significant group differences regarding education, age, and verbal IQ emerged (see Table 1); all analyses were repeated with IQ and age as covariates. If results remained unchanged, the pre-registered analyses (ANOVA) were reported. To investigate whether biases were reduced by treatment within the PTSD group, paired sample *t*-tests were performed for IAT scores and the dysfunctional appraisal score, while repeated-measure ANOVAs (within factors, two time points) were conducted for the VST. Split-half reliability of the IAT was determined with the R-package *IATscores* (Richetin et al., 2015), split-half reliabilities of the VST with the R package *splithalf* (Parsons, 2021).

3. Results

3.1. Demographic and psychopathological characteristics

Groups did differ with regard to age, education, verbal IQ, trauma type, and psychopathological symptoms, all $ps < .005$, and no group differences emerged regarding gender (see Table 1). Of the PTSD participants, 56% were recruited in clinical and 44% in non-clinical settings.

3.2. Group comparisons

Attention. The repeated-measures ANOVA revealed significant main effects of Word Category, $F(2, 254) = 18.35$, $p < .001$, $\eta_p^2 = .126$, and Group, $F(2, 127) = 8.96$, $p < .001$, $\eta_p^2 = .124$. However, neither the 2-way

Table 1. Sociodemographic and psychopathological information of the samples: frequencies and means (standard deviations).

Measures	PTSD ($n = 50$)	Non-PTSD ($n = 54$)	Non-trauma ($n = 57$)	Statistics
Age	37.66 (13.27)	35.20 (12.81)	30.12 (10.38)	$F(2, 101.68) = 5.91$, $p = .004$; PTSD > non-Trauma
Gender (f/m/d)	39/10/1	40/14/0	38/19/0	$\chi^2(4) = 4.50$, $p = .342$
Education (% High school degree)	58%	98%	96%	$\chi^2(2) = 42.03$, $p < .001$
Verbal IQ	101.56 (9.82)	108.76 (9.25)	106.88 (7.79)	$F(2. 158) = 8.97$, $p < .001$; PTSD < non-PTSD, non-Trauma
Average number of traumatic events (according to LEC items 1-17)	8.28 (3.94)	7.19 (4.59)		$t(102) = \|1.30\|$, $p = .197$
Trauma type (n)			–	$\chi^2(4) = 31.31$, $p < .001$
Sexual assault	28	12		
Physical assault	20	13		
Severe accident	1	14		
Death	1	14		
Other	0	1		
Current Comorbid Disorders				
Depressive Disorder (yes/no)	18/31			
Anxiety Disorder (yes/no)	8/41			
OCD (yes/no)	3/46			
PCL-5 Total	45.90 (13.91)[a]	4.33 (5.60)	4.53 (7.39)	$F(2, 93.20) = 198.44$, $p < .001$; PTSD > non-PTSD, non-Trauma
PTCI Total	123.65 (36.95)[a]	50.68 (15.10)[b]	–	$t(62.60) = \|12.87\|$, $p < .001$
CTQ Total	76.28 (20.49)[c]	43.78 (6.66)	42.74 (5.63)	$F(2, 86.19) = 57.95$, $p < .001$; PTSD > non-PTSD, non-Trauma
IDS Total	35.65 (11.75)[a]	7.31 (4.89)	7.61 (5.54)	$F(2, 93.96) = 129.01$, $p < .001$; PTSD > non-PTSD, non-Trauma

Note. [a] $n = 49$; [b] $n = 53$; [c] $n = 46$.
PCL-5 = PTSD Checklist for DSM-5. PTCI = Posttraumatic Cognitions Inventory. CTQ = Childhood Trauma Questionnaire. IDS = Inventory of Depressive Symptomatology.

interaction Word Category × Group, $F(4, 254) < 1$, $p = .915$, $\eta_p^2 = .004$, nor the relevant 3-way interaction Word Category × Condition × Group were significant, $F(4, 254) < 1$, $p = .541$, $\eta_p^2 = .012$ (see Table 2). In turn, a significant two-way interaction Word Category × Condition emerged, $F(2, 254) = 9.08$, $p < .001$, $\eta_p^2 = .067$. Follow-up repeated-measures ANOVAs within each condition revealed that RTs differed between the word categories within the facilitation condition, $F(2, 258) = 23.03$, $p < .001$, $\eta_p^2 = .151$. Bonferroni-corrected post-hoc tests showed that participants were faster when a trauma-related and a negative word served as the target stimulus compared to neutral words ($ps < .001$). For the interference condition, RTs for the different word categories also differed, $F(2, 258) = 5.79$, $p = .003$, $\eta_p^2 = .043$, with RTs being slower for trauma-related and neutral compared to negative distractors ($ps = .008$). Consequently, although an attentional bias for negative stimuli emerged across groups in the facilitation condition, attention allocation towards trauma-related stimuli did not differ between PTSD patients and control groups.[4]

