A novel process-based approach to improve resilience: Effects of computerized mouse-based (gaze)contingent attention training (MCAT) on reappraisal and rumination

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Abstract

Stress dysregulation is a transdiagnostic marker of emotional disorders, related to biases in attention toward negative information. We adapted a computerized process-based training targeting these attention mechanisms through mouse-based contingency responses and examined its effects on reappraisal and rumination. Forty-one participants were randomly assigned to either a control or an active training condition of mouse-based contingent attention training (MCAT). Participants in the active condition were instructed to allocate attention toward positive words to generate positive interpretations, by using attention regulation while receiving contingent feedback on their attention to emotional words. Participants in the control condition freely generated interpretations without receiving contingent feedback. Transfer to reappraisal and state rumination was evaluated by administering an emotion regulation paradigm before and after the training. Mouse-based attention estimations showed a high degree of congruency with real eye/gaze-based attention estimations, as measured with eye-tracking performed in parallel. Furthermore, active MCAT resulted in several beneficial effects, including: 1) a higher attention toward positive over negative information; 2) an improved reappraisal ability to down-regulate negative emotions, and 3) a larger state rumination reduction in comparison to the control group. Our findings supports MCAT as a promising way to monitor and train attention, being an innovative instrument for online interventions aimed to improve stress regulation and resilience.

Key words: Selective attention; gaze-contingent training; reappraisal; rumination; resilience

Introduction

The occurrence of major life stress significantly increases the risk to develop emotional disorders, including depression (Kendler, Karkowski, & Prescott, 1999) and anxiety (Blazer, Hughes, & George, 1987). Specifically, dysfunctional mood regulation in response to adverse or stressful events is considered to be one of the key factors involved in the onset and maintenance of both depression (Joormann & Quinn, 2014) and anxiety (Cisler, Olatunji, Feldner, & Forsyth, 2010). Despite increasing knowledge on how impaired stress regulation processes put individuals at risk to develop emotional disorders, the current occurrence rates of stress-related dysfunctions and the resulting mental health costs are still dramatic (e.g., Olesen, Gustavsson, Svensson, Wittchen, & Jönsson, 2012). This highlights the need to develop novel approaches to: 1) improve effective mental health promotion (i.e., stress resilience promotion in at-risk individuals) and 2) optimize interventions for individuals suffering from disorders resulting from dysfunctional stress regulation.

Among potential mechanisms, attention processes have been postulated to play an important role in vulnerability as well as resilience for the onset of stress-related emotional disorders. Moreover, attention has also been implicated in the subsequent maintenance of stress-related disorders (see Joormann & Gotlib, 2010; De Raedt & Koster, 2010). Anxious individuals show preferential attentional capture toward and sustained processing of negative information, whereas depressed individuals are characterized by both reduced attention toward positive information and sustained attention for negative information (Armstrong & Olatunji, 2012; Peckham, McHugh, & Otto, 2010). Consequently, during the last 15 years, a large body of research embarked on developing methods to experimentally manipulate and improve attention processes associated with the onset and maintenance of emotional disorders. Such research, termed “attention bias modification” (ABM), aims to modify pathological ways of attention processing of affective information through repeated practice of more adaptive processing (MacLeod, Koster, & Fox, 2009). Most previous ABM research employed variants of the visual dot-probe task (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002), simultaneously presenting two competing stimuli (e.g., a negative vs. a positive word), and using subsequent probe's replacements at the non-negative stimulus locations, to encourage individuals to orient attention away from negative information and toward more adaptive information. Although initial promising results suggested that ABM procedures could serve as an important clinical tool to directly change stress-pathogenic mechanisms involved in emotion disorders' onset and maintenance (e.g., Bar-Haim, 2010), more recent meta-analyses tempered this enthusiasm, indicating that these procedures have only limited success in changing attention and, in turn, reducing related symptoms (Beard, Sawyer, & Hofmann, 2012).

Therefore, although ABM represents an exciting translational development with potential clinical implications both for prevention and intervention, further innovations and refinements of ABM methodology are required (Koster & Bernstein, 2015). Part of previous inconsistent findings may be accounted for by the use of indirect reaction-time measures as the target of intervention. Together with their poor psychometrics (Waechter, Nelson, Wright, Hyatt, & Oakman, 2014), emotional biases reflected in reaction-time patterns only capture indirect effects of attention at the end of complex emotional processes. Therefore, further research requires fine-grained methodologies to detect specific attention mechanisms affected in emotional processes and, more innovatively, to target and modify the precise components linked to proximal processes of stress regulation. With this aim, recent research started using novel fine-grained eye-tracking techniques to assess specific attention processes and test their role in stress regulation impairments. Sanchez, Vazquez, Marker, LeMoult, and Joormann (2013) used an eye-tracking technique to evaluate direct processes of gaze disengagement from emotional stimuli. It was found that clinically depressed individuals are characterized by difficulties in disengaging attention from negative stimuli and that this specific bias is predictive of lower mood recovery in response to a stress induction. In a similar paradigm, Çek, Sanchez, and Timpano (2016) showed that highly anxious individuals are characterized by sustained visual fixations on negative social feedback, in turn, predicting impaired stress regulation and subsequent higher activation of repetitive negative thinking. In contrast, studies using eye-tracking techniques in healthy populations indicate that adaptive selective attention toward relevant positive and negative information is dynamic in nature and (sub)serves the use of stress regulation strategies. For instance, in a study using different experimental mood manipulations, it was found that healthy individuals increase their fixation times toward positive stimuli specifically in response to induced transient increases in negative mood. Moreover, larger attention change in this direction following the negative mood induction predicted more regulation of the induced negative mood (Sanchez, Vazquez, Gomez, & Joormann, 2014). Furthermore, a recent longitudinal study tested the predictive role of gaze disengagement from emotional information to ruminative brooding and depression changes during the following 5-months. Slower disengagement from positive information at baseline predicted decreased use of brooding in response to stressful events during the following 5 months, in last term predicting decreased depression (Sanchez-Lopez, Koster, van Put, & De Raedt, 2019).

Integrating this body of evidence, Sanchez-Lopez and colleagues have developed a new advanced eye-gaze contingent attention training (ECAT) aimed at directly targeting specific attention mechanisms implicated in stress (dys)regulation processes. In this procedure (Sanchez-Lopez, Everaert, van Put, De Raedt, & Koster, 2019; Sanchez, Everaert, & Koster, 2016), participants are trained to intentionally regulate attention allocation (intentionally reduce attentional processing of negative in favor of positive information), in order to generate positive (instead of alternative negative) self-referent interpretations (e.g., “the future looks very bright” instead of “the future looks very dismal”), while performing a scrambled sentence task (SST; e.g., unscrambling the sentence “future dismal very my bright looks”). To elicit a high degree of attention regulation, trainees receive: 1) online gaze-contingent feedback when their attention is captured by competing negative and positive words, as detected by an eye-tracker, in order to use top-down attentional regulation (i.e., intentionally disengage attention from negative words when they were fixated and maximize intentional visual search and engagement with alternative positive words), and 2) feedback on performance between blocks (i.e., visualization of times attending toward positive vs. negative stimuli both at the beginning of the task and during the training), in order to increase awareness of emotional biases to maximize regulatory control in redirecting attention in subsequent trials (see also Bernstein & Zvielli, 2014; Schnyer et al., 2015). Results from Sanchez-Lopez and colleagues indicated that this training, in comparison to a control condition (i.e., not receiving gaze-contingent feedback), is effective to facilitate top-down attention regulation during training (increases in the fixation durations to positive over negative words while performing the SST). This, in turn, facilitated maintained attention to positive over competing negative information in several types of attention transfer tasks (both in the dot-probe task, Sanchez et al., 2016; and eye-tracking based tasks, Sanchez-Lopez, Everaert, et al., 2019). Furthermore, previous ECAT studies also showed its effectiveness to maximize maintained attention on positive over negative material, in turn, leading to: a) improved use of cognitive reappraisal to reduce negative emotion levels, and b) reduced activation of repetitive negative thinking (state rumination) while viewing negative scenes.

