Digital Antianxiety Treatment and Cognitive Performance: an Experimental Study

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Abstract

We study the impact of an innovative antianxiety digital treatment on performance in a cognitive demanding task using a randomized control trial design. We exogenously manipulate a cognitive bias associated with anxiety – the tendency to disproportionately allocate attention to negative stimuli – in a group of young males and females. We observe that the treatment reduces the cognitive bias of treated females and significantly improves their performance in the cognitive task. Evidence from university examination results taken three months after the intervention suggests that the digital treatment may generate long-lasting benefits.

JEL codes: C91; I10; J16.

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1 Introduction

Anxiety disorders are a significant public health concern across the globe. According to the US National Institute of Mental Health (NIMH), anxiety disorders are the most

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common mental illness in the USA, affecting 19% of the American adult population annually. In England, data from the most recent Adult Psychiatric Morbidity Survey 2014 (McManus et al., 2016) show that about 17% of adults had been affected by a common mental disorder in the previous week,[1] with a mix of anxiety and depression (7.8%) and generalized anxiety disorder (5.9%) being the two most common disorders.[2] Some longitudinal studies document an increasing prevalence of anxiety and depression, particularly among the young population (Twenge et al., 2010).[3] A meta-analysis of anxiety prevalence statistics across countries shows that females are on average twice as likely to suffer from anxiety than males (e.g. Remes et al., 2016), a remarkable difference even when possible gender differences in symptom reporting are taken into account.[4]

Anxiety has important and long-lasting repercussions on individuals' health, social functioning and wellbeing. In the UK, mental illnesses are estimated to cost the economy about 4.5% of GDP every year (Stansfeld et al., 2016). Das-Munshi et al. (2008) estimate that mixed anxiety and depression are responsible for one-fifth of days off work, representing the most frequent cause of sickness absence in England. According to the UK Office for National Statistics (2018) there has been an increase in the proportion of younger workers aged 25-34, who attribute their sickness absence to mental health conditions, rising from 7.2% in 2009 to 9.6% in 2017.[5]

Several studies show that for the same level of ability, anxiety reduces educational performances and professional outcomes (see, e.g. Beard, 2011): anxiety can be thought of as a "tax on performance". Since anxiety prevalence varies across socio-demographic groups, the detrimental effect on performance can be expected to affect some groups more than others. A number of studies find gender differences in performance in high-pressure

[1]Common mental disorders include depression, generalized anxiety disorder, panic, phobias, obsessive compulsive disorder, and other not otherwise specified disorders referred to as "mixed anxiety and depression".

[2]Mental health statistics for the U.S. are taken from NIMH at `http://www.nimh.nih.gov/health/statistics/prevalence/any-anxiety-disorder-among-adults.shtml` and refer to the years 2001-2003; McManus et al. (2016) is available at `https://webarchive.nationalarchives.gov.uk/20180328140249/http://digital.nhs.uk/catalogue/PUB21748`

[3]Part of the observed increase in prevalence may be due to improvements in diagnosis and changes in the acceptability of reporting mental health disorders, but studies that take these confounders into account still show increases in the prevalence of mental health disorders (Twenge et al., 2010).

[4]According to the Adult Psychiatric Morbidity Survey 2014 Report from England (McManus et al., 2016), for the same level of mental health disorder (and assuming everyone who reports the disorder, receives treatment), for every five females who report it, only two out of five males report the same disorder.

[5]The ONS report and data are available at `https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/articles/sicknessabsencefallstothelowestratein24years/2018-07-30`.

environments where anxiety is likely to arise. For example, Paserman (2007) shows that in tennis tournaments females players make more errors than males as competitive pressure increases. In a controlled experiment Cahlíková et al. (2019) find that women under competitive conditions perform worse when they are stressed relative to when they are not stressed. Coffman (2014) shows that females attempt fewer questions in a quiz than males, even after controlling for knowledge and confidence. Anxiety may explain these differences: if anxiety triggers behaviors that are associated with poorer performance in stressful situations (e.g., being less focused), then the anxiety-driven penalty on performance penalizes females more than it does males. Given the prevalence of examination- and quiz-based assessments as screening devices, the anxiety tax on performance may be partly responsible for the gender imbalances observed in quiz-based rankings and the prejudices around females being less skillful in quantitative subjects (e.g. Guiso et al., 2008).[6]

An important question arises: Can specialized interventions help mitigate the detrimental impact of anxiety on performance? Here we provide an answer by evaluating the impact of an innovative form of antianxiety training, the cognitive bias modification (CBM), on performance in a cognitive test in groups of young males and females, using a randomized control trial (RCT) with a difference-in-difference design. Studies in cognitive psychology and neuroscience have shown that anxiety impairs the use of attentional control resources that are necessary inputs for successful performance in cognitive tasks.[7] CBM treatment aims to restore the use of attentional control resources.

CBM treatment was developed by cognitive psychologists (MacLeod et al., 1986) and is based on the premise that some of the cognitive biases through which an individual perceives reality are a cause of anxiety. CBM addresses attention bias, one of the most widely recognized biases associated with anxiety. Attention bias is the tendency to disproportionately and more rapidly attend to threatening stimuli in comparison with other concurrent neutral stimuli.[8]

[6]For example, in 2016 twice as many male students in Mathematics and Computer Science at the University of Oxford received a first-class honours – the highest grade classification in the UK higher education system – than female students. As a response, the university extended the duration of examinations in the belief that the observed gender gap in academic performance was due to females being more adversely affected by time pressure in examinations than males. See `https://www.telegraph.co.uk/education/2018/02/01/oxford-university-extends-exam-times-womens-benefit/`

[7]Attentional control resources include the ability to shift attention to specific features of the task that are most relevant for its completion, the ability to inhibit attention to distractors and interferences, and the ability to keep track of and to retrieve relevant information (see Derakshan and Eysenck, 2009).

