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Focus Article

Disentangling the mediating role of modifying interpretation bias on emotional distress using a novel cognitive bias modification program

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ABSTRACT

Background: Negative interpretation bias is a potential risk factor for emotional disorders. In this study, we tested a clinically inspired 4-session online Cognitive Bias Modification-Interpretation (CBM-I_{Clin}) program to modify negative interpretation biases.

Methods: We randomized one hundred and twenty-one volunteer young adults (Mean age = 21.6 years, SD = 3.5; 85 % women) with varying levels of emotional distress to either an experimental or waitlist control group. Mediation analyses were used to disentangle the associations between the intervention, changes in interpretation biases (assessed by both a self-report and an experimental task), and changes in measures of cognitive vulnerability and symptoms of depression and anxiety.

Results: The results showed that the CBM-I_{Clin} could change negative interpretation biases. Also, it had a direct effect on the change in negative memory bias, an indirect effect on the change in depression symptoms via the change in interpretation bias, and both direct and indirect effects on the change in self-reported dysfunctional attitudes.

Limitations: The study included a non-clinical sample of participants and it did not control for some potential confounding factors (e.g., attentional disorders). Furthermore, participants' engagement during the sessions at home was not supervised.

Conclusions: The CBM-I_{Clin} is a potential tool to prevent and intervene in emotional disorders in young adults and could complement other traditional CBM procedures or clinical interventions.

1. Introduction

Classical cognitive models of emotional disorders (Beck, 1967; Clark & Beck, 1988) consider that negative biases could be vulnerability elements that trigger the full development of symptoms. The association between depression, and anxiety and negative modes of processing information has been supported by meta-analytic evidence (Everaert, Podina, & Koster, 2017; Nieto, Robles, & Vazquez, 2020). The role of these biases as vulnerability factors has been shown in empirical studies where at-risk participants (e.g. children of depressed parents) present with higher levels of negative interpretation, attention, and memory biases than those at low risk (Platt, Waters, Schulte-Koerne, Engelmann, & Salemink, 2017; Sfärlea et al., 2020).

Although there are several treatments available for depression and anxiety, they are not universally effective, and relapse rates remain high upon recovery (Cuijpers, Karyotaki, Reijnders, & Huibers, 2018; Cuijpers, Stringaris, & Wolpert, 2020). A specific therapeutic and preventive target to improve treatment outcomes could be the direct modification of cognitive biases. Along that line, Cognitive Bias Modification (CBM) programs were developed to promote adaptive changes in cognitive biases through the repetition of trials containing positive or neutral information. The key idea behind these procedures is that the automatic processing of information can be changed (Fodor et al., 2020). Meta-analytic studies have shown that CBM has small to moderate efficacy in changing cognitive biases and symptoms (Cristea, Kok, & Cuijpers, 2015; Cristea, Huibers et al., 2015), making them suitable candidates to enhance the results found in other therapies. For example, attention bias modification may benefit youth who do not respond to cognitive-behavioural therapy (Pettit et al., 2020), and interpretation bias training has shown positive effects on adolescents' interpretation

Abbreviations: CBM, Cognitive Bias Modification; CBM-I_{Clin}, clinically inspired Cognitive Bias Modification for Interpretation; AST-D-II, Ambiguous Scenarios Test for Depression II; MCAT, Mouse-based (gaze) Contingent Attention Task; MBT, Memory Bias Task; ITT, intention-to-treat.

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processes and mood (Lothmann, Holmes, Chan, & Lau, 2011). Given the theoretical basis of the relationship between emotional disorders and cognitive biases, it is necessary to use statistical procedures that aim to approach causality and a mediated relationship can be considered an intrinsically causal relationship (Hayes, 2018). By using this approach, previous CBM studies have shown the mediational effect of change in cognitive biases (e.g., attention bias in Heeren, Reese, McNally, & Philippot, 2012) over selected outcomes (i.e., change in physiological reactivity). While pre-treatment levels of cognitive biases may moderate treatment effectiveness, change in cognitive bias is usually hypothesized to mediate this relationship (e.g. Kuckertz et al., 2014). However, little is known about the mediators and moderators of change (Jones & Sharpe, 2017), and methodological and design recommendations to test mediator variables are not followed consistently, making it difficult to derive clear conclusions (Lemmens, Müller, Arntz, & Huibers, 2016).

Given the need to enhance intervention procedures for depression and anxiety and the potential causal role of negative cognitive bias, it seems necessary to develop novel procedures to change biases not only in contexts of full-blown emotional disorders but also in prevention programs. Until now, only a few CBM procedures have used a preventive approach. The COgnitive bias modification to Prevent dEpression (COPE) trial (Basanovic et al., 2019) was a year-long randomized controlled trial of an online CBM program for participants reporting mild-to-moderate symptoms of depression at baseline. The authors did not find a reduction in the incidence of clinical symptoms of depression which could be explained by the lack of significant changes in attention and interpretation biases, given that CBM procedures are designed to reduce negative cognitive biases as a mechanism to improve symptoms (Clarke, Notebaert, & MacLeod, 2014). In fact, research has shown that changes in interpretation biases mediate the changes in anxiety symptoms (Salemink, van den Hout, & Kindt, 2010). Another approach to prevention has been used at discharge for patients who may need booster sessions to avoid relapse (Beard, Ramadurai, McHugh, Pollak, & Björgvinsson, 2021). The authors developed a smartphone app for people with acute mental health symptoms of different diagnoses that aimed to treat negative biases in interpretation processes of ambiguous information. Although preliminary, the results showed that both interpretation bias and emotional symptoms could be improved by this type of intervention.

We designed the present study, first, to provide a new intervention, based on clinical cognitive models (Beck, 1967; Clark & Beck, 1988), to change the negative interpretation biases that typically accompany depression and anxiety. The 'Relearning how to think' program was created as a clinically inspired Cognitive Bias Modification-Interpretation (CBM-I_{Clin}) program aiming to target elaborative processing of information [see a full description in Nieto & Vázquez, 2021]. Given the high comorbidity rates between depression and anxiety (Kalin, 2020), the CBM-I_{Clin} has the added value of a transdiagnostic perspective by including contents relevant for both disorders. The program was applied to university students, a population that, given all the challenges associated with the academic pressures and changes in lifestyles, are particularly vulnerable to developing emotional disorders (Eisenberg, Golberstein, & Hunt, 2009). Therefore, the impact of the CBM-I_{Clin} program was evaluated in young adults compared to a waitlist control group, following the procedures recommended for novel interventions (Gold et al., 2017). Our main hypothesis was that the CBM-I_{Clin} program would significantly reduce levels of negative interpretation biases (as measured with both self-report and experimental task), from baseline to post-intervention, in the experimental group, whereas the control group would show no significant changes.

Second, given the theoretical and empirical link between cognitive bias and emotional disorders, mediation models were used to explore the potential causal role of negative interpretation bias on symptoms of depression, stress, and anxiety, as well as levels of dysfunctional attitudes, and well-being. We expected that the effect of the online program (i.e., the change in negative interpretation bias) would mediate the change in these variables. Finally, we expected that the change in negative interpretation bias, given by the intervention, would mediate the change in other outcome variables. These outcome variables include negative attention and memory biases, and rumination and were selected based on previous evidence of the interaction between processing biases, emotional disorders, and emotion regulation (Sanchez-Lopez, Everaert, Van Put, De Raedt, & Koster, 2019; Everaert, Grahek et al., 2017; Sanchez-Lopez, Duque, Romero, & Vazquez, 2017).