Overall, ECAT represents an important step for new developments in treatment. The use of gaze-contingent techniques demonstrates to be a promising way to train precise attention components implicated in emotion (dys)regulation as proximal processes of emotional disorders

(Cisler et al., 2010; Joormann & Quinn, 2014). In the present study we aimed to test these techniques in a computerized way that may facilitate its future implementation online. This would eventually allow us to provide at risk-individuals (i.e., experiencing high stress levels and/or dysfunctional stress regulation) with effective online ECAT tools that can be used during daily functioning, maximizing the implementation of attention regulation (and related stress-regulation processes) to cope with daily stress. Similarly, this approach might have the benefit of providing patients suffering from ongoing stress-related disorders with a relevant add-on instrument to standard treatments. This could be used to monitor and train stress regulation processes at moments in daily life where such strategies are particularly required (e.g., regulating attention to reduce engaging in ruminative thinking in response to occurring negative events). As an initial step toward these aims, we developed and tested an ECAT variant comprising mouse-based contingent attention training (i.e., MCAT). In this new MCAT variant, information during SST performance (i.e., words within the scrambled sentence) is presented contiguously to participants' attentional behavior (i.e., only the currently attended word is shown on the screen at each moment), based on mouse cursor positioning. Contingent feedback to implement attention regulation is provided via mouse cursor coordination (i.e., participants move the mouse cursor to uncover words, while performing the training, and mouse pointer location coordinates are used to monitor and provide feedback on stimuli processing; see Methods section). This design was implemented following previous literature supporting a high degree of linkage between mouse cursor movements and actual eye gaze movements under conditions that facilitate mouse/gaze attention coupling (see, for instance, Deng, Chang, Kirkby, & Zhang, 2016; Liebling & Dumais, 2014). Eye-tracking was used in parallel, allowing us to first establish the level of gaze/mouse coordination during the performance of the MCAT variant (i.e., whether the mouse-cursor based method is precise enough to assess and intervene on attention mechanisms). Upon validation of the mouse-based tracking technique, we tested whether MCAT would replicate previous findings using ECAT (Sanchez et al., 2016; Sanchez-Lopez, Everaert et al., 2019) regarding its effectiveness to increase attention regulation during the training (Hypothesis 1) and transfer to outcome processes of stress regulation, including: a) an increase of maintained attention on positive over negative information (Hypothesis 2), b) a greater reappraisal capacity to down-regulate negative emotions (Hypothesis 3), and c) lower state rumination in response to the presentation of negative situations (Hypothesis 4). In sum, this proof-of-concept study aimed to validate a single session MCAT variant and its immediate effects in emotion regulation, as an initial step to establish its potential as a novel online attention-contingent training that can be used to promote stress resilience and intervene in transdiagnostic stress-related dysfunctions.

Methods

Participants

Forty-one undergraduates (25 women; 18-28 years) were recruited via the participant pool at Ghent University. All participants had normal or corrected to normal vision. Sample size was determined through a priori power analyses based on previous proof-of-concept studies testing the effectiveness of single session ECAT procedures (Sanchez et al., 2016; Sanchez-Lopez et al., 2019). First, sample size estimation was based on previous results from the original proof-of-concept study testing the effectiveness of a single-session ECAT to increase attention regulation as the result of active gaze-contingent training (medium-to-large effect size of Cohen's $f = .73$ in Sanchez et al., 2016). Setting α at .05, power ($1—\beta$) at .80, and expecting a correlation of $\rho = .20$ between repeated measurements and a nonsphericity correction= 1, with two groups and two measurements (Sanchez et al., 2016), power analysis (GPower 3.1.9.2) indicated that a sample size of at least 10 participants per group would yield adequate power to detect the expected effect size on the primary outcome (i.e., attention regulation during training). Second, sample size was also estimated in accordance to previous results on the effectiveness of a single-session ECAT to generate pre-post changes on gaze disengagement from emotional information, as our immediate transfer outcome measure (small-to-medium effect size of Cohen's f = .35 in Sanchez-Lopez et al., 2019). Setting α at .05, power (1—β) at .80, and expecting a correlation of ρ = .60 between repeated measurements and a nonsphericity correction= 1, with two groups and two measurements (Sanchez-Lopez et al., 2019), a sample size of at least 16 participants per group was estimated to yield adequate power to detect the expected effect size on the immediate transfer outcome (i.e., attentional disengagement from emotional information). In order to maximize our power to detect single-session MCAT effects on these outcomes and further test its transfer to emotion regulation outcomes (i.e., reappraisal, state rumination), we set the final sample to reach a number of at least 20 participants per group in the current study. Participants were paid 20 euro for their participation.

Design Overview

Figure 1 depicts the sequence of tasks. Before starting with the experimental procedure, participants filled out a questionnaire package including self-report measures of depressive symptoms (Beck Depression-Inventory-II, BDI-II; Beck, Steer, & Brown, 1996), and trait levels of rumination (RRS; Treynor, Gonzalez, & Nolen-Hoeksema, 2003), reappraisal (Emotion Regulation Questionnaire, ERQ; Gross & John, 2003), and stress resilience (Resilience Scale, RS; Wagnild & Young, 1993). This was followed by the experimental procedure, which was similar to the one employed in previous studies testing single-session ECAT effectiveness (Sanchez et al., 2016; Sanchez-Lopez, Everaert et al., 2019). As for the MCAT procedure, all participants started completing a baseline phase followed by random assignation to complete either the active MCAT condition or a control-comparison condition. Before and after completing the MCAT procedure, participants also completed: 1) an attentional engagement-disengagement task assessing the times to disengage gaze from positive and negative words, 2) an emotion regulation task assessing reappraisal ability, and 3) a self-report of the level of ruminative thinking experienced during the performance of the emotion regulation task. The full session lasted around 90 minutes.

MCAT procedure

The MCAT procedure comprised the same principles of action as in the original ECAT procedure (Sanchez et al., 2016; Sanchez-Lopez, Everaert et al., 2019), but was adapted to be controlled via mouse cursor contingencies in a computer. This procedure uses a variant of a task designed to measure interpretation biases, the SST (Wenzlaff & Bates, 1998), implementing eye-tracking based techniques to monitor attention toward positive and negative words while mentally forming emotional interpretations (Everaert, Duyck, & Koster, 2014).

In the initial *Baseline Phase* of MCAT, used to measure pre-training attention biases (see Figure 2), each trial starts with a fixation cross at the left side of the screen to elicit natural left-to-right reading patterns. Participants click with the mouse over the cross in order to start the reading section of the SST task. The *reading section* of the SST then comprises reading a 6-word emotional scrambled sentence (e.g., “am winner born loser a I”), with the instruction to unscramble the sentence to form a grammatically correct and meaningful statement using five of the six words as quickly as possible and within a time limit of 14 sec (e.g., “I am a born winner” or “I am a born loser”). Similar to previous ECAT procedures, eye-tracking based techniques are implemented to monitor attention to each word while participants mentally unscramble the sentence. In the MCAT procedure, this is achieved by implementing a mouse-contingent moving window technique while performing the reading section: each word is hidden under an individual blank mask and participants have to place the mouse cursor over each mask to uncover and read the corresponding word. Each time participants move the mouse cursor to a new masked position, the previously attended word is masked again and the new attended word is unmasked, leading to reading words one by one according to the mouse cursor's position. Thus, participants move the mouse cursor over the masks to uncover and read each word as often and as long as they need for a maximum of 14 sec, in order to mentally unscramble a 5-word sentence, while mouse pointer location coordinates are used to index the time attending to each of them. Upon completion participants click over a "Ready" button continuously visible at the bottom of the screen to start the following *response section*. The response section starts upon participants' click on the precedent "Ready" button or after the 14 sec time limit for reading is over. In the response section all words are visible for a maximum of 7 sec and participants have to click over the 5 corresponding words to form their chosen grammatically correct sentence, in the appropriate order, as fast as possible. Upon clicking over each word, a number appears over it, indicating the corresponding order of that word in the chosen sentence. If participants make a mistake in their selection, they can click again over the given word to unselect it and then click over the corresponding following word to continue forming the chosen sentence. Upon selection of the full unscrambled sentence (five words selected and numbered accordingly), participants click over the "Ready" button, continuously visible at the bottom of the screen. The response section finishes upon participants' click on the "Ready" button or after the 7 sec time limit for providing the response was over. This baseline phase (12 trials) is used to monitor and index baseline attention biases toward positive vs. negative words during the reading section, while performing a standard free interpretation task (i.e., instruction: report the first 5-word unscrambled sentence that comes to your mind, as fast as possible).