[8]Other biases associated with anxiety are memory bias and interpretative bias. The former is the tendency to retrieve memories selectively favoring negative information, while the latter is the tendency to resolve ambiguity toward a negative direction. The experimental psychopathology literature has focused

Anxiety reduces performance because it subconsciously drives an individual's attention toward threatening distractors that are irrelevant to the task to be completed (see, e.g Eysenck and Derakshan, 2011; Wilson and MacLeod, 2003). For example, while taking a test, an anxious student is more likely to be distracted by her worries about the test or other threatening cues in the surrounding environment. Performance will suffer from attentional control resources being diverted away from stimuli relevant to the completion of the task toward task-irrelevant stimuli. Anxious individuals may compensate for decrements in performance by exerting additional effort. However, such effort is costly and its effectiveness is decreasing, especially when the task is demanding.[9]

CBM treatment reduces attention bias by training individual attention. CBM is a computer-based training in which pairs of threatening and neutral stimuli appear sequentially on the screen. The subject is trained to divert attention away from threatening stimuli by requiring repeated identification of the location of the neutral stimulus in a pair of neutral and threatening stimuli. We expect CBM-treated participants to reduce their attention bias and to improve their performance in a cognitive task. The improvement in performance originates from liberating cognitive resources previously trapped by the focus on threatening and anxiety-generating stimuli. Larger reductions in attention bias may be expected in more anxious individuals, such as females, leading in turn to greater improvement in task performance.

CBM treatment has advantages in comparison with alternative treatments such as cognitive behavioral therapy (CBT) and antidepressant medications that aim to reduce the consequences of anxiety or the anxiety itself. The meta-analysis by Hakamata et al. (2010) shows that, on clinical patient samples, CBM treatment yields effect sizes of comparable magnitude to those from CBT and drug treatments. However, CBM is cheaper, easier to administer to patients, amenable to large-scale interventions, non-invasive and, insofar as it has been tested, well accepted by patients (Beard, 2011).

Our results show that CBM reduces attention bias in treated females and produces significant improvements in performance in a cognitive task for this group, measured as the number of attempted questions in the test. Treated females' performance increases on average by 38% compared with control group females' performance. Males do not show a significant reduction in bias, and consequently, have no performance improvement. This is

so far mainly on attention bias.

[9]Attentional control theory predicts that anxiety impairs attention control even in cases where there are no threat-related stimuli irrelevant to completion of the task. This is because the optimal strategy of anxious individuals, who often feel under general threat, is to allocate attentional resources widely in order to preempt dangers, rather than concentrating attentional resources on specific focuses. This implies a reduction in the attentional control resources available for any given cognitive task.

not due to a differential engagement with the treatment.[10] A more plausible explanation is that males are originally less anxious than females and may have less to gain from the treatment. Rather, it is the anxious females, who are more likely to be penalized by anxiety, who obtain the largest increases in performance.

This paper makes several contributions. First, our results inform the use of digital health treatments against one of the most common mental health conditions worldwide: anxiety. The results in this paper focus on CBM and extend the recent evidence on its efficacy in two ways. i) The results evidence the impact of CBM on a real behavioral outcome typically hindered by anxiety: performance in a cognitive task. Whereas previous psychological and psychopathological studies have demonstrated encouraging effects of CBM on measures of attention bias and anxiety, this study brings these findings a step forward by analysing the resulting changes in behavior. ii) The study's design tests the efficacy of CBM using a novel group of people that is larger and more representative of the levels of anxiety in the general population than previous studies, most of which were confined to small samples of pathologically anxious patients.[11] In contrast, this study's sample comprises 261 university students, with a broad range of anxiety levels reflecting the distribution of anxiety in the general population. For this reason, our findings are the first, as far as we know, to inform of the expected impact of CBM on a 'typical' user, as opposed to selective groups of responsive users.

Second, the finding that exogenous manipulation of attention bias can affect performance in cognitive tasks contributes to the understanding of the range of non-cognitive factors affecting performance. Our work adds to the literature on the roles of personality traits (Borghans et al., 2008; Moutafi et al., 2006), grit and determination (Alan et al., 2019). By focusing on a sample of young adults, the paper also contributes to the scant body of evidence on the response of non-cognitive skills to interventions in adulthood (Blattman et al., 2017, e.g.). Despite the recognised malleability of attitudes and behaviors during young adulthood (Krosnick and Alwin, 1989), the empirical evidence is thin in comparison to the large number of works documenting interventions in early childhood.

Third, the paper contributes to the current debate on the limitations of exams and standardised tests as screening devices for cognitive ability (Rear, 2019). Our results

[10] In additional analysis, we have studied whether the difference in the effect of CBM between genders could be attributed to female participants complying with the instructions differently compared to males and/or engaging with the CBM training with a different degree of commitment than males, to an extent sufficient to create different levels of intensity of the CBM treatment. However, we did not find any strong supporting evidence for this hypothesis. The analysis is available upon request.

[11] For example, among the pool of 12 studies included in the most recent meta-analysis of CBM efficacy by Hakamata et al. (2010), the largest sample size used comprises 94 subjects.

show that the performance of anxiety-prone individuals significantly increases following a reduction in attention bias. This is indicative of the extent to which typical assessments of cognitive ability may be poor proxies due to the impact of anxiety.

The remainder of paper is organized as follows: Section 2 explains the CBM treatment; Section 3 describes the experimental design; Section 4 presents the empirical strategy; Section 5 provides evidence that the CBM treatment was effective in reducing attention bias and increasing performance in a cognitive task; Section 6 concludes the paper. The Supplementary Material (SM) discusses robustness tests.