2. Method

2.1. Participants and recruitment

The sample was 121 volunteer young adults (M_{age} = 21.6 years, SD = 3.5; 85 % women). Participants were recruited by offering them a free online program, which was publicly announced as a procedure to 'learn how to control the influence of thoughts on emotional reactions.' Exclusion criteria were visual and/or auditory disabilities that could make participants unable to follow the online program, and lack of Internet access at home. Participants were given the opportunity to obtain course academic credits in exchange for their participation as framed within an official university program.

Following G*Power calculations, the minimum sample size (α set at 0.05, power at 0.95) to find a difference in interpretation bias before and after a CBM intervention (Repeated Measures ANOVA), and based on an effect size of d = .43 (Menne-Lothmann et al., 2014), was 73 participants. Based on expected attrition found in similar studies (e.g., Crutzen, Viechtbauer, Spigt, & Kotz, 2015), we planned to recruit twenty percent more participants. CONSORT 2010 Flow Diagram is shown in Fig. 1. The study was approved by the university school of psychology Ethics Committee (Ref. 2018/2019-017) and all participants provided informed consent before participation. To ensure anonymity, we coded their names with numbers.

2.2. The 'Relearning how to think' program

The CBM-I_{Clin} program aimed to reduce negative interpretation biases associated with emotional disorders, based on classical descriptions (Beck, 1976; Burns & Beck, 1999), such as dichotomous thinking, or overgeneralization. The program comprises four sessions combining psychoeducation, video examples, open-ended questions, and cognitive restructuring training exercises aiming to enhance elaborative processing of information (Nieto & Vazquez, 2021). The rationale behind this program was that teaching participants the meaning and consequences of negative cognitive biases could increase the awareness of their cognitive processes and, then, help them change possible maladaptive biases by training conscious processing with techniques similar to those used in the clinical field (Vittengl, Clark, Dunn, & Jarrett, 2007). Fig. 2 shows the organization of each session of the program.

2.3. Measures

a) Current and past episodes of depression and anxiety

Patient Health Questionnaire-9. The PHQ-9 (Spitzer, Kroenke, Williams, & Group, 1999) is a 9-item self-report questionnaire to assess episodes of depression based on DSM-IV (American Psychiatric Association, 1994) diagnostic criteria. The questionnaire showed good internal reliability in our sample (α = .82). An adapted PHQ-9 was also used to measure past episodes of depression by asking participants to complete it if 'they ever had a 2-week period, or longer, (different from the previous two weeks) when they: felt sad, depressed or empty, or lost interest for most of the things in life.' Both versions were used to assess participants' pre-intervention depression levels. The internal reliability

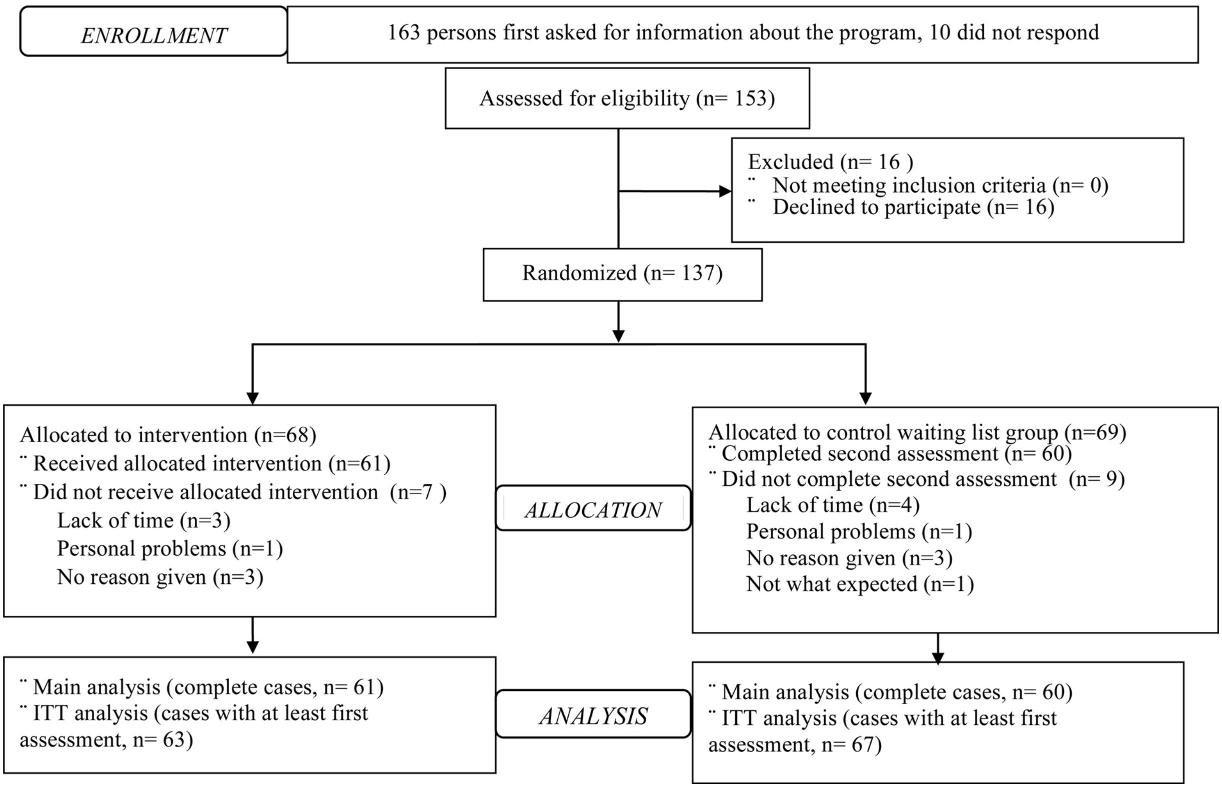

Fig. 1. CONSORT 2010 Flow Diagram.