Then, in the next *Modification Phase*, participants are randomly assigned to complete 8 new blocks of 6 emotional scrambled sentences, either following the same procedure as in the baseline phase (i.e., control comparison condition) or receiving active MCAT (i.e., active training condition). The active MCAT condition comprises several manipulations. First, participants are now instructed to unscramble all sentences into positive self-statements (Sanchez, Everaert, De Putter, Mueller, & Koster, 2015) and to focus attention on positive over negative words, as this would help to identify and form positive meanings more efficiently. Then, participants are provided with online gaze-contingent feedback on their attentional deployment while completing the reading section: while using the mouse cursor to uncover the words during the reading section, a red or green square respectively frames the negative or positive words each time those words are uncovered and read by participants. Green and red colors were chosen to allow trainees to easily identify the target and distractor cue words, while mentally searching for a positive unscrambled solution. This allows them to easily implement required attention regulation toward and away from the former and latter cue words respectively. Finally, the time spent attending to positive over negative words in each block is computed and participants are presented with this real-time feedback on their attention behavior upon completion of the corresponding training block, in a way that they are able to compare their actual attention performance (e.g., "62% of the time attending at the positive word") with their initial attention behavior during at the baseline phase (e.g., "42% of the time attending at the positive word at baseline"). This procedure intends to increase awareness of progresses across the training condition compared with baseline. A full visual illustration of the functioning of the standard assessment procedure in the baseline phase, the training procedure in the modification phase and visual block-wise progress feedback procedures can be seen in the video titled "video_MCAT_visual_example.mp4, provided as supplemental material.

In line with prior work (Everaert et al., 2014; Sanchez et al., 2016), the index of attention bias for processing positive vs. negative material was computed by dividing the total time attending on (uncovering) positive words by the total time attending on (uncovering) emotional (positive and negative) words, separately for each training phase (i.e., baseline phase vs. modification phase). These indices served to test the hypothesis that participants would implement attention regulation in the active MCAT condition (i.e., significant increases in attention bias to positive over negative material from the baseline to the modification phase, as observed in previous ECAT studies: Sanchez et al., 2016; Sanchez-Lopez, Everaert et al., 2019). During the completion of the MCAT procedure, eye-tracking was performed in parallel to examine the degree of consistency between the mouse-based pointer location estimations of the time attending to positive and negative words during the reading section (times the mouse cursor was placed over each word to uncover them) and the actual times participants fixated on these word areas, as directly measured with the eye-tracker.

Transfer measures

Attentional Disengagement. A variant of the eye-tracking engagement-disengagement task (Sanchez et al., 2013) was used to separately index processes of attentional disengagement from negative and positive words, before and after receiving MCAT. In this task, each trial starts with the presentation of a blank screen for 500 ms, followed by the display of a central fixation cross. Immediately after the eye-tracker detects that a participant makes a visual fixation of 200 ms in the cross area, two words (positive–negative or neutral–neutral pairs) are simultaneously presented for 1000 ms at either side of fixation (above vs. below fixation). After the free-viewing time is finished, a “wait for fixation” period is introduced, where stimuli presentation does not continue until participants fixate on a given word (pre-specified in each trial) for 100 ms. Once this occurs, a frame consisting of either a square or a circle appears surrounding the opposite word. Participants are then instructed to direct their gaze toward that frame (i.e., disengaging gaze from one word to fixate on the opposite word location) as quickly as possible and press one of two response keys to indicate the frame type.

Forty-eight positive–negative and 24 neutral–neutral word pairs were used. Positive, negative, and neutral words were matched on word length, word class, and word frequency (Duyck, Desmet, Verbeke, & Brysbaert, 2004), all *F's*< 1. The total set of 288 trials (72 word pairs × 2 word locations × 2 frame locations) was divided to create two task versions. Each version contained 144 trials (96 positive-negative trials, 48 neutral-neutral trials) with word and frame location counterbalanced. The two versions served as pre- and post-MCAT procedure measures of attention disengagement indices. Administration of the versions was counterbalanced across participants [1]. Half of the positive-negative trials in each assessment (n= 48) indexed disengagement from negative information: the time to move gaze away from a negative word when prompted to engage with a positive word, whereas the other half of trials (n= 48) indexed disengagement from positive information: the time to move gaze away from a positive word when prompted to engage with a negative word. This allowed to test whether specific trained attention regulation in the MCAT procedure transferred to: a) faster attentional disengagement from negative information when positive information is also available, and/or b) increased attention to (i.e., delayed disengagement from) positive over competing negative information. A further control neutral - neutral words condition (n= 48) was included, where participants had to move their gaze from one neutral to another neutral word to detect the frame. The neutral-to-neutral disengagement index served to control for variance in general disengagement changes in our main analyses on the role of MCAT on changes in emotional disengagement (see Results).

[1] The stimulus set employed and the design of the transfer task were identical to the ones used in the proof-of-concept study validating the original ECAT procedure (Sanchez et al., 2016), with the exception that the former study tested transfer effects on a dot-probe task and the current study used the eye-tracking engagement-disengagement task for this purpose. The similarity between studies allowed us to measure transfer effects on attention bias changes using the exact same stimulus material as in the original ECAT procedure, but being able to differentiate training effects into separate components of disengagement from negative, positive and neutral information, through direct indicators of gaze behavior.

Criteria for identifying valid disengagement patterns were identical to previous research (see Sanchez, Vanderhasselt, et al., 2016). An average of 95.5% trials per participants (95% at pre-training, 96% at post-training) were identified as valid. Internal consistencies for the indices were very good both at pre- and post-training assessments (disengagement from negative to positive: pre-training α= .84, post-training α= .87; from positive to negative: pre-training α= .82, post-training α= .89; from neutral to neutral: pre-training α= .83, post-training α= .86).

Reappraisal. The emotion regulation task employed in Sanchez et al. (2016) and Sanchez-Lopez, Everaert, et al. (2018) was used to assess transfer to reappraisal capacity. This task comprises viewing thirty-two negative IAPS pictures (Lang, Bradley, & Cuthbert, 2008) depicting depression-relevant themes (e.g., crying people, loneliness; further details in Sanchez et al., 2016). In each assessment (i.e., pre- and post-training), half of the pictures are instructed to be appraised and the other half to be reappraised. Pictures and regulatory instructions are randomly presented with the constraint that maximum 2 pictures with the same regulatory instruction occurred consecutively. On each trial, a negative picture is presented and, after 2000 ms, participants have to rate their negative emotional experience on a 10-point scale (0 – 'not at all' to 9 – 'very much'). A cue then prompts participants to appraise (i.e., look at the picture and freely experience the elicited feelings) or reappraise the picture's meaning (i.e., reinterpret the picture's meaning in a less negative way by changing the emotions, actions, and outcomes of individuals depicted in the picture; Ochsner, Bunge, Gross, & Gabrieli, 2002). After 10 s, participants have to rate their negative emotional experience in a 10-point rating scale. When instructed to reappraise, participants also have to provide a written description of how they reappraised the picture.