Implicit dysfunctional appraisals. Groups significantly differed in their ratio of implicitly assessed dysfunctional appraisals, $F(2, 158) = 71.65$, $p < .001$, $\eta^2 = .48$ (95% CI [0.36 –0.56]). Participants of the PTSD group ($M = 0.68$, $SD = 0.20$) showed significantly stronger implicitly assessed dysfunctional appraisals compared to non-PTSD participants ($M = 0.25$, $SD = 0.19$), $p < .001$, and non-traumatized participants ($M = 0.33$, $SD = 0.19$), $p < .001$, with no significant difference between the latter two groups, $p = .068$.

Memory associations. Groups significantly differed regarding their IAT scores in the self-traumatized IAT, $F(2, 157) = 43.44$, $p < .001$, $\eta^2 = .36$ (95% CI [0.24 –0.45]), and the vulnerability IAT, $F(2, 158) = 8.77$, $p < .001$, $\eta^2 = .10$ (95% CI [0.02 –0.19]), see Figure 2. Bonferroni-corrected post-hoc tests showed that in both IATs, participants with PTSD showed stronger associations between the concepts *Self* and *traumatized/vulnerable* compared to participants of both control groups (traumatized IAT: PTSD ≠ non-PTSD, non-Trauma, $ps < .001$; vulnerability IAT: PTSD vs. non-PTSD, $p < .001$, PTSD vs. non-Trauma,

Table 2. Mean Reaction Times in the Visual Search Task: Means (SD).

Condition	Word category	PTSD ($n = 48$)	Non-PTSD ($n = 36$)	Non-trauma ($n = 46$)
Facilitation	Trauma-related	2006.17 (454.36)	1833.14 (414.98)	1705.96 (305.15)
	Negative	2008.59 (422.36)	1817.80 (459.57)	1723.55 (260.63)
	Neutral	2094.79 (443.99)	1926.83 (406.96)	1807.61 (276.08)
Interference	Trauma-related	2158.28 (610.97)	1893.22 (471.81)	1759.93 (279.66)
	Negative	2099.28 (577.51)	1876.80 (418.92)	1713.16 (282.75)
	Neutral	2151.20 (498.36)	1887.70 (399.72)	1785.06 (283.68)