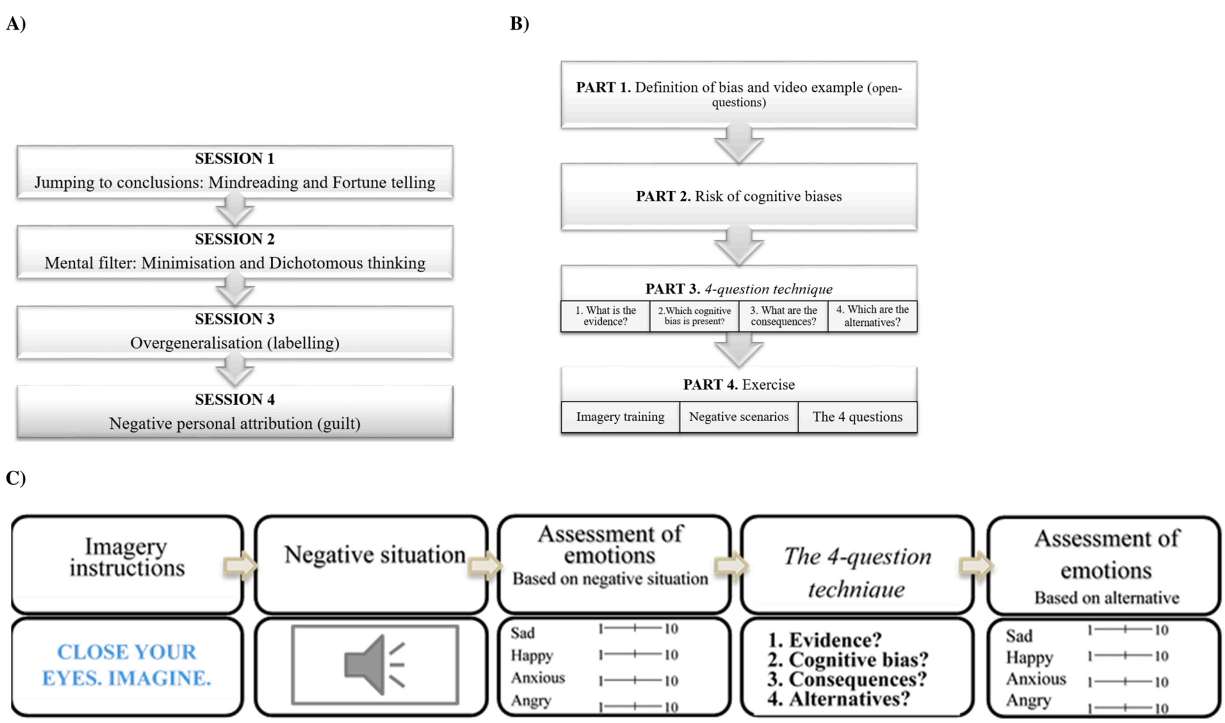

Fig. 2. Structure of the online intervention: A) classification of the specific cognitive biases targeted in the four online sessions based on cognitive models (Beck, 1976; Burns & Beck, 1999), the Cognitive Error Rating Scales (CERS; Drapeau, Perry, Dunkley, & Blake, 2010), and the CBM-errors (Lester, Mathews, Davison, Burgess, & Yiend, 2011) B) the four parts in which each session was divided: psychoeducation with definitions and examples of each type of cognitive bias with open-questions to increase participants' engagement, psychoeducation about the negative effects of these negative automatic interpretations, explanation of the 4-question technique, and practice exercise in which participants apply the 4-question technique to 5 negative scenarios in audio format. This technique involves four steps to re-evaluate the negative interpretation of a given situation: 1) finding evidence for negative thoughts, 2) detecting potential cognitive biases, 3) identifying negative consequences of holding those biases, and 4) creating alternative adaptive ways of thinking.

observed in our sample for this adaptation was α = .85.

Generalized Anxiety Disorder-7. The GAD-7 (Spitzer, Kroenke, Williams, & Löwe, 2006) is a 7-item self-report questionnaire that assesses episodes of anxiety according to the DSM-IV (American Psychiatric Association, 1994) diagnostic criteria. The internal reliability of the scale in our sample was α = .89. An adapted version of this questionnaire was also used to measure past episodes of anxiety by asking participants to complete it if 'they ever had a six-month period, or longer, when they: felt nervous, anxious, or agitated, or could not control their worry.' Both versions were used to assess participants' pre-intervention anxiety levels. The internal reliability found in our sample for this adaptation was α = .66.

b) Credibility and quality of the intervention

Credibility and Expectancy Questionnaire. The CEQ (Devilly & Borkovec, 2000) is a 6-item measure used to assess participants' expectancy and rationale credibility of an intervention. The items were completed by participants at baseline and the internal reliability of the scale in our sample was α = .64.

The Working Alliance Inventory for Internet interventions. The WAI-I (Gómez Penedo et al., 2019) is a self-report measure of the alliance in internet interventions. In this study, only the 8-item subscale of 'task and goal agreement with the program' was used to measure the level of concordance of the program with participants' interests. We assessed this variable only in the experimental group after the intervention. Cronbach's α in our sample for this subscale was good (α = .83).

c) Self-report cognitive bias measures

Ambiguous Scenarios Test for Depression-II. The AST-D-II (Rohrbacher & Reinecke, 2014) is a self-report measure of interpretation bias that was used both at pre- and post-intervention. It comprises 15 ambiguous scenarios which must be rated on a scale from -5 (Very unpleasant) to 5 (Very pleasant), with higher scores indicating more positive interpretations. Participants were asked to imagine each scenario as vividly as possible and happening to them (e.g. *As you enter the room, the commission welcomes you and begins with the oral examination. After just a few minutes, you know intuitively how the examination will go*.). For the current study, the internal consistency of the scale was good (α = .80).

d) Experimental cognitive bias tasks

Attentional and interpretation bias task. The Mouse-based (gaze) Contingent Attention Task (MCAT; (Sanchez-Lopez, De Raedt, van Put, & Koster, 2019) was used both at pre- and post-intervention to measure interpretation bias ($MCAT_{Int}$) while monitoring attention towards emotional stimuli ($MCAT_{Att}$). At the beginning of the task, participants were instructed to click a fixation cross on the left side of the computer screen to facilitate natural left-to-right standard reading patterns. Then, the *reading screen* was presented with an emotional scrambled sentence (e.g., "am winner born loser a I") consisting of 6 words, all hidden with a blank mask. Participants had to move the mouse cursor over each mask to read the word hidden so that the time spent reading each word (duration in milliseconds) was recorded. When the mouse was pointed to the next blank space, an extra word was revealed while the previous one was hidden again. Participants were instructed to mentally form a grammatically correct sentence using only five words with a time limit of 14 s per sentence. Then, the *answer screen* was presented with the six words unmasked for participants to click, in 7 s, the words in the sentence's order they had mentally formed. The task consisted of 4 practice trials and 20 actual trials divided into two blocks of 10. Participants were given the possibility to rest for some minutes between blocks. At the beginning of the task, participants were asked to memorize a 6-digit number (presented on the screen for 5 s) and keep that number in mind during the entire task to maximize the appearance of biases by increasing the cognitive load. We calculated two ratios in this procedure. First, we calculated the number of correctly unscrambled negative sentences divided by the total number of correctly unscrambled positive and negative sentences as an index of automatic negative interpretation bias. Second, we calculated time spent (in ms) reading negative words on the *reading screen* divided by the total time spent (ms) reading positive and negative words as the index of overall negative attentional bias. In both cases, higher scores represented more negative cognitive biases. The split-half reliability was 0.95 for the index of overall negative attentional bias, and 0.87 for the index of automatic negative interpretation bias.

Memory Bias Task (MBT). As a measure of memory bias, participants were given 5 min to freely remember the sentences they had constructed during the MCAT procedure (both at pre- and post-intervention). We coded memories as positive or negative based on the valence of the recalled items. To avoid the inclusion of false memories, memories that did not match the content of the original task items were not coded. The ratio between negative sentences and the total number of emotional sentences recalled was used as an index of negative memory bias.

e) Outcome measures

Depression, Anxiety and Stress Scale-21. The DASS-21 (Lovibond & Lovibond, 1995) is a 21-item self-report questionnaire used to measure symptoms of depression, stress, and anxiety both at pre- and post-intervention. Each of the three subscales contains 7 items and provides a different score for each construct. In the current study, the internal reliability for each subscale was α = .89, α = .82, and α = .74, respectively.

Dysfunctional Attitudes Scale. The DAS (Weissman & Beck, 1978) is an instrument of 40 sentences reflecting dysfunctional cognitive schemas mainly related to themes of dependency (e.g., 'If others dislike you, you cannot be happy'), self-control (e.g., 'Taking even a small risk is foolish because the loss is likely to be a disaster'), or achievement (e.g., 'I should be upset if I make a mistake'), which are common in depression and anxiety (Kush, 2004). It was administered to participants both at pre- and post-intervention. In our sample, the scale showed good internal reliability (α = .79).

Ruminative Responses Scale. The RRS (Nolen-Hoeksema & Morrow, 1991) includes two subscales measuring a ruminative cognitive style. In the current study, we used only the 5-item brooding subscale both at pre- and post-intervention. The internal reliability for the scale was α = .72 in our sample.

Pemberton Happiness Index. The PHI (Hervas & Vazquez, 2013) is an 11-item self-report questionnaire measuring general, eudemonic, hedonic, and social well-being. It was administered to participants both at pre- and post-intervention. It showed good reliability in the present study (α = .82).