Participants demonstrated a high level of compliance with the instruction (percentage of reappraisal trials with no written descriptions being provided = 6%, both at pre- and post-training). Pre- and post-training reappraisal ability scores were computed using the narrative descriptions provided by participants. Two blind raters were trained on reappraisal theories and the use of criteria to determine the adjustment of individual narratives to actual forms of scenes' reappraisal (i.e., changing the immediate meaning of given actors' expressions or actions in the scene or the full scenes' representation into more benign representations of the scene or its potential outcome) in each of the scenes. Blind raters evaluated how successful participants were at generating reappraisals of the negative scenes using a 5-point scale (0–No Description, 1–Not at all, 2–A little, 3–Good, 4–Very good). They were instructed on how to use scoring criteria for each type of scene and (to reduce potential biases in scoring) only assigned "4" scores ("very good") in those cases where the reappraisal description fitted with a full reappraisal of the meaning and/or expected consequences of the given scenario. There was a high inter-rater agreement on the codification of reappraisal descriptions (intra-class correlation= .87, p=.001). Therefore, reappraisal ability was indexed through objective scores (i.e., not dependent of own participants' bias on the self-assessment quality of their reappraisals), comprising the average of the blind raters' scores separately for the pre- and post-training procedure. Higher scores indicate better reappraisal.

State Rumination. Immediately after completing the emotion regulation task (both at pre- and post-training), participants rated the extent to which they had ruminated while viewing the negative scenes (i.e., while trying to reappraise scenes in one half of the trials but also passively viewing and appraising the negative contents of scenes in the other half of trials). The rumination measure comprised five 10 cm visual analogue scales (VAS: "I was focusing on my feelings", "I was focusing on my problems", "I was thinking about a recent situation, wishing it had gone better", "I was thinking: why do I have problems other people don't have?", "I was thinking: what am I doing to deserve this?") adapted from Moberly and Watkins (2008) and previously validated (Sanchez-Lopez, Everaert et al., 2018). The rumination items showed good internal consistency both at pre- and post-training: α = .81 and α = .79, respectively.

Eye-tracker

A Tobii TX300 eye-tracker was used to record gaze behavior during the engagement-disengagement and MCAT procedure (gaze position sampling rate at 300 Hz). Participants were seated approximately 60 cm from the eye tracker. Visual fixations were defined as longer than 100 milliseconds (ms). Stimulus presentation and eye movement recording were controlled with E-prime Professional software and E-prime extensions (TET and Clearview PackageCalls).

Results

Sample Characteristics

Table 1 presents descriptives and statitistics regarding differences between the two MCAT groups on demographics and variables assessed at pre-training. The participants in the control versus the active training MCAT condition did not significantly differ in age, gender ratio, depressive symptoms, trait rumination, trait reappraisal or trait stress resilience.

Reliability of Mouse-Based Gaze Tracking Estimations

We first explored the level of gaze/mouse coordination achieved through the mouse-based moving window technique implemented during the *Reading Section* of the MCAT. Visual inspections of the eye-tracking video recordings performed in parallel indicated a high level of coordination between mouse and real gaze positions during the performance of this task, with only slight delays between actual eye saccades to the word locations and subsequent mouse cursor placements over the locations (i.e., eyes fixating slightly earlier on the mask, immediately followed by the mouse cursor being positioned over it to uncover the corresponding word). We specifically wanted to determine the reliability of the mouse-based tracking estimations of the time attending to (reading) the target positive and negative words, in relation to the direct estimations provided by the eye-tracker regarding the actual times participants fixated on these areas. Therefore, we separately computed the times attending to positive and negative words during the MCAT Reading Section, as estimated with either mouse-based tracking (i..e, mouse pointer location) and with direct eye-tracking (i.e., actual gaze location), and modelled the two types of estimates using mixed linear models, nesting the corresponding attention time estimates for each trial within participants, and estimating their contemporaneous relation (i.e., within-individual partial correlation between mouse and eye estimations at each trial, while controlling for random effects by participants). These analyses were performed with the lme4 R package. The level of congruency between attention time estimates using mouse-based tracking and eye-tracking was very high (overall= 0.78: time attending to positive= 0.78, t= 31.28; p< .001; time attending to negative= 0.79, t= 28.69, p< .002), supporting the reliability of the mouse-based tracking procedure to provide with accurate indices of attention processing in our paradigm. Full details of mixed effect models and plots of the resulting effects for the full sample as well as for each subject separately are provided as Supplementary Material.

MCAT Effectiveness to Implement Attention Regulation During Training

Table 2 presents descriptives (mean and standard deviation) of the main variables in the study and summarizes the results regarding the effects of the active MCAT compared to control condition on each of those variables.

A series of 2 (MCAT Condition: Training, Control) x 2 (Phase: Baseline, Modification) mixed measures ANOVAs were performed with the estimations of the time attending to positive over negative words as depedent variable. One ANOVA corresponded to estimations based on mouse-based tracking and a second ANOVA corresponded to direct estimations based on eye-tracking. In both cases, the main effects of Time were accounted by significant MCAT Codition by Time interactions (see Table 2). Regarding the Control condition, follow-up Bonferroni-corrected tests showed that participants did not show any significant change in their times attending to positive over negative words from the Baseline to the Modification phase, neither when estimated with mouse-based tracking, $F(1,39)=1.47$, $p=.23$, $\eta_p^2=.04$, nor when estimated with direct eye-tracking, $F(1,39)=0.21$, $p=.65$, $\eta_p^2=.01$. In contrast, supporting the effectiveness of active MCAT to implement attention regulation, participants in the Active Training condition showed significant increases in their times attending to positive over negative words from the Baseline to the Modification phase, as estimated with both mouse-based tracking, $F(1,39)=26.48$, $p=.001$, $\eta_p^2=.40$, and direct eye-tracking, $F(1,39)=12.31$, $p=.001$, $\eta_p^2=.24$.

MCAT Transfer

A series of 2 (MCAT Condition: Training, Control) x 2 (Time: Pre-, Post-MCAT) mixed measures ANOVAs were performed for each of the transfer measures of the study. These results, together with the mean and standard deviation of each transfer measure at each assessment time, are summarized in Table 2 and discussed into detail below.

Attentional Disengagement Processes. Regarding the control condition of *attentional disengagement from neutral to neutral words*, there was a main effect of Time, indicating that participants in general became faster from pre- to post-MCAT in moving their gaze away from neutral words when prompted to. In order to control in the main analyses for shared variance due to this general practice effect (i.e., general improved disengagement speed from T1 to T2, irrespective of the emotional material being processed), analyses of MCAT transfer to the main dependent variables (disengagement from negative words and disengagement from positive words) were performed controlling for the pre-post changes in the neutral-neutral condition as a covariate. In short, ANCOVAs served to control for shared variance between changes in the actual disengagement indices of interest and changes in the control disengagement condition (i.e., neutral to neutral), allowing us to parcel out specific variability in the target indices (i.e., not due to general executive function improvements through practice, as observed in the neutral-neutral condition) and to test the effects of MCAT conditions on it (for a similar approach parceling out variance of separate gaze disengagement conditions, see Yaroslavsky, Allard, & Sanchez-Lopez, 2018).