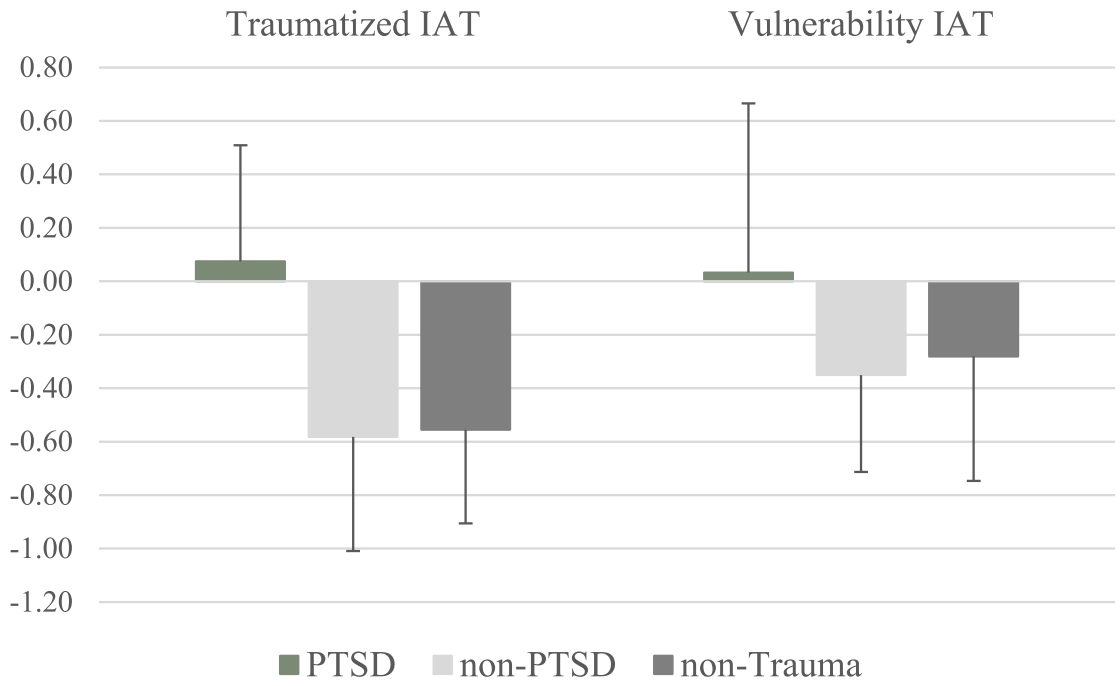

Figure 2. IAT scores (with standard deviation) for the traumatized and the vulnerability IAT for each group.

$p = .004$, see Figure 2). Associations between the different biases and PTSD symptoms are depicted in Table 3.

3.3. Exploratory analyses: change of PTSD symptoms and cognitive biases

PTSD symptoms. Paired *t*-tests on PCL-5 and PTCI scores examined symptom changes in PTSD patients during treatment ($n = 22$). The severity of PTSD symptoms and dysfunctional cognitions significantly decreased from pre- to post-treatment: PCL-5 ($M_{pre} = 49.27$, $SD = 11.37$; $M_{post} = 33.73$, $SD = 18.04$), $t(21) = 4.17$, $p < .001$, $d = 0.89$, 95%CI [0.39–1.38], and PTCI ($M_{pre} = 131.14$, $SD = 39.84$; $M_{post} = 109.23$, $SD = 42.24$), $t(21) = 3.06$, $p = .006$, $d = 0.65$, 95%CI [0.19–1.12].

Attention. Regarding changes in attention allocation over the course of treatment, a repeated-measures ANOVA with Word Category, Condition, and Time as within-subject factors revealed a significant main effect of Time, $F(1, 18) = 17.61$, $p < .001$, $\eta_p^2 = .495$; however, the 2-way interaction Word Category x Time, $F(2, 36) < 1$, $p = .588$, $\eta_p^2 = .029$, and the 3-way interaction of Word Category × Condition × Time, $F(2, 36) < 1$, $p = .966$, $\eta_p^2 = .002$, were non-significant (for RTs of PTSD patients with pre- and post-VSTs see Table S4 in the Supplement).

Implicit dysfunctional appraisals. In the subgroup of patients receiving trauma-focused treatment, the dysfunctional appraisal score significantly decreased ($M_{pre} = 0.68$, $SD = 0.21$; $M_{post} = 0.50$, $SD = 0.29$), $t(21) = 3.61$, $p = .002$, $d = 0.77$ [95%CI 0.28–1.24], bootstrapping: $M_{diff} = 0.17$, $p = .008$ [95%CI 0.08 – 0.27], indicating that PTSD patients showed weaker implicitly assessed dysfunctional appraisals after treatment. The Spearman-Brown corrected average split-half reliability was $r = .95$ post-intervention ($n = 22$).

Memory associations. Bootstrapped paired sampled *t*-tests revealed that the patients´ D-score of the self-traumatized IAT changed over the course of treatment: while patients showed a positive IAT score at baseline (i.e. stronger trauma association), after

Table 3. Associations (Kendall-Tau-b) between the different biases and PTSD-related symptoms in traumatized groups.

Measures	PCL-5		PTCI		CTQ		Self-traumatized IAT		Self-vulnerable IAT		Appraisal score	
	τ_b	*p*	τ_b	*p*	τ_b	*p*	τ_b	*p*	τ_b	*p*	τ_b	*p*
Self-traumatized IAT	**.384**[a]	<.001	**.391**[b]	<.001	**.389**[c]	<.001	1	-	-	-	-	-
Self-vulnerable IAT	**.225**[d]	<.001	**.238**[a]	<.001	**.209**[e]	.002	**.344**	<.001	1	-	-	-
Appraisal score	**.576**[d]	<.001	**.636**[a]	<.001	**.438**[e]	<.001	**.350**	<.001	**.249**	<.001	1	-
Interference score trauma	.003[f]	.972	.059[g]	.437	.019[h]	.800	.096	.201	.026	.728	−.016	.832
Interference score negative	−.095[f]	.209	−.085[g]	.262	−.125[h]	.103	−.029	.697	.092	.214	−.082	.274
Facilitation score trauma	−.067[f]	.375	.010[g]	.892	−.115[h]	.133	.001	.984	.055	.463	.010	.892
Facilitation score negative	−.005[f]	.947	.046[g]	.543	−.048[h]	.530	−.031	.680	−.050	.497	.010	.898