2 The Treatment: Cognitive Bias Modification

CBM treatment aims to mitigate the consequences of anxiety by re-diverting the sub-conscious focus on threatening stimuli toward neutral or positive ones. The treatment is computer-based and involves the rapid sequential appearance of pairs of visual stimuli on the screen. We adopted the version of CBM that uses pairs of photographs of human faces as visual stimuli. In each pair of photographs, the face of the same person appears with an angry expression (threat stimulus) and an emotionally neutral expression (neutral stimulus). Figure SM.1 in the SM presents an example of the pair of faces used in the experiment.[12]

Participants see each pair of angry and neutral faces at the center of their computer screen for 500 milliseconds (ms), before the faces disappear. The photographs are juxtaposed from left to right with a space in between. The location of the angry and the neutral faces on the right or on the left of the screen is randomized. After the faces have disappeared, a probe (in the form of a small cross) pops up for 500 ms at the location of one of the two images. The task for the participant is to identify the location of the probe as rapidly and accurately as possible by clicking on a prespecified key on the keyboard, one for the left and one for the right position. Then, another screen with another pair of faces appears and the procedure repeats. A CBM session consists of 360 consecutive screens. A session lasts for about 10 minutes. The participants in our study completed a minimum of 16 sessions (one per day). Section 3 on experimental design describes how

[12]Visual stimuli used in CBM procedures include words, such as in the pioneering work by MacLeod et al. (1986), or faces such as in Eldar and Bar-Haim (2010) which is the protocol that we follow, or See et al. (2009) and Li et al. (2008). Faces are taken from validated databases; we used the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist et al., 1998). Validation guarantees that the expressions portrayed by the actors are accurately recognized by third parties as communicating the intended emotions (Goeleven et al., 2008). The KDEF contains seventy different pairs of faces, half of which use male actors and half female actors.

we ensure compliance throughout the study period. Figure SM.2 in the SM presents an example of the CBM task.

CBM trains participants in the treatment group to avoid threats by presenting the probe always at the location of the neutral face. In the control condition the probe is equally likely to replace the neutral or the angry face. The response latency, i.e., the time that passes from the moment when the probe appears to the moment when the participant clicks on the keyboard to indicate its location, is a measure of attention. Participants have an attention bias if they respond considerably faster to probes replacing the threatening stimulus in comparison with the neutral one.

The efficacy of the CBM treatment in reducing attention bias is supported by a variety of studies. A meta-analysis of CBM in 12 RCTs (Hakamata et al., 2010) found significant improvements in attention bias, with a rather large effect size (d=1.16, CI=(0.82,1.5)), and in various anxiety measures, with a medium effect size (d=0.61, CI= (0.42, 0.81)) on average, and a larger effect for individuals who were pathologically anxious (d=0.78) than for those who were not (d=0.48).

Selected CBM sessions are preceded and followed by 60 screens equivalent to the control condition, i.e. the probe replaces either stimulus with equal frequency. Therefore these longer sessions include a sequence of 60 screens (random probe) + 360 screens (CBM treatment/control condition) + 60 screens (random probe) and are called assessment sessions. These sessions are useful to assess the response latency toward threatening stimuli in the treatment group (which otherwise would not be observed) and therefore validate the efficacy of the CBM treatment over different sessions. Selected days for assessment sessions are the same for all participants, whether in the treatment or control conditions.

3 Experimental Design

In this section we describe our sampling frame, the way in which we administered the CBM treatment and the experimental design.

Our sample comes from a database of students from the University of Lausanne and the Swiss Federal Institute of Technology in Lausanne. A total of 6,000 students received an invitation to complete a questionnaire to measure their trait anxiety, the tendency to experience anxiety in general. We adopt an established questionnaire called the State–Trait Anxiety Inventory (STAI) developed by Spielberger (1980). The STAI is composed of 40 questions addressed at identifying two dimensions of anxiety: a permanent stable

trait (trait anxiety) and a temporary stimulus-induced anxiety state (state anxiety). For either dimension, the STAI produces a scale ranging from 20 to 80 points in which a value above 45 is considered to indicate a highly anxious individual (see Salemink et al., 2009; Yiend et al., 2005).[13] To increase the variation of trait anxiety in the experimental sample while offering the treatment to people who would potentially gain from it, we defined treatment beneficiaries as those who scored a value of at least 35 points in trait anxiety.

The sample includes the first 300 students with trait anxiety above 35 who accepted our invitation. Owing to no-shows ($n = 7$) and a small rate of attrition, the final longitudinal empirical sample consists of 261 subjects. Attrition is not correlated with treatment, and is balanced in terms of observables; see Table SM.1 in SM.[14]

The experiment is based on a longitudinal design with randomization of the treatment at the individual level. Participants took part in a baseline laboratory session that included the first CBM intervention and was an assessment session (i.e., $60 + 360 + 60$ screens). The treatment was assigned randomly when participants attended their first laboratory session.[15] Part of the CBM treatment was conducted at home, over a period of three weeks, for a total of 14 CBM completed sessions (Figure 1 illustrates the timeline of the experiment).[16] A CBM session is considered completed if the participant identifies the location of the probe correctly in a minimum of 90% of the screens. We extensively monitored treatment compliance.[17] The experiment concluded with a follow-up labora-

[13]Typical questions to measure trait anxiety in the STAI ask subjects to indicate which answers among "almost never","sometimes", "often","almost always" they feel satisfied with themselves, or how frequently they feel as happy as others seem to be, etc.

[14]Out of the 300 students, 7 did not show up to the initial laboratory session and were excluded for the study; 32 (15 treated and 17 control subjects) were dropped from the sample because they either did not turn up at the final laboratory session or they did not comply with the rules of the training.