2.4. Procedure

First, we randomly assigned participants to the experimental group ($CBM\text{-}I_{Clin}$) or the waiting list control group, using an Excel macro. Then, the day before their first visit to the lab, we sent participants, via e-mail, a brief information document about the 'Relearning how think' program together with a Qualtrics link to fill out the baseline questionnaires (i.e., PHQ-9, GAD-7, CEQ, AST-D-II, DASS-21, DAS, RRS, PHI). During their first visit, we explained to participants the rationale of the intervention and then signed the consent form and completed the experimental tasks measuring cognitive biases (MCAT and MBT). At the end of the first visit, the experimental group received the link via email to start the $CBM\text{-}I_{Clin}$. We re-invited participants in both groups for a second assessment approximately 10 days later. Further descriptions of the procedure are detailed in the Supplementary file.

This study was pre-registered in Clinicaltrials.gov (NCT03987477) and PsyArXiv (doi:10.31234/osf.io/auhm6).

2.5. Data analysis

First, baseline group differences were analysed with ANOVAs for continuous variables and chi-square tests for nominal variables. Also, we conducted a series of 2 (Group: experimental vs. control) x 2 (Time: pre-intervention vs. post- intervention) repeated measures ANOVAs[1] to test significant pre-post intervention differences.

Following Preacher and Hayes (2004), simple mediation models were used to determine the degree to which a change in interpretation bias, given the intervention, explained the change in cognitive and symptom variables (see Outcome measures). Fig. 3 illustrates the effects tested in the mediation models and further details can be found in the Supplementary Materials file.

Main analyses were complete-case analyses, i.e. including those participants who completed both pre- and post-intervention measures. Sensitivity analyses were computed from two different approaches: intention-to-treat analyses (using the iterative expectation-maximization method; Newman, 2014) and correcting for outliers (further details are provided in the Supplementary file). We only report the results of both sensitivity analyses when there is a significant deviation from the main analyses.

SPSS Statistics 20 was used to conduct ANOVAs, $\chi 2$ tests, and ITT analyses. R 4.0.2 was used to finding and correct for outliers and to calculate split-half reliabilities. The PROCESS SPSS macro was used to test the mediation models (Hayes, 2018).

3. Results

Demographic and baseline differences between groups are shown in Table 1. 24.4 % of the sample showed current symptoms of depression (PHQ-9 $\geq$ 10; He et al., 2020), 32.2 % showed current symptoms of anxiety (GAD-7 $\geq$ 10; Spitzer et al., 2006) and 31.1 % reported past symptoms of depression and/or anxiety (past PHQ-9 $\geq$ 10, past GAD-7 $\geq$ 10). More details about the distribution of participants based on present and past symptoms of depression and anxiety can be found in the Supplementary materials file. Regarding task and goal agreement with the program (WAI-I), participants in the experimental group showed an elevated level at post-intervention, comparable to previous studies for online interventions (Gómez Penedo et al., 2019).

3.1. Changes from pre- to post-intervention

a) Cognitive biases

A 2 (Group: experimental vs. control) x 2 (Time: pre- intervention vs. post- intervention) repeated measures ANOVA for interpretation biases showed that there was a significant main effect of Time, either when assessed with self-report (AST-D-II: $F(1,117) = 47.65$, $p < .001$, $\eta^2 = 0.29$) or with the experimental task ($MCAT_{Int}$: $F(1, 117) = 14.15$, $p < .001$, $\eta^2 = 0.11$). Post-hoc analyses showed that positive interpretation bias was significantly lower at baseline than at post- intervention (AST-D-II $F(1,117) = 47.65$, $p < .001$) and negative interpretation bias was significantly higher at baseline than at post- intervention (MCATInt: $F(1,117) = 14.15$, $p < .001$). There was no significant main effect of Group for any measure (AST-D-II: $F(1,117) = 2.66$, $p = .11$, $\eta^2 = 0.02$); $MCAT_{Int}$: $F(1,117) = 0.08$, $p = .78$, $\eta^2 = 0.001$). However, there was a significant Time x Group interaction for self-reported interpretation bias (AST-D-II: $F(1,117) = 14.24$, $p<.001$, $\eta^2 = 0.11$). Post-hoc Bonferroni analyses revealed that, although both groups were not significantly different at baseline ($t(118)$= -0.56, $p = .99$), the experimental group showed significantly more positive interpretations than the control group at post-intervention ($t(118) = 10.271$, $p = .003$; see Table 1). This interaction did not reach significance when interpretation bias was measured with the experimental task ($MCAT_{Int}$: $F(1,117) = 3.73$, $p = .056$, $\eta^2 = 0.03$).[2]

A 2 (Group: experimental vs. control) x 2 (Time: pre-intervention vs. post- intervention) repeated measures ANOVA for attention bias (i.e. $MCAT_{Att}$) showed no significant main effects of Time ($F(1,117) = 0.01$, $p = .92$, $\eta^2 = 0.00$), Group ($F(1,117) = 1.70$, $p = .20$, $\eta^2 = 0.01$), or interaction ($F(1,117) = 0.11$, $p = .74$, $\eta^2 = 0.001$).

For the memory bias task (MBT), there was no significant effect of Group ($F(1,119) = 0.02$, $p = .89$, $\eta^2 = 0.00$), but there was a significant effect of Time ($F(1,119) = 7.07$, $p = .009$, $\eta^2 = 0.06$). This was qualified by a significant Time x Group interaction ($F(1,119) = 11.50$, $p = .001$, $\eta^2 = 0.09$). Post-hoc analyses with Bonferroni correction showed that the experimental group ($t(120) = 0.13$, $p < .001$), but not the control group ($t(120)$= -0.02, $p = .61$), significantly reduced the negative memory bias between the two assessments (see Table 1).

b) Outcome variables

Regarding the DASS-21, a 2 × 2 repeated measures ANOVA for depression symptoms showed no significant main effects of Time ($F(1,116) = 0.20$, $p = .89$, $\eta^2 = 0.00$) or Group ($F(1,116) = 0.33$, $p = .57$, $\eta^2 = 0.003$). However, there was a significant Time x Group interaction ($F(1,116) = 6.04$, $p = .02$, $\eta^2 = 0.05$). Post-hoc tests showed changes in the expected direction. In the experimental group, depressive symptoms decreased between assessments ($t(117) = 0.88$, $p = .07$), while the control group exhibited an increase on them ($t(117)$=-0.78, $p = .10$), although none of these effects were significant. No significant main or interaction effects were found for stress (Time: $F(1,116) = 0.06$, $p = .81$, $\eta^2 = 0.00$; Group: $F(1,116) = 1.09$, $p = .30$. $\eta^2 = 0.01$; Time x Group: $F(1,116) = 1.05$, $p = .31$, $\eta^2 = 0.01$) or anxiety symptoms (Time: $F(1,116) = 1.66$, $p = .20$, $\eta^2 = 0.04$; Group: $F(1,116) = 0.35$, $p = .56$. $\eta^2 = 0.35$; Time x Group: $F(1,116) = 0.65$, $p = .42$, $\eta^2 = 0.01$).

The 2 × 2 repeated measures ANOVA for dysfunctional attitudes (DAS) showed no significant main effects (Time: $F(1,116) = 3.40$, $p = .07$, $\eta^2 = 0.03$; Group: $F(1,116) = 0.42$, $p = .52$. $\eta^2 = 0.004$), but there was a significant Time x Group interaction ($F(1,116) = 18.72$, $p < .001$, $\eta^2 = 0.14$). Bonferroni corrected post-hoc analyses revealed that the experimental group significantly reduced dysfunctional attitudes ($t(117) = 13.35$, $p < .001$), while the control group showed no change ($t(117)$=-5.37, $p = .08$). No significant main or interaction effects were found for rumination (Time: $F(1,116) = 2.17$, $p = .14$, $\eta^2 = 0.02$; Group: $F(1,116) = 0.04$, $p = .84$. $\eta^2 = 0.00$; Time x Group: $F(1,116) = 1.57$, $p = .21$, $\eta^2 = 0.01$), or well-being (Time: $F(1,110) = 2.11$, $p = .15$, $\eta^2 = 0.02$; Group: $F(1,110) = 0.14$, $p = .71$. $\eta^2 = 0$; Time x Group: $F(1,110) = 1.79$, $p = .18$, $\eta^2 = 0.02$) measures.