As for *attentional disengagement from negative words*, the 2 x 2 ANCOVA showed a main effect of Time. This indicates that both groups became faster to disengage gaze from negative words when prompted to engage with positive words, with this effect not being accounted by a significant MCAT Condition by Time interaction. In contrast, a significant MCAT Condition by Time interaction was supported for *attentional disengagement from positive words*. Bonferroni post-hoc analyses showed that the participants in the Control condition showed a significant decrease in the time to disengage gaze from positive words when prompted to engage with negative words, $F(1,38)=6.06$, $p=.02$, $\eta_p^2=.14$. In contrast, participants in the Active Training condition did not show reductions in the time to disengage gaze from positive to negative words from pre- to post-training, $F(1,38)=0.71$, $p=.40$, $\eta_p^2=.02$. [2]

[2] A series of 2 (MCAT Condition: Training, Control) x 2 (Time: Pre-, Post-MCAT) mixed measures ANOVAs with disengagement from negative and disengagement from positive indices as dependent variables was also performed, producing similar results as the ANCOVAs further controlling for general improvement in the disengagement from neutral to neutral word condition. As for disengagement from negative words, there was a marginally significant effect of Time, $F(1,39)=3.45$, $p=.07$ $\eta_p^2=.08$, showing a general trend across both training conditions to become faster from pre- to post-MCAT assessment in moving gaze away from negative words. This effect was not qualified

Reappraisal. The 2 x 2 ANOVA supported a significant MCAT Condition by Time interaction (see Table 2). Bonferroni post-hoc analyses showed that whereas participants in the Control condition did not show changes in reappraisal, $F(1,39)=0.06$, $p=.81$, $\eta_p^2=.01$, participants in the Active Training condition significantly increased their reappraisal capacity from pre- to post-training, $F(1,39)=8.34$, $p=.006$, $\eta_p^2=.18$.

State Rumination. The 2 x 2 ANOVA supported a main effect of Time, partially accounted by the MCAT Condition by Time interaction (see Table 2). Bonferroni post-hoc analyses showed that participants in the Control and the Active Training conditions both showed significant reductions in state rumination from pre- to post-training, $F(1,39)=6.35$, $p=.02$, $\eta_p^2=.14$, and, $F(1,39)=26.06$, $p=.001$, $\eta_p^2=.40$, respectively. Yet, when compared, analyses showed that the state rumination reductions in the Active Training condition were significantly larger than the ones in the Control condition, $t(39)= 2.24$, $p= .03$.

Further Regression Analyses

Group-level analyses confirmed the effectiveness of MCAT to implement attention regulation and transfer to attentional disengagement from positive information, improved reappraisal and decreased rumination. We then further modelled specific pathways of influence among these different transfer effects at the individual level. More specifically, we used regression analyses to test the predictive role of individual differences in the degree of attention regulation implemented during MCAT (i.e., change scores in times attending to positive over negative words

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by a significant MCAT Condition x Time interaction, $F(1,39)=0.44$, $p=.51$ $\eta_p^2=.01$. As for disengagement from positive words, the main effect of Time did not reach significance, $F(1,39)=1.04$, $p=.31$ $\eta_p^2=.03$. Nonetheless, similar as with the ANCOVA approach, a significant MCAT Condition by Time interaction was obtained, $F(1,39)=6.46$, $p=.01$ $\eta_p^2=.14$, confirming MCAT transfer effects in this component of attentional disengagement. For the sake of the precise determination of MCAT effects in this disengagement component, results from the ANCOVA reported in the manuscript may be more accurate to estimate the specific size of this effect, once common variance due to general practice effects (as measured in the neutral-neutral condition) has been parceled out.

from the baseline to the modification phase) on individual differences in pre-post changes in the transfer measures. This approach allowed us to compare the current results with those ones from previous studies testing ECAT pathways of transfer effects at the individual level (Sanchez et al., 2016; Sanchez-Lopez, Everaert et al., 2019). First, previous ECAT studies have shown that attention regulation implemented during the training predicts larger attention biases to positive over negative information in the post-training transfer attention tasks. Consistently, in the current study, regression analyses showed that higher attention regulation during MCAT (i.e., larger increases in the time attending to positive over negative words from the baseline to the modification phase, as measured with mouse-based tracking) predict subsequent longer times to disengage gaze from positive to negative words following MCAT, $B = 0.42$, $p = .006$. In turn, and in line with previous results from Sanchez-Lopez and colleagues, resulting longer times to disengage gaze from positive to negative words following MCAT predicted larger improvements in reappraisal from pre- to post-training, $B = 0.41$, $p = .008$, but did not significantly predict larger reductions in state rumination, $B = -0.16$, $p = .32$. In contrast, and consistent with Sanchez-Lopez et al. (2018) findings, transfer effects in decreased state rumination from pre- to post-training were directly predicted by higher levels of attention regulation achieved during active MCAT, $B = -0.32$ $p = .04$. In sum, and consistent with previous studies testing ECAT mechanisms of transfer, regression analyses on individual differences in the transfer measures showed that larger MCAT effectiveness (i.e., higher attention regulation during the training) had two pathways of influence: a) one leading to longer times to disengage gaze from positive words, which in turn predicted reappraisal increases; and b) another one leading to larger reductions in rumination (irrespective of changes in positive disengagement and reappraisal).

Discussion

In the present study we tested a new variant of attention contingent training controlled via mouse cursor, MCAT. The new MCAT procedure relied on the exact same principles of action of ECAT, but was adapted to be controlled via mouse cursor contingencies to allow larger online dissemination. Gaze-contingent attention feedback was provided, as similar as in the original ECAT paradigm, but based on the times that the mouse remained over the critical positive and negative words, while using a mouse-based moving window paradigm to uncover and process the relevant emotional material. This procedure was developed based on studies reporting a high degree of coordination between gaze and mouse movements in context of physical pointing computer tasks (e.g., Deng et al., 2016; Helsen, Elliott, Starkes, & Ricker, 1998). The effectiveness of the MCAT variant was then determined by: 1) the degree of coordination between gaze and mouse position measures for the time spent over critical positive vs. negative words during the training, and 2) the similarity of its effects with the original ECAT effects (Sanchez-Lopez, Everaert et al., 2018) in increasing attention regulation across the training and transferring to proximal processes of stress (dys)regulation (i.e., attentional disengagement, reappraisal and state rumination).

A critical feature of the original ECAT intervention is the use of gaze-contingent feedback to implement efficient attention regulation, requiring the use of eye-tracking technology for its measurement. Thus, the alternative way of implementation that we investigated in the present study first required testing the coordination between gaze and mouse cursor movements during the performance of the MCAT intervention variant. Our results confirmed a high degree of convergence between real eye-tracking data and mouse cursor-based tracking data in the estimation of the times attending to positive vs. negative words during the performance of MCAT. This way, we ensured that mouse cursor can be used to provide close approximations of eye movement data in this variant, allowing its future implementation as an eye-tracking based intervention outside from the lab (i.e., not requiring eye-tracking equipment for its application).

Regarding the effectiveness of the MCAT variant, the training resulted in similar benefits as the ones observed with the original ECAT procedure (Sanchez et al., 2016; Sanchez-Lopez, Everaert et al., 2019). First, attention regulation implementation during training via active MCAT was evidenced by increases in the times attending to positive over negative words in the active training group, both as estimated via direct real eye-tracking as well as via our validated mouse-based tracking procedure. Therefore, Hypothesis 1 was supported, demonstrating that the MCAT variant can be used to alter attention processing in the same way as achieved with original ECAT techniques and that mouse-based tracking can be used for reliable attention processing evaluation and intervention.