[15]Participants were randomly allocated to computer cubicles in the lab. On the cubicle's desk, they found the CBM instruction pack with an ID number stapled to the first page of the pack. A range of ID numbers were associated with the control condition and a different range was associated with the treatment condition. Nowhere in the instructions was there a reference to the treatment or control condition. The instructions are available upon request.

[16]The CBM training was programmed using *Inquisit 4*. The instructions to access the CBM training include four simple steps: opening a webpage, entering a unique ID, downloading and running the application that produces the CBM task, and completing the task. The URL link to access the training and the dates on which the home-sessions had to be completed were printed in the instruction pack given to participants in their first laboratory sessions. Access to all CBM sessions occurred in the same manner, whether the CBM session was conducted in the laboratory or from a personal computer at home. Participants could ask questions in regard to the procedure to access the CBM training in person, during the first laboratory session, and by email during the training period. The home-session completion and click accuracy were monitored.

[17]To ensure that participants completed the necessary sessions of CBM at home, we sent daily reminder e-mails and called participants on the phone if they missed a CBM session. The CBM sessions had to

tory CBM session that was an assessment session. We incentivized participation with a contribution of CHF 110 (approximately €91) to be paid at the end of the study on condition of full compliance.

The baseline and follow-up laboratory sessions included a cognitive task and were programmed using *zTree* (Fischbacher, 2007)). The task consisted in answering a selection of questions taken from the Raven's Progressive Matrices booklet (Raven et al., 2003). Each question includes a group of logically related geometric designs with one missing piece that the participant had to identify from some available options. Participants were asked to answer correctly as many questions as possible in 10 minutes. Two different sets of questions were drawn at baseline and follow-up to minimize the possibility of memorizing answers. In the first laboratory session, the cognitive task was done before the CBM treatment, whereas in the follow-up laboratory session, the CBM treatment preceded the cognitive task.

Our measure of performance in the cognitive task is the number of attempted questions within the 10 minutes, regardless of whether the answers are correct or incorrect. This choice rests on the purpose of CBM: restoring attentional control resources that enable participants to be more focused and efficient in answering cognitively demanding questions. CBM is not expected to change cognitive ability and therefore we expect the ratio of the number of correct answers to attempted questions to remain constant. An alternative outcome variable would be the number of correct answers. Whereas attempting a question can be directly linked to cognitive resources being freed up, answering a question correctly is a probabilistic outcome conditional on attempting the question. The probability of a correct answer depends on several individual factors (such as subject's IQ, familiarity with the questions, etc.) and a (random) luck component. This individual heterogeneity is expected to increase the residual variance of the measurement. We report our results with respect to correct answers in the Supplementary Material.[18]

For every CBM screen, we collected the length of time (in milliseconds) taken by the

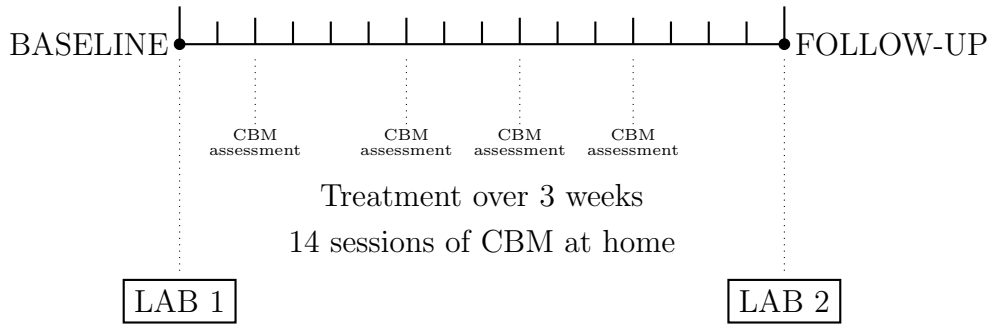
be completed by 10 p.m. every day. If catching up of a missed session was required or the participant did not meet the required 90% score of correct clicks, then the participant was instructed to conduct the CBM session during the weekend. Noncompliers were eliminated from the experiment. In rare instances, subjects completed more than one CBM session on the same day. In these cases, only the first completed session is included in the analysis. Overall average click accuracy per sessions was 95%.

[18]The Raven's questions appeared sequentially on the computer screen. The score in this task – that is, the number of correct answers– was not directly incentivized; however, participants were informed that (i) the experimenter would calculate their score, and (ii) this score would affect successive tasks and the final earnings. We have no reason to believe that subjects did not aim to answer the task questions correctly. The overall ratio of correct answers to attempted questions is 0.65 (pre-treatment); if subjects had answered questions randomly this ratio would be close to 1/6 since there is one correct answer out of six possible options.

participant to identify the location of the probe on the screen. Typically, CBM studies exclude latencies that are too fast or too slow because these are not indicative of sensible response times given the task. We follow Zvielli et al. (2014) and See et al. (2009) and exclude latencies smaller than 200 ms and greater than 1,500 ms, which results in 2.7% of the latencies observations being dropped.

To measure attention bias at baseline we average (within subject) response latencies to threat and neutral stimuli in the first 60 screens of the first laboratory assessment session (in which the probe replaces threat and neutral stimuli with equal frequency for both control and treatment groups). The attention bias measure is $(\bar{N} - \bar{T})_{\text{pre,i}}$, where $\bar{N}$ and $\bar{T}$ are averages within subject over the 60 screens and the subscript "pre" indicates that the measurement is pre-treatment. When $(\bar{N} - \bar{T})_{\text{pre,i}} > 0$ attention bias is present.