Note. [a] $n = 102$; [b] $n = 101$; [c] $n = 99$; [d] $n = 103$; [e] $n = 100$; [f] $n = 83$; [g] $n = 82$; [h] $n = 81$.

trauma-focused treatment the pattern was reversed such that patients showed a negative IAT score, that is, stronger functional associations ($M = -0.19$, $SD = 0.39$), $t(21) = 2.67$, $p = .014$, $d = 0.48$ [95%CI 0.11–1.02], which significantly differed from zero, $t(21) = 2.27$, $p = .034$. Using bootstrapping, the mean difference was $M_{diff} = 0.27$, $p = .016$, 95%CI [0.08–0.47], indicating that there was a significant change of the self-traumatized IAT score from pre- to post-treatment. Regarding the self-vulnerable IAT score, there was no significant change over the course of treatment ($M = -0.13$, $SD = 0.43$), $t(21) = 1.66$, $p = .113$, $d = 0.50$ [95%CI – 0.08–0.78], bootstrapping: $M_{diff} = 0.18$, $p = .131$, 95%CI [−0.04 –0.36]. Split-half reliabilities post-intervention can be considered good (self-traumatized IAT: .74; self-vulnerable IAT: .91).

4. Discussion

This study assessed different cognitive biases in a diagnosed PTSD sample compared to trauma-exposed healthy and non-traumatized healthy participants. Additionally, via exploratory analyses, it was examined whether these biases would be reduced after treatment including trauma-focused interventions.

Contrary to expectations, no evidence emerged for biased attentional processing of trauma-related stimuli in PTSD. If anything, all groups responded faster when negative and trauma-related stimuli served as target stimuli in the facilitation condition (however, including age and IQ as covariates turned this finding non-significant). This finding adds to the overall inconsistent literature on attentional biases in PTSD (Cisler et al., 2011; Kimble et al., 2009; Woud et al. 2017), though it contrasts with earlier VST findings (Pineles et al., 2007; Pineles et al., 2009). Several explanations are conceivable: First, attentional biases may not be a robust cognitive marker, and attentional bias variability (ABV), rather than static bias, may better distinguish trauma-exposed from healthy individuals and correlate with PTSD (Todd et al., 2022). Second, limited reliability of the VST may have contributed to the null findings. However, to address potential methodological concerns (i.e. specificity), stimulus ratings confirmed that trauma-related items were perceived as significantly more trauma-related by PTSD than control participants (Pergamin-Hight et al., 2015).

Importantly, hypotheses 2 and 3 were supported, i.e. PTSD participants showed both stronger dysfunctional appraisals and stronger implicit trauma and vulnerability associations than controls. These results clearly extend prior findings (Blackwell et al., 2023; Lindgren et al., 2013; Woud et al., 2019; Woud et al., 2021) by demonstrating that both the scenario task and self-traumatized/self-vulnerable IATs distinguish between trauma-exposed individuals with and without PTSD, supporting task validity and cognitive concepts. Higher appraisal scores in the PTSD group suggest that open-ended trauma scenarios can elicit dysfunctional appraisals without explicit instruction to reveal them. Stronger implicit associations between the self and concepts of traumatized corroborate findings of Woud et al. (2021), but contrast with a study that included a veteran sample with PTSD (Lindgren et al., 2023). A possible explanation for the discrepant findings could lie in the sample: While the PTSD samples in Woud et al. and the present study included mainly female participants who mostly experienced interpersonal trauma, Lindgren et al. included (mainly) male veterans who mostly developed PTSD after military deployment. Moreover, individuals in military service are explicitly prepared for potentially dangerous situations, making trauma exposure during service more anticipated and situated outside the boundaries of everyday life. Military culture is further characterized by norms that discourage the expression of vulnerability. In contrast, traumatic events occurring within civilian daily life may more strongly violate fundamental assumptions about the self as safe (vs. helpless, vulnerable). Consequently, trauma experienced in military service versus interpersonal trauma may be associated with distinct patterns of negative self-appraisals.