3.2. Mediation effect of interpretation bias change given the intervention

Following the repeated measures ANOVA results, three simple mediation models were tested. Fig. 3 illustrates these models and the results can be found in Table 2. Change scores refer to the residualized change scores obtained in the linear regression of pre-intervention on post-intervention (further details can be found in the Supplementary Materials file).

[1] ANOVA assumptions were tested with Q-Q plots and boxplots for normality, Levene's test for homoscedasticity, and Box's M test for equality of covariance matrices. Although data met the two latter assumptions, normality plots revealed extreme values in some of the variables. Therefore, sensitivity analyses without outliers were conducted. Details can be found in the Supplementary File.

[2] The interaction between Time and Group became significant in sensitivity analyses without outliers ($MCAT_{Int}$: $F(1,117)$=4.65, p=.03, η^2 =0.04) and in ITT analyses ($MCAT_{Int}$: $F(1,117)$=5.71, p=.02, η^2 =0.04).

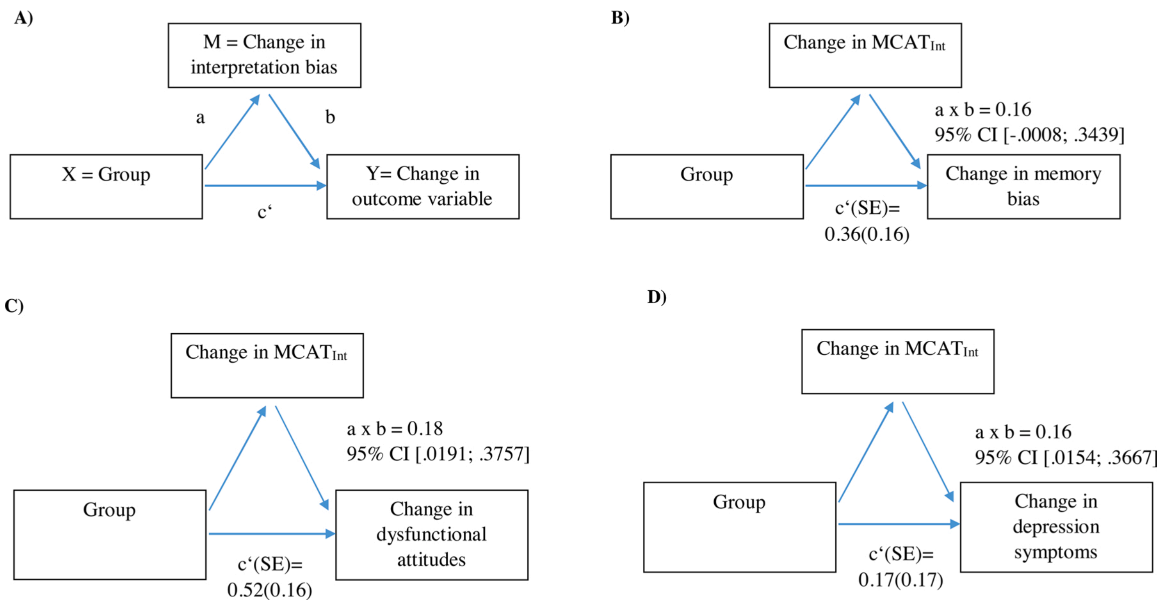

Fig. 3. A) Generic mediation model design: 'c' represents the direct effect of X (Group) on Y (change in outcome variables) after controlling for M (change in interpretation bias), and a x b represents the indirect effect of X (Group) on Y (change in outcome variables) through M (change in interpretation bias) B) Results of the mediation analysis with memory bias as the outcome variable C) Results of the mediation analysis with dysfunctional attitudes as the outcome variable D) Results of the mediation analysis with depression symptoms as the outcome variable. The mediator variable in B), C), and D) is the $MCAT_{Int}$.

Table 1
Descriptive statistics, differences at baseline between groups, and results at post-intervention.

	Baseline						Post-intervention			
	Experimental		Control				Experimental		Control	
	N	%	N	%	χ^2	p-value	N	%	N	%
Gender (female)	55	45.5	48	39.7	2.47	.12	55	45.5	48	39.7
	M	SD	M	SD	t	p-value	M	SD	M	SD
Age	21.66	4.23	21.47	2.45	0.30	.77	21.66	4.23	21.47	2.45
PHQ-9	7.52	4.91	7.13	4.18	0.46	.65				
PHQ-9 past	11.14	8.04	9.82	7.99	0.90	.37				
GAD-7	7.35	4.35	7.77	5.14	−0.48	.63				
GAD-7 past	5.90	7.09	5.17	7.17	0.56	.58				
AST-D-II	12.66	20.60	12.72	17.26	−0.06	.99	27.27	17.84	17	18.71
$MCAT_{Att}$	0.50	0.02	0.50	0.02	0.00	.87	0.49	0.03	0.50	0.03
$MCAT_{Int}$	0.33	0.19	0.32	0.19	0.01	.69	0.26	0.17	0.29	0.19
MBT	0.38	0.25	0.31	0.23	0.08	.09	0.26	0.19	0.32	0.23
DASS21D	4.95	5.01	3.70	3.87	1.25	.13	4.07	4.10	4.48	4.45
DASS21S	7.40	4.35	7.78	5.22	−0.39	.66	7.09	3.97	8.28	4.90
DASS21A	4.41	3.69	4.56	3.92	−0.14	.85	3.76	4.04	4.40	4.21
DAS	125.93	34.84	120.12	28.90	5.81	.33	112.59	31.25	125.48	32.82
RRS	13.16	3.38	12.75	3.61	0.41	.53	12.53	3.30	12.70	3.56
PHI	71.62	15.75	74.65	12.75	−3.03	.27	76.52	12.53	74.85	12.15
CEQ	0.52	4.71	−0.56	4.92	1.19	.24				
WAI-I	–	–	–	–	–		3.74	0.53	–	–

Note: Higher scores in the AST-D-II reflect lower negative interpretation bias, while higher $MCAT_{Int}$ scores represent higher negative interpretation bias. N = number of participants, M = mean, SD = standard deviation. **Variables measured only at baseline**: PHQ-9 = Patient Health Questionnaire-9; GAD-7 = Generalized Anxiety Disorder-7; CEQ = Credibility Expectancy Questionnaire. **Variables measured at baseline and post-intervention: Cognitive bias measures**: AST-D-II = Ambiguous Scenarios Test for Depression II; $MCAT_{Att}$ = Mouse-based Contingent Attention Task-Attention bias index; $MCAT_{Int}$ = Mouse-based Contingent Attention Task -Interpretation bias index; MBT = Memory Bias Task. **Outcome measures**: DASS21D = Depression, Anxiety and Stress Scale-21-Depression subscale; DASS21S = Depression, Anxiety and Stress Scale-21-Stress subscale; DASS21A = Depression, Anxiety and Stress Scale-21-Anxiety subscale, DAS = Dysfunctional Attitudes Scale; RRS = Ruminative Responses Scale-brooding subscale; PHI = Pemberton Happiness Index. **Variables measured only at post-intervention**: WAI-I = Working Alliance Inventory for Internet interventions.

a) Model 1. Mediation effect of the $CBM\text{-}I_{Clin}$ on the change in memory bias

Model 1 tested the effect of the $CBM\text{-}I_{Clin}$ on the change in memory bias, with the change in interpretation bias as a mediator variable. We computed separate models for each measure of interpretation bias (AST-D-II and $MCAT_{Int}$).