Figure 1: Timeline of experiment



1. Cognitive task (timed)
2. 1st CBM session [assessment]

1. 16th (last) CBM session [assessment]
2. Cognitive task (timed)

4 Empirical Strategy

To examine the causal effect of the CBM training on attention bias and performance in the cognitive test, we adopt an empirical model explaining pre-post treatment changes in attempted questions (a difference-in-difference design). This allows us to control for unobserved (time-invariant) factors that may influence the outcome variable and might be correlated with the CBM treatment condition, despite the treatment being randomized by design. The baseline model specification is:

$$y_{it} = \beta_0 + a_i + \beta_1 CBM_{it} + \delta_0 t_{endline} + u_{it}, \quad t = 1, 2. \tag{1}$$

where a_i captures unobserved individual-specific traits; CBM_{it} is an indicator variable

representing treatment assignment, that equals 1 if the subject is in the treatment group and 0 if the subject is in the control group. $t_{endline}$ is an indicator variable for the post-treatment period. Finally, u_{it} is a disturbance term. We estimate the treatment effect by estimating the following first-differenced equation, which removes a_i:

$$\Delta y_i = \beta_1 \Delta CBM_i + \delta_0 + \Delta u_i \tag{2}$$

The empirical specification (2) further controls for observed heterogeneity due to age, trait anxiety (and its squared value) and type of study (in the robustness analysis) measured at the pre-treatment stage. The causal interpretation of the impact of CBM relies on the assumption that $\mathbb{E}(\Delta \text{CBM}_i \Delta u_i) = 0$, i.e., the change in treatment status is assumed to be uncorrelated with the change in the idiosyncratic errors. The ordinary least squares (OLS) estimator of β_1 gives a consistent estimate of the average treatment effect. We bootstrap standard errors at the level of the individual.

We estimate the model by sex. We split the sample by sex because of biological and neurological differences between males and females which may influence our outcome variables differently. The estimation by sex allows the control variables to yield different effects on the outcome in regard to both sign and magnitude (something that we observe empirically, for example for the effect of age).

5 Results

This section discusses two sets of results: first, we evaluate the efficacy of the CBM treatment in reducing attention bias; second, we evaluate the impact on participant performance in the cognitive test.

There are no systematic differences between treatment and control group in terms of individual characteristics, such as age, program of study, years of study, (self-reported) average grades and trait anxiety between the male and female samples (Tables SM.2 for females and SM.3 for males in SM). T-tests of mean differences in attempted questions show statistical significant differences within genders. These differences are due to a small number of 'extreme' observations in the lower tail of the distribution of the outcome variable. The SM provides a robustness analysis on a restricted sample where observations below the 5th and above the 95th percentile of the outcome distribution are excluded (Table SM.7, which we discuss in subsection 5.2). Attention bias at baseline shows significant heterogeneity among participants: attention bias is observed in 54% of female and male samples, with an average attention bias of 21 ms in females and 20 ms in males (see Table

SM.4). This means that our average treatment effect (ATE) estimates are lower bound estimates of the CBM impact, since only about 54% of subjects display an observable attention bias.

In the female sample, we observe a mildly higher baseline $(\bar{N}-\bar{T})_{\text{pre,i}}$ in the treatment arm on average, but the difference is not statistically significant. The average number of attempted questions and correct answers in the cognitive test (which are outcome variables) at baseline are moderately higher in the control group. The difference-in-difference empirical strategy will correct for initial differences between treatment arms. Across gender, we observe females having higher levels of trait anxiety than males (p-value < 0.01), in line with the higher prevalence of anxiety in females in the population. Surprisingly, we do not find a strong correlation between the measures of trait anxiety and attention bias. We adopted the STAI test to measure trait anxiety to keep with the existing literature, however future research may wish to investigate more sophisticated and objective measures, such as biomarkers.

5.1 Validation of Treatment Efficacy

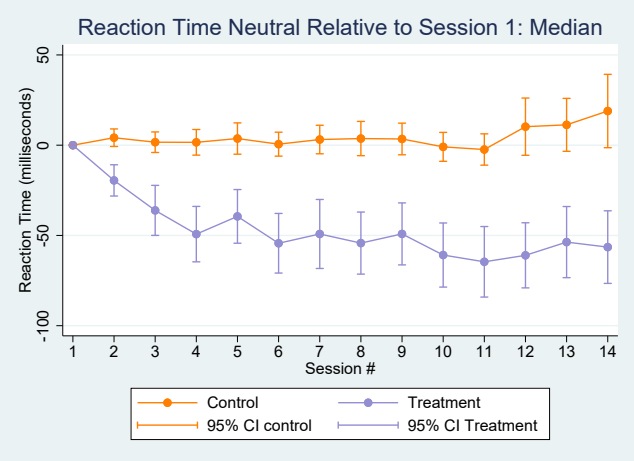
Participants in the CBM treatment condition, where the probe always replaces the neutral stimulus, are trained to become faster at locating the neutral stimulus. Participants in the control condition, where the probe randomly replaces either the neutral or the threatening stimulus, are not expected to change their response times, at least not in a different way for either one of the stimuli (since, potentially, they can become faster at identifying the location of both, an indication of possible 'learning effects'). In the spirit of a validation test, the comparison between response latencies to the *neutral* stimuli in the treatment and control groups over CBM sessions provides a first test of the efficacy of the CBM treatment in reducing the attention bias.

In Figure 2 we compare the *median* response time to neutral stimuli between treatment and control group in each session relative to the initial (i.e., the first CBM session in the laboratory) median response time. Figure 2 shows a significant decrease in response latency in the treatment group over sessions. A large proportion of the decrease occurs within the first four sessions, after which the rate of decrease is slower. Reaction times to neutral stimuli in the control group remain stable, except for some variability in the later sessions.[19] We show the median response latency since it is less sensitive to outliers and

[19]Figure SM.3 in SM shows that, in the control group, the median reaction times to threat stimuli closely mirror the median reaction times to neutral stimuli across sessions. This evidence speaks against the idea that latencies to neutral or threat stimuli change in a different way over time. This also allays

therefore is a more conservative measure than the mean. Figure SM.4 in the SM shows that using the mean reaction times does not produce a different pattern.