With regard to our exploratory analyses, the fourth hypothesis was partly confirmed. While attentional biases were not reduced following treatment, implicitly assessed appraisals were significantly reduced in the treatment seeking PTSD sample. Regarding the former, the null finding might not be surprising given that there was no evidence of an AB at pre-intervention. Regarding the latter, these findings should be interpreted with caution as they were derived from a small sample in an uncontrolled study conducted in routine clinical care. Consequently, replications with both adequately powered samples and controlled study settings are needed before firm conclusions can be drawn. If findings would be replicated, this could have important clinical implications. While preliminary evidence suggests reductions in dysfunctional appraisals mediate treatment effects (Woud et al., 2021), it is important to further examine whether changes in different biases contribute beyond explicit measures. Although effective PTSD treatments exist (American Psychological Association, 2017; International Society for Traumatic Stress, 2019), some patients remain symptomatic or relapse, possibly due to persistent cognitive biases. Examining whether post-treatment biases predict follow-up symptoms could inform interventions targeting memory associations and implicit appraisals to enhance treatment efficacy, e.g. by implementing add-on training procedures designed to directly target

memory associations and implicit dysfunctional appraisals (Woud et al., 2021).

4.1. Limitations

Despite efforts to match groups, PTSD participants differed from controls in age, IQ, and trauma type. IQ differences may influence RTs (Sheppard & Vernon, 2008) but are unlikely to affect appraisal or memory associations. Because recruiting participants for the non-PTSD group proved particularly challenging under the strict inclusion criteria, these criteria were made more lenient for this group only. However, this decision may account for the greater variability in trauma types within the non-PTSD group compared to the PTSD group and for the trauma-type differences observed between groups. Differences between trauma types may have influenced findings, as most PTSD participants experienced early interpersonal trauma, potentially linked to stronger biases. Finally, treatment type and duration varied, and patients in inpatient care received multiple therapeutic components beyond trauma-focused interventions. Consequently, other treatment elements may have contributed to the observed effects, and the specific effects of trauma-focused care remain unclear. Future studies should employ standardized interventions and include a control condition to determine whether observed effects are attributable specifically to trauma-focused treatment elements rather than to time alone.

4.2. Conclusion

This study assessed cognitive biases in attention, interpretation, and memory associations and their change with treatment in exploratory analyses. While attentional biases were not found, PTSD participants showed stronger dysfunctional appraisals and memory associations than controls, which were reduced after treatment. Future research should examine whether changes in implicit biases mediate treatment effects and predict long-term outcomes.

Notes

1. Although 'classical' memory biases, e.g. selective memory bias assessed through paradigms such as word-stem completion or overgeneral memory bias assessed through paradigms such as the Autobiographical Memory Task, have been identified in PTSD (Woud et al., 2017), their investigation is beyond the scope of the present study.
2. As data collection was significantly delayed due to restrictions and the closure of university buildings during the COVID-19 pandemic and only a limited number of participants could be recruited for the traumatized non-PTSD group, the inclusion criteria for this group were made more lenient. The original inclusion criteria for the non-PTSD group were: (1) experience of a traumatic event falling into one of the following three categories: sexual trauma, physical violence, severe traffic accident, (2) no lifetime diagnosis of a psychological/psychiatric disorder, (3) no current use of psychotropic drugs, and (4) no lifetime psychological/psychiatric treatment. Although it was stated in the Amendment of the preregistration (https://aspredicted.org/dg7st.pdf) that the inclusion criteria for the PTSD group would remain unchanged, accidently one patient with PTSD having experienced another type if traumatic event was included in the PTSD group (see Table 1).
3. In a first step, a four-way ANOVA was conducted with Order of Condition (facilitation first, interference first) as an additional between-subject factor. As none of the relevant interactions were modified by Order of Condition, this factor was not included to increase statistical power.
4. When analyses were repeated with age and IQ as covariates, the main effects Word Type and Group as well as the two-way interaction Word Type x Condition were non-significant, $ps > .165$.

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Open Data Badge

This article has earned the Center for Open Science badges for Open Data and Preregistered. The data and materials are openly accessible at https://osf.io/n34cd/ and https://aspredicted.org/jy5nb.pdf 2. amendment: https://aspredicted.org/dg7st.pdf.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT in order to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the published article.

Ethical standards

The study was approved by the ethics committee of LMU Munich (14_Wittekind_b). The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Data availability statement

Data and analysis code will be made publicly available upon acceptance at the OSF and can be accessed at [https://osf.io/n34cd/].

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