We then examined MCAT transfer effects to specific attentional disengagement processes from emotional information that have been involved in impaired-stress regulation in emotional disorders (Çek et al., 2016; Sanchez et al., 2013). Supporting Hypothesis 2, analyses showed that active MCAT transferred to higher attention biases toward positive over negative information following training. This is in line with evidence from previous ECAT studies. An initial study testing the original ECAT procedure (Sanchez et al., 2016) demonstrated transfer effects of the intervention on increasing attention biases to positive over negative information, as indexed with a composite measure based on reaction times in the dot-probe task. Sanchez-Lopez, Everaert et al. (2019) implemented the eye-tracking engagement-disengagement task used in this study to disentangle specific transfer effects to the different attention mechanisms trained during ECAT (namely, disengaging attention from negative information and increasing attention toward positive information while viewing competing negative vs. positive stimuli). Using this approach, it was shown that ECAT transferred to longer times to disengage gaze from happy faces when prompted to engage with disgusted faces at post-training. However, no transfer effects in the component of attentional disengagement from disgusted (when prompted to engage with happy) faces was observed. The same set of results was found in the current study testing the MCAT variant: individuals receiving active MCAT maintained longer attention over positive words when they were prompted to disengage from it to engage with negative word counterparts at post-training. In contrast, no transfer effects were observed for the component of disengagement from negative information, where all participants (irrespectively of the training condition) showed faster attentional disengagement from negative words at post-training.

Taken together, results suggest that MCAT (and original ECAT techniques) may specifically facilitate a maintained attentional focus on positive features in the environment when they compete with alternative negative features, which may then have important implications for the way that the processed information is used to regulate emotions. In this sense, further individual-level analyses showed that the extent to which trainees sustained attention toward positive words when prompted to engage with negative counterparts in the engagement-disengagement task, in turn, predict larger improvements in the ability to reappraise negative scenes in the emotion regulation task. This pathway of interplays following MCAT is similar to the one found in previous ECAT studies (i.e., active training → attention regulation implementation → maintained attention on positive when prompted to engage with negative information → improved reappraisal; Sanchez et al., 2016; Sanchez-Lopez, Everaert et al., 2019), and it is in line with previous research showing that maximizing attention toward positive information is predictive of more adaptive regulation of transient stress states (Taylor, Bomyea, & Amir, 2011; Sanchez et al., 2014). Interestingly, across these different studies, the mediating role of maintained attention on positive over negative information to account for training effects in reappraisal has been shown for different forms of emotional contents (either self-referent material or socially relevant facial expressions). This highlights the potential of our approach to target transdiagnostic attentional mechanisms of emotion regulation, making this approach particularly promising to explore future clinical applications as an add-on for treatments for different types of emotional dysfunctions.

Our main group-level analyses also confirmed the hypothesis that MCAT would transfer to an improved use of reappraisal while viewing negative scenes (Hypothesis 3). Reappraising the meaning of emotion-eliciting events to decrease their negative impact is a fundamental regulatory process, integral to both stress resilience and vulnerability to emotional disorders (Gross, 2014). Reappraisal is effective at increasing positive and decreasing negative emotions (Augustine & Hemenover, 2009; Webb, Miles, & Sheeran, 2012) and is associated with better interpersonal functioning (Gross & John, 2003) and enhanced stress recovery (Jamieson, Nock, & Mendes, 2012). In contrast, failures to use reappraisal are largely documented in clinical populations (e.g., Aldao, Nolen-Hoeksema, & Schweizer, 2010; Johnstone, van Reekum, Urry, Kalin, & Davidson, 2007). Overall, our findings support the role of MCAT to promote an efficient use of this strategy, through the training attentional mechanisms that are on the basis of its efficient implementation (Joormann & D’Avanzato, 2010; Sheppes, Suri, & Gross, 2015).

Finally, we also found support for the prediction that MCAT would result in a reduction of repetitive negative thinking (i.e., state rumination) while viewing negative scenes (Hypothesis 4). Group-level analyses showed that, although both groups reduced their levels of state rumination from pre- to post-training, that reduction was significantly larger in the active MCAT group. Engaging with repetitive negative thinking is considered a maladaptive regulatory process, since it augments negative mood in response to stressful events (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008), and its habitual use is a strong predictor of emotional disorders’ onset and maintenance (Ruscio et al., 2016). The evidence that MCAT reduces state rumination is therefore very promising and opens the possibility to use this intervention not only to promote more adaptive emotion regulation strategies (i.e., reappraisal), but also to preclude from engaging with repetitive negative thinking, further reducing stress-related symptoms (i.e., maintained negative affect in both depression and anxiety disorders, Ehring & Watkins, 2008). Interestingly, individual-level analyses showed that larger rumination reductions were related to higher levels of attention regulation during MCAT but, different to reappraisal improvements, rumination change was not related to the MCAT transfer effects in external attention processes (maintained attention to positive over negative words in the engagement-disengagement task).

The above findings replicate the different pathways of transfer effects to reappraisal and rumination found in previous ECAT studies (Sanchez-Lopez, Everaert et al., 2019), indicating that there may be different mechanisms of action of this type of training. Different to standard ABM approaches (dot-probe based attention training) that typically present pairs of competing words or pictures and merely use probe replacements to try to modify attention through repetition, the MCAT procedure provides trainees with more complex contexts (i.e., scrambled sentences), instructions, and feedback to help them to activate and construct relevant positive meanings in a self-referent manner. Importantly, an efficient activation of positive self-views about oneself, the word and the future, as trained in our approach, has been shown to reflect an important mechanism of stress resilience, which mediates the association between higher trait resilience levels and healthier psychological adjustment (i.e., lower depression and higher well-being; Mak, Ng, & Wong, 2011). Furthermore, the efficient construction of adaptive self-relevant sentences in our training is performed through individualized feedback on trainees' attention allocation performance during the training. This intends to help trainees to improve external attention regulation according to an explicitly instructed pattern (i.e., intentionally (re)direct attention to positive over negative information to form positive self-referent sentences). To the extent that attention regulation is effectively implemented and that there is transfer to other external attentional processes typically impaired in emotional disorders (engagement-disengagement task; Sanchez et al., 2013), this may transfer to emotion regulation capacities. Specifically, such external attention regulation improvement may facilitate the detection of alternative emotional information in the environment during the confrontation of negative contexts, facilitating the effective use of reappraisal (Strauss, Ossenfort, & Whearty, 2016), as shown by our results. Furthermore, is it plausible that through MCAT, not only external but also internal attention processes are being targeted. Internal attention refers to the selection, modulation, and maintenance of internally generated information, with a high dependence on external attention processes subserving it (Chun, Golomb, & Turk-Browne, 2010). Attention-contingent feedback in MCAT is intended to not merely train attention allocation toward external emotional information, but also attention to alternative internal representations resulting from such external processing. Regulating attention toward specific external emotional features (e.g., “bright” vs. “dismal”) in our paradigm may subserve a second-order attention process of access and activation of specific internal representations in working memory (e.g., “the future looks very bright” vs. “the future looks very dismal”). Therefore, the extent to which individuals benefit from MCAT in regulating external attention should also be related to the way that individuals are able to activate and maintain specific internal representations (e.g., “the future looks very bright”) while inhibiting alternative ones (e.g., “the future looks very dismal”). Importantly, these internal attention mechanisms are thought to be causally involved in the use of maladaptive repetitive negative thinking (Joormann, 2006; Joormann & Gotlib, 2008), which may help to account for the direct MCAT effects on state rumination observed in our study (i.e., independent from transfer effects on external attention operations). These potential pathways to beneficial effects of MCAT clearly deserve further scrutiny.