Figure 2: Median response time to neutral face relative to the first assessment session



Note: The figure shows the median reaction time towards neutral stimuli in each session relative to the initial median reaction time (session 1 in the laboratory) in the treatment group (purple) and control group (orange). The 95% confidence intervals are computed using the between-subjects variation.

A second way to test the efficacy of CBM is to measure the extent to which an entire course of CBM training reduces attention bias in the treatment group relative to the control. To measure and compare the attention bias, we need to observe the reaction times to neutral and threatening stimuli. We can compare the response times to neutral stimuli between treatment and control groups *in each CBM session*, but we do not have observations for threatening stimuli for participants in the treatment group since they always observe the probe replacing the neutral stimuli. However, both treatment and control groups see neutral and threatening stimuli in the assessment sessions. We evaluate the impact of the entire course of CBM training on attention bias by measuring the attention bias in the 60 screens preceding the first CBM session at baseline (i.e., first assessment session) and in the 60 screens following the last CBM session in the follow-up (post-treatment) laboratory session (which completes the three-week-long CBM treatment) for the treatment and control groups.

We calculate the average change in attention bias, that is $\frac{1}{n}\Sigma_i^n[(\bar{N}-\bar{T})_{\text{post,i}}-(\bar{N}-\bar{T})_{\text{pre,i}}]$ where $\bar{N}$ and $\bar{T}$ are the (average) reaction times (in milliseconds, and the average is

the concern that latencies toward neutral stimuli might be easier to modify relative to latencies to threat stimuli.

taken over the 60 screens within subject) to neutral (N) and threat (T) stimuli and the subscripts 'post' and 'pre' indicate that the measurement is post-treatment and pre-treatment, respectively. If CBM is effective, one would expect a negative overall difference (since attention bias post-treatment will be smaller than the initial bias).

Table 1 reports the CBM average treatment effect on attention bias on all females and males (Panel: Everyone) and on the sample of female and male participants with pre-treatment attention bias (Panel: Conditional on attention bias). The average treatment impact is a reduction in attention bias of -18 ms for females. There is no evidence of attention bias reduction for males. The CBM impact on subjects with (pre-treatment) attention bias gives an indication of the average CBM treatment effect on the *treated*. The unconditional effects are plotted in Figure 3.[20] CBM-treated females with attention bias show a reduction of -23 ms on average (p-value $= 0.001$), as compared with females with attention bias in the control group. Table SM.6 shows that larger decreases in attention bias occur among female participants who start with a higher pre-treatment attention bias. In this category, CBM reduces approximately 60% of the average attention bias.

5.2 Impacts on Cognitive Performance

Table 2 reports the estimated impact of CBM on performance in the cognitive test, measured as the number of attempted questions as described in Section 3. CBM-treated female participants significantly improve their performance; however, there is no significant impact for males on average, although the coefficient is positive. The magnitude of the impact on females is large: the impact equates to approximately one additional attempted question above an average of 2.7 (equivalent to an approximately 37% increase). These results are consistent with the effects of CBM reported in Section 5.1, which suggest that CBM reduces attention bias for treated females but not for treated males.

One explanation for the gender heterogeneity of the treatment impact is that the effects of CBM are more visible at higher levels of anxiety, which females display more

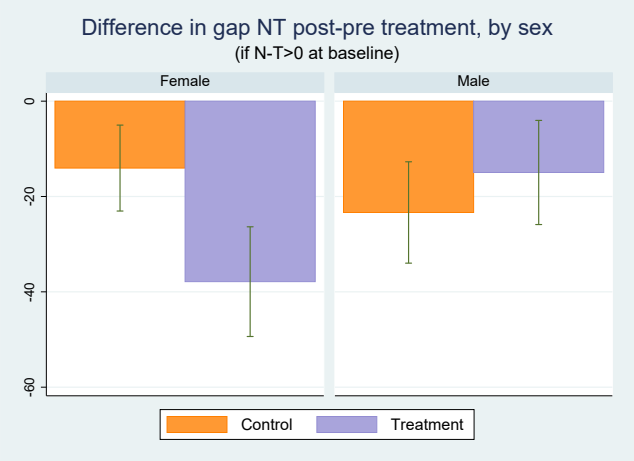
[20] One may expect the change in attention bias between post- and pre-treatment to be zero for the control group. While theoretically possible, this does not happen empirically. We observe that for control group participants who have attention bias at baseline, the gap $(\bar{N}-\bar{T})_{\text{post},i}$ in the post-treatment session shrinks relative to its pre-treatment value, so that the overall difference post- and pre-treatment is negative on average. Reduction in attention bias in the control group is a feature reported in other evaluations as well (Eldar and Bar-Haim, 2010). It would be concerning if $\bar{N}$ and $\bar{T}$ in the *control* group went in opposite directions (e.g., with $\bar{T}$ increasing and $\bar{N}$ decreasing, or vice versa). Panel A in Table SM.5 in the SM reports $\bar{N}$ and $\bar{T}$ of control participants with baseline attention bias for each session and shows that the two measures move in the same direction. This is reassuring. A similar pattern is observed in the entire sample (panel B of Table SM.5). Furthermore, we use a difference-in-difference approach, which controls for pre–post-treatment changes in the control group.