Results showed that the intervention had significant total (AST-D-II coefficient = 0.51, $t = 2.86$, $p = .005$; $MCAT_{Int}$ coefficient = 0.52, $t = 2.92$, $p = .004$) and direct (AST-D-II coefficient =0.48, $t = 2.52$, $p = .01$; $MCAT_{Int}$ coefficient = 0.36, $t = 2.23$, $p = .03$) effects on the change in memory bias (i.e., the intervention affected the change in negative memory bias even after controlling for change in negative interpretation bias). A non-significant indirect effect was found for this model,

Table 2
Results of the mediation models.

Model	X	M	Y	Total effect			Direct effect		Indirect effect	
				R^2	c (SE)	t (p)	c' (SE)	t (p)	a x b	95 % CI
1	Gr	$MCAT_{Int}$ change	MBT change	0.07	0.52 (0.18)	2.92 (.004)	0.36 (0.16)	2.23 (.03)	0.16	[−.0008, .3439]
		AST-D-II change		0.07	0.51 (0.18)	2.86 (.005)	0.48 (0.19)	2.52 (.01)	0.03	[−.1298, .2136]
2	Gr	$MCAT_{Int}$ change	DASSD change	0.03	0.34 (0.18)	1.84 (.07)	0.17 (0.17)	1.01 (.32)	0.16	[.0154, .3667]
		AST-D-II change		0.03	0.35 (0.18)	1.94 (.05)	0.24 (0.19)	1.24 (.22)	0.11	[−.0482, .3016]
3	Gr	$MCAT_{Int}$ change	DAS change	0.13	0.71 (0.17)	4.07 (<.001)	0.52 (0.16)	3.38 (.001)	0.18	[.0191, .3757]
		AST-D-II change		0.13	0.72 (0.17)	4.22 (<.001)	0.37 (0.16)	2.29 (.02)	0.35	[.1528, .6120]

X = independent variable, M = mediator variable, Y = dependent variable, Gr = Group; $MCAT_{Int}$ = Interpretation bias scores in the Mouse-based Contingent Attention Task; AST-D-II = Interpretation bias scores in the Ambiguous Scenarios Test for Depression II; MBT = Memory Bias Task, DASSD = Depression, Anxiety and Stress Scale-21-Depression subscale; DAS = Dysfunctional Attitudes Scale.

suggesting that the change in interpretation bias did not mediate the association between group and change in memory bias. The same pattern of results was found when interpretation bias was self-reported (AST-D-II indirect effect = 0.03 [-0.1298; 0.2136]) or measured with the $MCAT_{Int}$[3] (Fig. 3).

b) Model 2. Mediation effect of the $CBM\text{-}I_{Clin}$ on the change in depression symptoms

Mediation model 2 tested the total, direct, and indirect (via a change in interpretation bias) effects of the intervention on the change in depression symptoms. Results showed that the program did not have significant total (AST-D-II coefficient = 0.35, $t = 1.94$, $p = .05$; $MCAT_{Int}$ coefficient = 0.34, $t = 1.84$, $p = .07$) or direct (AST-D-II coefficient = 0.24, t=1,24, p=.22; $MCAT_{Int}$ coefficient = 0.17, $t = 1.01$, $p = .31$) effects on the change in depression symptoms (i.e., the intervention did not affect the change in depression symptoms when controlling for the change in negative interpretation bias). However, there was a significant indirect effect through the change in negative interpretation bias, suggesting that the association between group and change in depression symptoms was mediated by the change in negative interpretation bias This effect was found when interpretation bias was measured with the experimental task ($MCAT_{Int}$) (see Fig. 3), but not when self-reported in the questionnaire (AST-D-II indirect effect = 0.11 [-0.0482; 0.3016]).

c) Model 3: Mediation effect of the $CBM\text{-}I_{Clin}$ on the change in dysfunctional attitudes

The final model tested the effects of the intervention on the change in dysfunctional attitudes. Results showed that the intervention had a significant total (AST-D-II coefficient = 0.72, $t = 4.22$, $p < .001$; $MCAT_{Int}$ coefficient = 0.71, $t = 1.07$, $p < .001$) effect on changes in dysfunctional attitudes. Also, the intervention had significant direct and indirect effects on the change in dysfunctional attitudes). Thus, the intervention both directly and indirectly affected dysfunctional attitudes (i.e. when controlling for changes in interpretation bias, but also via the change in interpretation bias). Importantly, these effects appeared both when interpretation bias was measured with the $MCAT_{Int}$ (see Fig. 3) and when assessed through self-report (AST-D-II direct effect = 0.37, t = 2.29, p=.02; indirect effect = 0.35 [0.1528; 0.6120]).

4. Discussion

The present study investigated the effects and operating mechanisms of a novel transdiagnostic online CBM program on young adults with varying levels of emotional distress. The program was based on standard clinical cognitive-behavioral procedures and aimed to reduce negative interpretation biases. We found that the experimental group showed significantly higher levels of positive interpretations after the intervention, compared to the control group. This effect, however, appeared when interpretation bias was assessed with a self-report questionnaire, but not when we used an experimental task ($MCAT_{Int}$). Several explanations can be offered to account for this discrepancy. For example, a previous review suggested that subclinical populations may not be an optimal sample to detect CBM changes when using these types of tasks, but it may also be the case that the content of the intervention is more closely related to some measures (e.g. AST-D-II), but not others (e.g. $MCAT_{Int}$) (Hirsch, Meeten, Krahé, & Reeder, 2016). Also, some studies in the field differentiate between the increase of positive interpretations and the decrease of negative ones (e.g. Beard & Amir, 2008). Given that the AST-D-II measures the *pleasantness* of ambiguous scenarios, while the experimental task index focuses on the construction of negative sentences, it is possible that the discrepancy in results may reveal that the $CBM\text{-}_{IClin}$ is well-suited to increase positive interpretations, but not to decrease negative ones. New clinical approaches must consider separately both types of outcomes given that emotional disorders are characterized not only by high negative cognitions and distress but also by a diminished tendency towards positivity (Dunn, 2012; Vazquez, 2017).

Discrepant results when using different instruments to measure cognitive biases are not a new phenomenon (Kappenman, MacNamara, & Proudfit, 2015; Sfärlea et al., 2020), and could also reflect a difference in the underlying constructs that they are measuring. It has been shown that even low departures from perfect convergent validity between proxies can lead to different research results and conclusions (Carlson & Herdman, 2012). A recent study of the convergence between different measures of interpretation bias, more specifically, interpretation bias questionnaire (Wisco & Nolen-Hoeksema, 2010), scrambled sentences test (Wenzlaff & Bates, 1998), homograph interpretation task (Grey & Mathews, 2000), and word-sentence association paradigm (Cowden Hindash & Amir, 2012), concluded that these measures may be tapping on different subcomponents of interpretation, which might explain the inconsistent findings in CBM-I research (O'Connor, Everaert, & Fitzgerald, 2021). Furthermore, some authors have proposed that the use of an experimental task with time constraints and a cognitive load to measure interpretation bias, such as the one used in this study, may help to capture automatic instead of elaborative processes (Everaert, Podina et al., 2017). If this is so, it suggests that the change in interpretation bias may have been produced at a conscious rather than implicit level. Despite these alternative explanations, we must remind that sensitivity analyses showed a significant interaction between Time and Group also when interpretation bias was measured with the $MCAT_{Int}$. Therefore, it is still possible that the intervention had a real effect in reducing negative interpretation bias but, given the presence of extreme values, the results did not reach significance.

The second aim of this study was to explore the change in other key cognitive and symptom variables upon undergoing the intervention.