Despite the support for the validity of the MCAT procedure and its effectiveness, there are some limitations that must be acknowledged. First, this study and the previous ones validating the original ECAT have been conducted in nonclinical samples, which limits the generalizability of our findings to at-risk and clinical populations. For instance, this may have limited our ability to detect MCAT transfer effects in other attention mechanisms (attentional disengagement from negative information) that are known to be impaired and play an important role in emotion dysregulation in both anxious and depressed populations (Schofield, Johnson, Inhoff, & Coles, 2012; Sanchez et al., 2013). Nonetheless, this was intended to be a proof-of-concept study for a potential new MCAT variant of the original ECAT approach, and a single session with a convenience sample was considered adequate to test the hypothesized causal mechanisms resulting from MCAT on attention performance and emotion regulation processes. Overall, the large body of transfer effects resulting from MCAT suggest that at-risk and clinical populations characterized by stress-related impairments in cognitive control, attention biases and emotion dysregulation might considerably benefit from this sort of intervention. Future research, however, needs to address this open question through multi-session applications of the MCAT procedure. The use of a single-session of MCAT is another important limitation, since such approach is unlikely to have long-term impact on stress-pathogenic processes and may limit our ability to explore potential transfer effects of the training to anxiety and depression. Extended multi-session variants of MCAT will therefore be necessary to examine the endurance of the training transfer effects in attention and stress regulation, as well as to determine its effectiveness to: 1) promote stress resilience in at-risk individuals and 2) reduce symptom severity in disordered populations. Finally, although the predictive role of attention regulation on transfer outcomes (i.e., reappraisal improvements, state rumination reductions) has been supported and replicated in this study and the original ECAT studies, the specific attention regulation mechanisms being targeted by the training remain to be clarified. Attention regulation involves both stimulus-driven bottom-up factors as well as voluntary top-down strategies. Our procedure comprises specific instructions to the participants (i.e., unscramble positive sentences), which taps into these latter aspects of attention regulation. Yet, manipulating the on-line low-level features of specific stimuli during reading (via online gaze-contingent visual feedback) might also be related the more automatic stimulus-driven aspects of control. These two distinct influences may to some extent complicate the precise interpretation of attention regulation improvements achieved following active MCAT. For instance, the influence of top-down control could target explicit emotional biases whereas online gaze-contingent feedback might affect more implicit biases, with different roles of each in different emotion regulation capacities. Further research is needed to isolate each of the manipulations including explicit instructions – but see previous findings from Sanchez et al. (2015) -, online gaze-contingent feedback, and block wise visualizations of attention change and progress, to disentangle each mechanism being targeted, as well as its contribution to the different emotion regulation outcomes.

Overall, the MCAT variant validated in the current study represents a crucial initial step to achieve this goal. First, the reliability of the mouse-based tracking attention estimations in the new paradigm, in relation to their convergence with actual eye-tracking estimations, supports MCAT as a reliable way to monitor and train attention, no longer requiring eye-tracking equipment for its application. This implies that fine-grained eye-tracking based training techniques with a demonstrated role in the modification of proximal processes of stress (dys)regulation (i.e., reappraisal and state rumination) can now be used as regular computerized interventions. This represents an important step to achieve large-scale implementation of original ECAT procedures, making possible the use of multi-session interventions of personalized MCAT. Second, MCAT is designed to serve as a performance-based cognitive training, where feedback and training are personalized in several regards, including the use of baseline attention evaluation to individualize the training regime and the use of detailed visual feedback to monitor individual training progress, with potential to maximize training effects, as compared to other ABM approaches (for further discussion, see Koster & Bernstein, 2015). Third, the ability to implement such a procedure online opens the possibility to personalize training regimes also in terms of individuals' needs during their daily functioning (e.g., specific training delivery before anticipated stressful events, or during or following events with a negative impact). Overall, all these features indicate that MCAT may be a promising tool to target and train stress resilience mechanisms in at-risk populations, and open the possibility that might show utility as a transdiagnostic add-on approach to strengthen effects of existing treatments for stress-related dysfunctions.

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Table 1. *Descriptive statistics for the pre-training measures in the study.*

	Training (N=20)		*Control (N=21)*		
Variables	*M*	*SD*	*M*	*SD*	Group differences
Demographics					
Gender (male/female)	7/13		9/12		$\chi^2(1)$= -0.27, *p*=.61 *d*= .16
Age	22.10	2.49	22.33	2.78	*t*(39)= -0.28, *p*=.78, *d*= .09
Baseline self-report measures					
Depressive symptoms (BDI-II: 0-63)	7.00	6.57	6.86	6.80	*t*(39)= 0.07, *p*=.95, *d*= .02
Trait Rumination (RRS: 22-88)	34.55	10.71	32.57	8.45	*t*(39)= 0.66, *p*=.51, *d*= .21
Trait Reappraisal (ERQ: 6-42)	28.30	4.40	26.90	4.71	*t*(39)= 0.98, *p*=.33, *d*= .30
Trait Resilience (RS: 25-100)	79.50	8.97	81.19	7.16	*t*(39)= -0.67, *p*=.51, *d*= .21

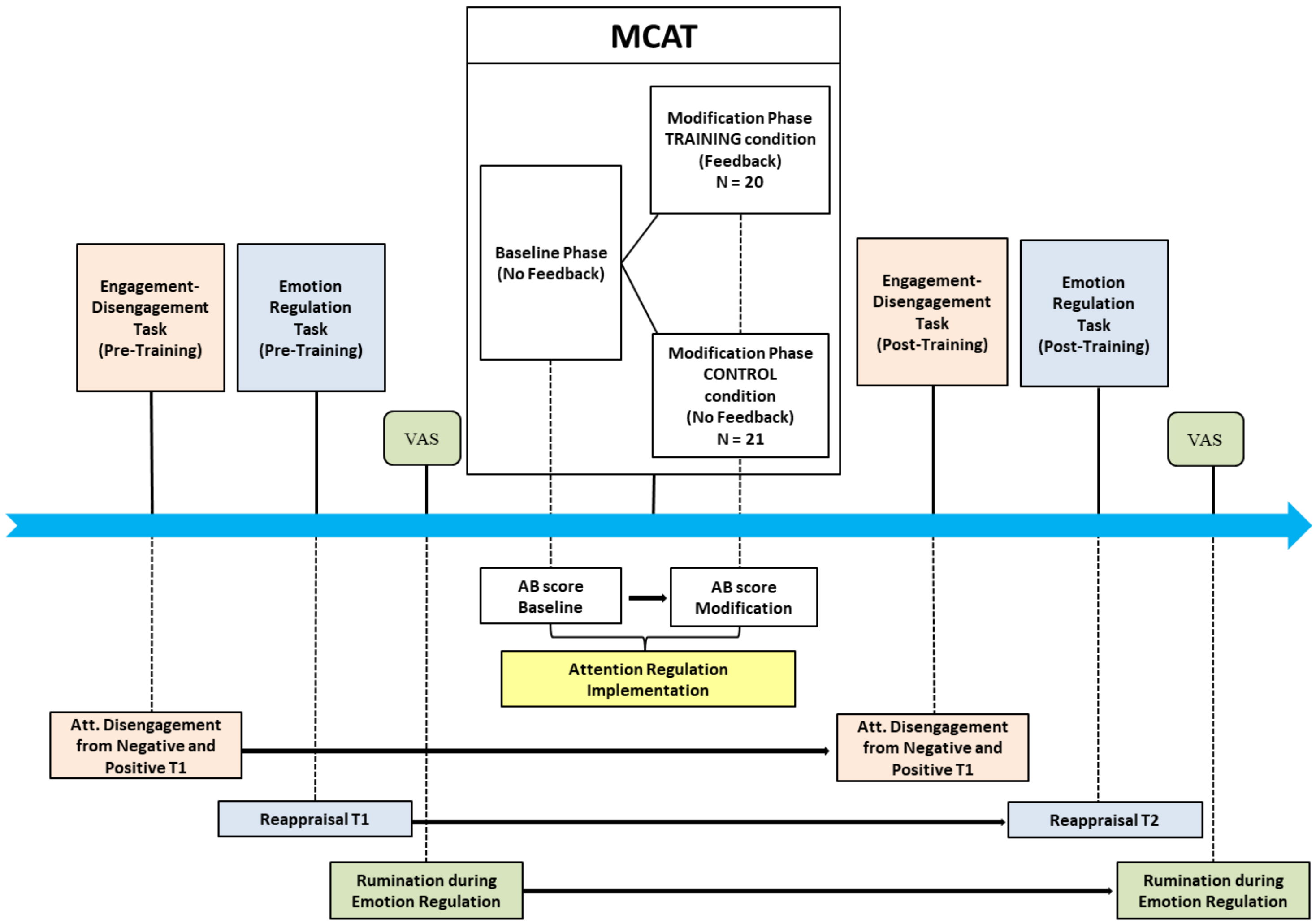
Notes. M = Mean; SD = Standard deviation; d = Cohen's d effect size