Table 1: CBM impact on changes in attention bias: everyone and conditional on Attention bias, N-T>0

Panel: Everyone	Female	Male	Female	Male
CBM	-18.369***	3.968	-16.691**	3.910
	(7.008)	(6.310)	(6.953)	(6.489)
Age			2.655*	1.580
			(1.485)	(1.286)
Trait anxiety (pre-treatment)			-2.909	0.618
			(2.942)	(2.744)
Trait anxiety (squared)			0.033	-0.004
			(0.033)	(0.031)
Constant	3.224	-2.639	6.251	-53.295
	(4.650)	(4.934)	(61.042)	(68.566)
adj.R^2	0.053	-0.005	0.066	-0.018
N	129	126	129	125
Panel: Conditional on Attention bias, N-T>0	Female	Male	Female	Male
CBM	-23.823***	8.389	-22.666***	7.056
	(6.870)	(8.007)	(7.961)	(7.763)
Age			-0.098	1.201
			(1.752)	(1.671)
Trait anxiety (pre-treatment)			-2.829	-0.208
			(3.249)	(2.697)
Trait anxiety (squared)			0.031	0.007
			(0.036)	(0.030)
Constant	-14.038***	-23.351***	47.857	-53.408
	(4.617)	(5.393)	(67.347)	(68.152)
adj.R^2	0.127	0.004	0.102	-0.022
N	69	68	69	67

Note: The table shows the CBM impact on changes in attention bias between pre and post-treatment (equation 2). Attention bias is measured as the difference in response latency to neutral versus threat stimuli. Regressions in panel: Conditional on Attention bias are estimated on the sample of subjects with pre-treatment positive attention bias. Estimations are based on OLS regressions. Standard errors are bootstrapped with 150 replications and reported in brackets. Levels of significance: $^*p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

Figure 3: Change in attention bias, by treatment and sex



Note: The figure shows the reduction in attention bias pre- and post- treatment for the female and male samples in treatment and control groups. The figure plots the average unconditional changes, $\frac{1}{n}\Sigma_i^n[(\bar{N}-\bar{T})_{post,i}-(\bar{N}-\bar{T})_{pre,i}]$. For the changes conditional on controls, see Table 1.

than males. Consistent with this interpretation, Table 3 confirms that CBM treatment is more effective on those females scoring baseline anxiety levels higher than the females group's median. The impact on anxious females is three times as large than on less anxious females (p-value < 0.000). As a robustness test, in Table SM.9 in the SM we show that the gender heterogeneity of the treatment impact persists when the number of correct answers in the cognitive test is used as the outcome variable. The average treatment effect on the entire female sample (Panel A) is, however, less precisely estimated due to a larger unobserved heterogeneity in the measurement. These estimates match neatly those in the main analysis: treated anxious females, who attempt more questions after treatment, also increase their score of correct answers by a similar proportion. As cognitive attentional resources are restored by the CBM treatment, anxious (female) participants are able to attempt more questions in a given time and consequently achieve better scores in the cognitive test. The results in Table SM.9 (Panel A) suggest that CBM may not change the performance ranking of the average woman but it may improve the performance ranking of anxious women. Taken together, these results suggest that anxious females are those who benefit most from CBM treatment.

We also conduct a number of robustness tests. First, one might worry that students in science- and mathematics-based study programs[21] are more accustomed to tests similar

[21]These include Biology, Medicine, Life Sciences, Geology Architecture, Engineering, Computer Science, Business and Economics, Management of Technology.

Table 2: CBM impact on changes in attempted questions in cognitive test

	Male	Female	Male	Female
CBM	-0.005	0.995**	0.148	1.106**
	(0.462)	(0.458)	(0.460)	(0.458)
Trait anxiety (pre-treatment)			0.412**	-0.476**
			(0.180)	(0.242)
Trait anxiety (squared)			-0.005**	0.005*
			(0.002)	(0.003)
Age			0.340***	-0.016
			(0.092)	(0.116)
Constant	2.841***	2.697***	-12.548***	13.070***
	(0.290)	(0.307)	(4.439)	(4.778)
R^2	0.000	0.030	0.110	0.076
N	130	131	130	131
Mean Δ Attempted (control)	2.841	2.696	2.841	2.696

Note: The table shows the CBM impact on (changes in) attempted questions in the Raven's Matrices test between pre- and post-treatment by gender estimated according to equation 2 in columns 1-2 and adjusted for pre-treatment covariates in columns 3.4. Estimations are based on OLS regressions. Standard errors are bootstrapped with 150 replications and reported in brackets. Levels of significance: $^*p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

to the task used in the laboratory sessions and hence perform better than students from other disciplines. This would bias our results *within* gender if the students in science and mathematics programs were also disproportionally represented in the treatment group. This is not the case for either females or males (see Tables SM.2 for females and SM.3 for males in SM). Controlling for enrollment in a science/mathematics program as an indicator in a robustness test does not change the results (Table SM.10, columns 1 and 2, in SM).[22]

Second, we cannot exclude that the length of higher education experience has an impact on performance via other channels – through, for example, "training" students to be more resilient to anxiety – which may interact with the effect of CBM and be correlated with participation in the experiment (but not the treatment allocation which was randomized).[23] When we restrict the sample to first-year students, for whom the effect of education training is minimal since they had been in higher education for about one month at the start of the CBM training, we still observe an impact on treated females (Table SM.10, columns 3 and 4.).

[22]Note that female participants in humanities programs have a higher average number of attempted questions at baseline compared with females in science- and mathematics-based degrees, while it is the opposite for males. Since it is arguably harder to increase performance when starting from a higher baseline value and females are over-represented in humanities degrees, our main results are likely to be attenuated.

[23]We observe a higher number of participants from first-year bachelor students (39%) than from second- and third-year and Master's students.