[3] This indirect effect for this model when interpretation bias was measured with the $MCAT_{Int}$ became significant in intention-to-treat analyses (a x b = 0.18, 95%CI [0.0198; 0.3543]) and when data were analysed without outliers (a x b = 0.16, 95%CI [0.0185; 0.03120]).

While there was no significant change in negative attention bias, anxiety, stress symptoms, brooding, or well-being, the CBM-I_{Clin} significantly changed negative memory biases, depression symptoms, and dysfunctional attitudes. Mediation models showed that the change in negative interpretation bias did not mediate the effect of the intervention on negative memory biases. This could be surprising given the evidence that attention, interpretation, and memory biases interact with each other (Everaert & Koster, 2020; Mogg & Bradley, 2018). The combined cognitive bias hypothesis (CCBH) (Hirsch, Clark, & Mathews, 2006) states that cognitive biases influence each other, and this interactive effect is stronger than if the biases were working in isolation. However, it is possible that the program directly improved negative memory biases given that it was designed to increase awareness of one's own cognitive processes (i.e. participants in the experimental group might have selectively remembered the positive stimuli among all that were presented). Experimental literature has shown that memory bias does not only depend on the codification of a memory from a prior negative interpretation, but also depends on the degree to which individuals imagine themselves as actors in those scenarios (Hertel & Brozovich, 2010). It is possible that the CBM-I_{Clin} helped participants not only to create more positive interpretations, but also to imagine themselves less in the negative ones. Finally, research on the interaction between interpretation and memory processes suggest that CBM-I could create a new 'frame of mind' that promotes the retrieval of information that is congruent with that frame (Salemink & Hertel, 2010), which could explain the direct effect of the CBM-I_{Clin} on memory. The asymmetrical effect of CBM procedures on different types of emotional processing (attention, interpretation, memory) has previously been found in a sample of young adults (Bowler et al., 2017). Clarifying these potential pathways between different cognitive biases could be important to increase the efficacy of interventions. For instance, future research could study whether extant CBM interventions aimed at modifying memory biases (e.g., Barry, Sze, & Raes, 2019) might facilitate subsequent changes in attention or interpretation biases.

The change in depression symptoms because of the intervention cannot be interpreted unequivocally. ANOVA results showed no significant changes in depression symptoms in any group. Yet, mediation models showed that, while the intervention did not have a significant total or direct effect on change in depression symptoms, there was a significant indirect effect of the intervention through a change in negative interpretation bias. We only found this effect when interpretation bias was assessed using the experimental task ($MCAT_{Int}$), and not when assessed through self-report (AST-D-II). Interestingly, although the most recent meta-analysis on the field of CBM concludes that these programs moderately improve depression and anxiety symptoms, there is high variability between studies (Fodor et al., 2020). For example, a previous study about CBM-I in social anxiety found that changes in positive interpretations, but not in threat interpretations, mediated the effect of group on social anxiety symptoms (Beard & Amir, 2008). Although sources of variability are still unknown, it could be possible that part of it stems from the type of instruments used to measure symptoms and cognitive biases. For example, two meta-analyses on attention bias training in anxiety reached different conclusions regarding the efficacy of the intervention in the reduction of symptoms when examining the effect with different measures (Linetzky, Pergamin-Hight, Pine, & Bar-Haim, 2015; Price et al., 2016). As Fried (2017) recently pointed out, the standard instruments used to assess problems like depression poorly reflect the wide variety of symptoms that characterize the disorders, which limits the validity of research results. Similarly, regarding cognitive biases, a recent meta-analysis has also found that there is a high variety of self-report instruments and unfortunately, many of them have limited evidence to support their psychometric robustness (Nieto et al., 2020).

Dysfunctional attitudes significantly changed after the CBM-I_{Clin}, which was explained by both a direct effect of the intervention and an indirect effect through a change in interpretation bias. We found these effects both when interpretation biases were self-reported and when measured with an experimental task. The direct effect of the program is consistent with the fact that its content was based on the negative cognitive biases proposed in the classical cognitive models of emotional disorders (Beck & Clark, 1997), which directly link negative processing of information with dysfunctional attitudes. Moreover, dysfunctional attitudes were measured by the DAS (Weissman & Beck, 1978), i.e. an instrument that assesses maladaptive cognitions such as concerns with evaluation or negative causal attributions that are present both in depression and anxiety (Dyck, 1992). Although dysfunctional attitudes are theoretically conceived as rather permanent cognitive schemas, empirical evidence has shown that they are susceptible to change (Haeffel et al., 2005). For instance, research has found that patients who respond to cognitive therapy do not show increased levels of dysfunctional attitudes (cognitive reactivity) after a sad mood induction procedure (Jarrett et al., 2012), which might reflect the acquisition of therapeutic techniques aimed at evaluating, challenging, and modifying dysfunctional thoughts, similar to the ones used in the 'Relearning how to think' program. The clinical implications are relevant, given the potential role of negative cognitive schemas as vulnerability factors (Beck & Clark, 1997). However, this role needs further investigation given that meta-analytic conclusions on the role of dysfunctional cognitions in maintaining or exacerbating depressive symptoms are mixed (Cristea, Kok et al., 2015; Wojnarowski, Firth, Finegan, & Delgadillo, 2019).

Finally, the lack of change in symptoms of anxiety and stress after the intervention could have several explanations. A previous meta-analysis investigating CBM for attention and interpretation bias found that the change in anxiety and depression symptoms after training only appeared when participants were assessed in response to a stressful task (Hallion & Ruscio, 2011). Congruent with the diathesis-stress model, this finding suggests that CBM efficacy is better evaluated when cognitive biases are more likely to appear in the face of a stressor. Moreover, although cognitive-behavioral therapy moderately reduces anxiety symptoms (van Dis et al., 2020), it is possible that the specific focus of the CBM_{Clin}, designed to enhance elaborative information processing, benefits the improvement of depression symptoms, but it cannot tackle some automatic mechanisms (e.g., biases in orienting responses) which are more related to anxiety disorders (Teachman, Joormann, Steinman, & Gotlib, 2012). The same argument could explain the lack of changes found in negative attention biases. While research has consistently found that depression is characterized by interpretation biases, anxiety is more associated with attention biases than other types of biases (Mathews & MacLeod, 2005). Yet, the literature about attention bias training to improve anxiety symptoms has led to mixed conclusions (Linetzky et al., 2015; Price et al., 2016), which has questioned some conceptual foundations of this training (McNally, 2019; Mogg & Bradley, 2018). The lack of changes in attention biases can also be explained from previous studies supporting the idea that attention bias impacts psychological functioning through its relationship with other elaborative processes (e.g., Marchetti et al., 2018; Sanchez, Everaert, De Putter, Mueller, & Koster, 2015). Therefore, possible effects on attention biases may underlay the changes in interpretation and memory processing.

Secondary hypotheses were not met. The CBM-I_{Clin} did not affect rumination or well-being, although these results must be considered with caution as the internal consistency of the rumination and well-being scales (i.e., RRS, PHI) were low to moderate (Nunnally, 1978) in our sample. Regarding rumination, repetitive negative thinking has been related to cognitive biases in general (Villalobos, Pacios, & Vázquez, 2021) and negative interpretation bias in particular (Hirsch et al., 2016). Moreover, previous studies have found that the change in interpretation bias after CBM mediates the change in worry and rumination processes (Hayes, Hirsch, Krebs, & Mathews, 2010; Hertel, Mor, Ferrari, Hunt, & Agrawal, 2014). However, the evidence on the possibility of changing rumination through CBM has yielded mixed results. Whereas some studies have shown positive results (Sanchez-Lopez, Everaert et al., 2019), others have failed to do it so (Hirsch et al., 2020).