Table 2. *Descriptive statistics and group differences on the main variables in the study*

Variables	***Training (N=20)*** *M (SD)*	*M (SD)*	***Control (N=21)*** *M (SD)*	*M (SD)*	Main Time Effect	MCAT x Time Interaction
Attention Regulation during MCAT	**Baseline Phase**	**Modif. Phase**	**Baseline Phase**	**Modif. Phase**		
Mouse-Tracking Estimation: Time fixating on positive over negative words (prop)	0.51 (0.03)	0.58 (0.07)	0.52 (0.02)	0.50 (0.02)	F(1,39)=6.02, p=.02 η_p^2=.13	F(1,39)=26.56, p=.001, η_p^2=.41
Eye-Tracking Estimation: Time fixating on positive over negative words (prop)	0.50 (0.03)	0.56 (0.06)	0.51 (0.03)	0.51 (0.03)	F(1,39)=6.56, p=.01, η_p^2=.14	F(1,39)=10.84, p=.003, η_p^2=.21
Training transfer indices	**Pre-MCAT**	**Post-MCAT**	**Pre-MCAT**	**Post-MCAT**		
Gaze disengagement from neutral to neutral (ms)	291 (46)	282 (46)	288 (44)	271 (46)	F(1,39)=6.45, p=.01, η_p^2=.14	F(1,39)=0.66, p=.42, η_p^2=.02
[a] Gaze disengagement from negative to positive (ms)	303 (50)	296 (57)	286 (43)	271 (42)	F(1,39)=4.82, p=.03, η_p^2=.11	F(1,39)=0.06, p=.81, η_p^2=.01
[a] Gaze disengagement from positive to negative (ms)	289 (51)	295 (53)	284 (47)	268 (53)	F(1,39)=1.45, p=.24, η_p^2=.03	F(1,39)=5.33, p=.03, η_p^2=.12
Reappraisal (average blind raters' coding; range 0-4)	2.43 (0.60)	2.73 (0.55)	2.42 (0.63)	2.40 (0.69)	F(1,39)=3.61, p=.06, η_p^2=.08	F(1,39)=4.98, p=.03, η_p^2=.11
State Rumination (self-reported; range 1-50)	11.05 (7.76)	6.70 (6.54)	12.38 (7.19)	10.29 (7.46)	F(1,39)=29.30, p=.01, η_p^2=.43	F(1,39)=3.59, p=.05, η_p^2=.09

Notes. M= Mean; SD= Standard deviation; ms= milliseconds; prop= proportion; MCAT= Mouse-based contingent attention training; Modif.= modification phase
[a] Analyses controlling covariance due to general speed changes in the times to move gaze away from neutral to neutral words

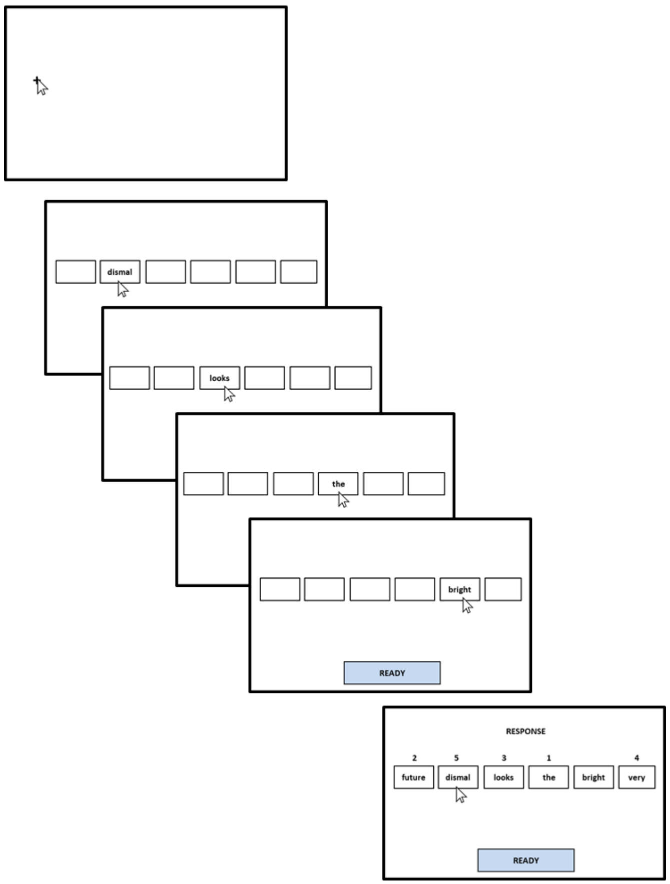
Figure 1. Schematic on the task sequence during the experimental session, and overview of indices computed in each task



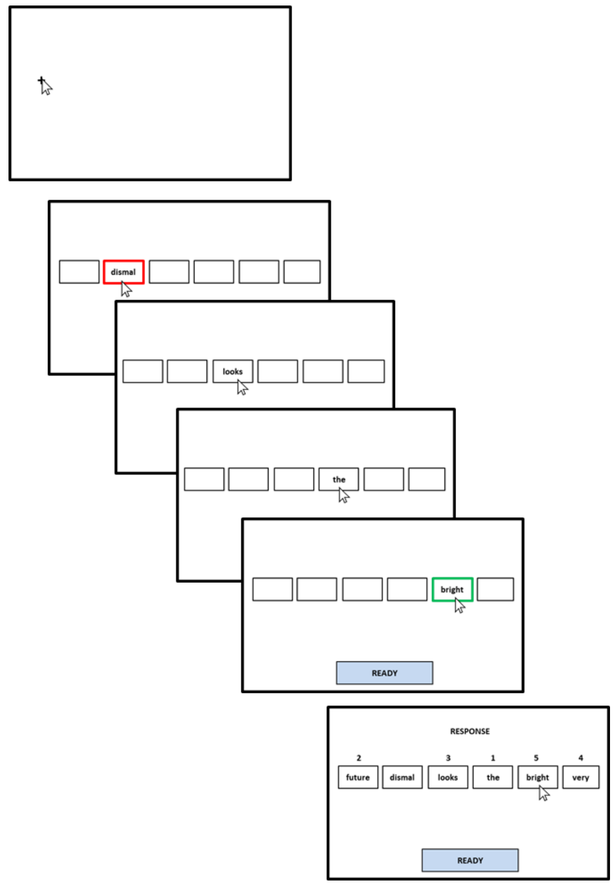
Notes. MCAT = Mouse contingent attention training; AB = Attention bias; T1 = Time 1 (pre-training); T2 = Time 2 (post-training), VAS = Visual analogue scale

Figure 2. Schematic of MCAT procedure

Baseline Phase
(Instruction: Unscramble the sentence to form the first grammatically statement that comes to your mind)



Modification Phase
(Instruction: Unscramble the sentence into a positive self-statement, using the online to maximize your attention to positive over negative words)



Fixation Cross:
To elicit natural left-to-right reading at the beginning of the trial
Duration: until participant clicks on the cross area

Reading Section:
All words are masked until participant places the mouse cursor over them. Only one word is visible at each time (controlled via mouse cursor). The system computes the time that positive and negative words are attended (unmasked).
Duration: until participant clicks on Ready to start providing the selected 5-word solution, or after 14 sec limit

Response Section:
Participant click over the 5 corresponding words and appropriate order to provide the solution.
Duration: until participant clicks on Ready, or after 7 sec limit