Future studies would benefit from identifying the active components of different interventions that make them effective for specific symptoms or modes of processing (like ruminative thinking) which will facilitate the administration of more personalized interventions (Lopez-Gomez et al., 2019).

Regarding well-being, it was expected that the creation of more positive interpretations would lead to higher levels of well-being. Previous studies have shown that negative interpretations are connected to lower levels of well-being (Blanco, Boemo, & Sanchez-Lopez, n.d.) and that CBM-I can increase positive mood (Holmes, Mathews, Dalgleish, & Mackintosh, 2006). However, there were no significant results in this direction. Nevertheless, the assessment of well-being utilizing the PHI was perhaps not an optimal choice. In the context of a CBM intervention, a focus on positive emotions, which are more sensitive to circumstances than overall assessments of well-being, might have been the best assessment option. Yet, future CBM studies are encouraged to include measures of emotion regulation and well-being in their research given the evidence of the interconnection between these variables (Gross, Uusberg, & Uusberg, 2019).

It is possible that the results of CBM interventions would be better with longer treatments blended with evidence-based treatments. Several studies suggest that the modification of negative interpretation processes could have an augmentation effect in CBT results (Beard, Rifkin, Silverman, & Björgvinsson, 2019; Teachman, Marker, & Clerkin, 2010). If these results are confirmed, CBM programs could be an additional tool to respond to the serious consequences associated with emotional disorders in terms of disability, chronicity, and relapse (Lorimer, Kellett, Nye, & Delgadillo, 2020; Wojnarowski et al., 2019; World Health Organization, 2017).

4.1. Strengths and limitations

We must address some limitations of the current study. First, the recruitment procedure implied the inclusion of participants who were interested in a program to 'learn how to control the influence of thoughts on emotional reactions' (see *Participants and recruitment*). This selection of participants could have biased the results given that it is a sample potentially more willing to change. Also, our study did not specifically select individuals with significant cognitive biases or with high levels of symptoms. Interpretation bias trainings could be more beneficial for those adolescents and young adults who show greater levels of negative cognitions before undergoing the intervention (de Voogd, Wiers, de Jong, Zwitser, & Salemink, 2018; Micco, Henin, & Hirshfeld-Becker, 2014). Some CBM studies have shown that higher levels of negative processing increase the clinical response to these trainings (Amir, Taylor, & Donohue, 2011). However, the meta-analytic literature shows no clear evidence regarding the moderating role of symptom severity (clinical, subclinical, and healthy samples) in the benefits of CBM interventions (Jones & Sharpe, 2017). While the use of non-clinical samples is still a common practice in CBM studies (e.g. Mętel et al., 2019; Beard & Amir, 2008), future research must determine the characteristics of participants that could benefit the most from these interventions.

Second, the ability to disengage from negative materials, which is a key component of attention in emotional disorders (Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013), was not assessed in this study. Future research should include tasks that allow exploration of the differences between these diverse attention bias indices (e.g., orienting towards, maintaining attention or delayed disengagement, and orienting away) (Mogg & Bradley, 2018). These types of measures are relevant as there is already evidence that psychological interventions can significant improve engagement and disengagement attentional processes in depressed individuals (Vazquez et al., 2018).

Third, some design and methodological limitations should be noted. The recruitment procedure did not involve the exclusion of some potential confounding variables, such as drug use or attentional disorders. Given the dependence of the assessment and intervention on memory and reading abilities, more stringent inclusion and exclusion criteria should be used in future CBM studies to better discern the effect of these intervention procedures. Also, it has been argued that the analysis of moderation effects using residualized change scores models can lead to biased estimates of the true mediated effect given that the pre-test and post-test mediator and dependent variable scores are reduced to a single score (M and Y, respectively) (Valente & MacKinnon, 2017). Given these different approaches, future studies are encouraged to consider them (see Valente & MacKinnon, 2017).

Fourth, an enriching approximation for future cognitive bias research would be to incorporate other cognitive processes such as the lack of positive biases (Gruber, Villanueva, Burr, Purcell, & Karoly, 2020; Hirsch & Mathews, 2000; Matt, Vazquez, & Campbell, 1992), emotion regulation strategies, or cognitive control processes (LeMoult & Gotlib, 2019; Mogg & Bradley, 2018) with long-term follow-ups to reveal changes in underlying processes (Everaert & Koster, 2020). If CBM procedures aim to be clinically used, it is important to determine whether post-treatment effects are transient improvements of cognitive patterns or whether they may lead to long-term changes in information processing and emotional symptoms.

Finally, given that the CBM-I_{Clin} was administered individually at home, it is difficult to know the level of participant engagement when completing the sessions. Adherence to treatment in unguided web-based interventions for depression is lower than guided web-based interventions given that feelings of accountability may be reduced when there is no contact with a therapist or supervisor (Mohr, Cuijpers, & Lehman, 2011; Richards & Richardson, 2012). Future online CBM interventions should include monitoring mechanisms to guarantee the level of engagement of participants while completing the sessions. This seems necessary as this could be an obstacle to the scalability of this type of internet-based intervention (McNally, 2019).

The present study has several strengths. First, 'Relearning how to think' was designed to improve the traditional approaches to change cognitive biases, in line with previous recommendations (Koster & Bernstein, 2015; Pe et al., 2015). For example, our training program includes mental imagery, which is beneficial for cognitive change given the close relationship between imagery and emotions (Holmes & Mathews, 2005; Jones & Sharpe, 2017). Also, the CBM_{Clin} was created based on materials (e.g., clinical vignettes) already used and validated in previous interventions (Barlow et al., 2017). The program included materials with specific contents related to depression or anxiety, rather than negative topics in general, which is relevant to activate cognitive biases (Armstrong & Olatunji, 2012). Yet, given our results, it could be possible that the focus of the program on elaborative processing makes it more suitable for disorders like depression, which are better characterized by deficits in elaborative mechanisms (Duque, López-Gómez, Blanco, & Vázquez, 2015). Second, the use of both self-report and experimental tasks to measure cognitive biases has been encouraged to know whether direct and indirect measures reflect the same cognitive processes and whether negative cognitive biases operate both at explicit or implicit levels in emotional disorders (Everaert, Podina et al., 2017; Hirsch et al., 2016). Also, the use of measures that differentiate from the intervention content is important to discern real changes in interpretation from participants' learning on how to answer to a specific format. This is important, given previous evidence that changes in interpretation on a training task did not generalize to a different task (Salemink, van den Hout, & Kindt, 2007). Finally, the online format of the procedure benefits from high accessibility and the cost-effectiveness that comes with internet-based interventions (Kazdin & Blase, 2011).

In sum, this study provides a promising program to change negative interpretation biases. To our knowledge, this is the first CBM procedure that is not designed to change automatic information processing through repetition but aimed at increasing participants' construction of alternative adaptive interpretations of ambiguous scenarios. Our approach may accommodate more naturally to the clinical nature of evidence-based cognitive-behavioral therapies for emotional disorders. This study also sheds light on the mechanisms of action that seem to be relevant in the proposed intervention to modify interpretation biases, which we believe are not only valuable for clinical purposes but also for the advancement of theory and research.

Contributors

Ines Nieto (IN) and Carmelo Vazquez (CV) conceived the study and designed the intervention program. IN implemented the evaluations and performed the statistical analyses under the supervision of CV. IN and CV wrote the article.

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Ethics approval and consent to participate

This project was approved by the School of Psychology Ethics Committee on June 17, 2019 (Ref. 2018/2019-017). All participants provided informed consent before starting the first study session. To ensure anonymity, their names were coded with numbers.

Registry: This study was pre-registered in PsyArXiv (DOI: 10.31234/osf.io/auhm6) and ClinicalTrials.gov (NCT03987477).

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Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.janxdis.2021.102459.

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