Table 3: CBM impact on changes in attempted questions in cognitive test by trait anxiety and by gender

Female sample	Low anxiety	High anxiety	Low anxiety	High anxiety
CBM	0.458	1.594**	0.499	1.642**
	(0.606)	(0.728)	(0.703)	(0.780)
Age			-0.098	0.038
			(0.154)	(0.187)
Trait anxiety			-1.157	0.288
(pre-treatment)			(0.953)	(1.075)
Trait anxiety			0.015	-0.002
(squared)			(0.014)	(0.010)
Constant	2.971***	2.406***	26.959	-9.064
	(0.392)	(0.471)	(17.308)	(28.713)
R^2	0.007	0.068	0.078	0.121
N	69	62	69	62
Mean Δ Attempted (control)	2.97	2.40	2.97	2.40

Male sample	Low anxiety	High anxiety	Low anxiety	High anxiety
CBM	0.242	-0.248	0.698	0.080
	(0.585)	(0.734)	(0.767)	(0.736)
Age			0.255**	0.457***
			(0.112)	(0.171)
Trait anxiety			2.004*	-0.706
(pre-treatment)			(1.079)	(0.784)
Trait anxiety			-0.030	0.006
(squared)			(0.017)	(0.008)
Constant	2.758***	2.933***	-36.158*	12.487
	(0.331)	(0.482)	(17.340)	(20.327)
R^2	0.002	0.002	0.143	0.149
N	65	65	65	65
Mean Δ Attempted (control)	2.75	2.93	2.75	2.93

Note: The table shows the CBM impact on (changes in) attempted questions in the Raven's Matrices test between pre- and post-treatment estimated according to equation 2 (adjusted for covariates) by anxious and non-anxious type. A subject is classified in the group of 'High anxiety' if her Trait Anxiety score is higher than the median Trait Anxiety within her gender group, otherwise the subject is classified in the group 'Low anxiety'. Estimations are based on OLS regressions. Standard errors are bootstrapped with 150 replications and reported in brackets. Levels of significance: $^*p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

Several additional robustness tests are presented in the SM. We test the possibility that confounding effects attributable to observations coming from the tails of the outcome distribution (within gender) might be impacting the results. Table SM.7 in the SM reports the treatment effect on a 'trimmed' sample from which observations equal or below the 5th percentile and equal or above the 95th percentile of the (pre-treatment) outcome distribution (within gender) are excluded. The cost of trimming is a reduction in statistical power. However, the magnitude of the treatment effect is unaltered across specifications and is very similar to the regressions using the full sample.

Despite the treatment randomisation, one may worry about the influence of unaccounted unobservables. Table SM.8 in the SM presents evidence on how strong the selection on unobservables would need to be in order to reduce the coefficient of the treatment effect to zero using the methods suggested by Altonji et al. (2005) and Oster (2019). Both Altonji's and Oster's ratios statistics are negative for both female and male samples. Negative ratios arise when the observable controls are on average negatively correlated with the treatment and positively with the outcome (or vice-versa). The test assumes the unobservables have the same pattern of correlation as the included variables. The tests' negative ratios suggest that our estimates are attenuated towards zero by unobservable characteristics (i.e. the estimates are downward biased).

To determine whether the impact of CBM training is long-lived and improves actual examination performance, we collected the participants' examination results in the exam session which took place about three months after the follow-up data collection.[24] Examination results have a low variability and we do not observe a significant impact on average grade. However, the negative correlation between trait anxiety and university examination results that exists among females in the control group is absent in the treatment group three months after the training. This suggests that the intervention may generate long-lasting benefits (Table 4).

6 Conclusions

Lower performance in cognitive tasks is associated with attention bias towards negative stimuli. Attention bias is associated to anxiety and has a detrimental effect on perfor-

[24]On approval by the student faculties of affiliation, we were able to retrieve examination data for 136 subjects (52% of the original sample of participants) directly from faculty administration offices. The data were assembled by a member of staff at the University of Lausanne. The authors never had access to any personal data available to the administration offices that could be used to link the students in our sample to their examination data and do not own the examination data.

Table 4: Long term effects of CBM on correlation between university exam grades and anxiety trait scores

	Male	Female
Treatment group:		
Correlation	0.031	-0.125
(p-value)	(0.877)	(0.475)
Tracked subjects	27	35
Average exam grades	4.117	4.159
SD of exam grades	1.022	1.219
Control Group:		
Correlation	0.152	-0.339
(p-value)	(0.479)	(0.072)
Tracked subjects	24	29
Average exam grade	4.375	4.446
SD of exam grades	0.87	0.551

Note: The table shows the Pearson's correlation (corr) between trait anxiety scores and university exam grades (averaged across exam sat) by treatment and control group and by sex (sample of N=136). The correlation's p-values are reported in brackets. 'tracked subjects' indicate the number of subject for whom we were able to receive exam data.

mance because it diverts cognitive resources away from the completion of a task. We randomized an antianxiety digital treatment, cognitive bias manipulation (CBM), that aims at reducing attention bias. Existing studies focused on pathologically anxious subjects, whereas the participants of our experiment are college students.

The results show that CBM reduces attention bias and improves the cognitive performance of females in the treatment group. The magnitude of the impact is large (37% increase in performance) and is associated to the more anxious females in the sample. There is no significant effect for males. Since according to medical statistics anxiety prevalence is higher in females on average, these results suggest the potential for cognitive bias modification to be an effective way to reduce the detrimental effects of anxiety on cognitive performance and the resulting gender disparities in opportunities.

Future studies may seek to replicate these results and analyse hypotheses that we were unable to test due to lack of data. One hypothesis, suggested by an anonymous referee, concerns a differential reaction in latencies to stimuli when the face shown corresponds with the sex of the respondent. This would be a useful addition to the current results because, if it is the case that the participant's latency responds better to same-gender faces, then CBM training programs can be easily personalised to increase their effectiveness.

CBM interventions are shorter, cheaper and more easily administered than alternative available treatments, such as cognitive behavioral therapy and medications. As an

illustration, a private session of CBT currently costs between £40 and £100, according to NHS statistics, whereas the administration of CBM, once programmed, can run at almost zero marginal costs.

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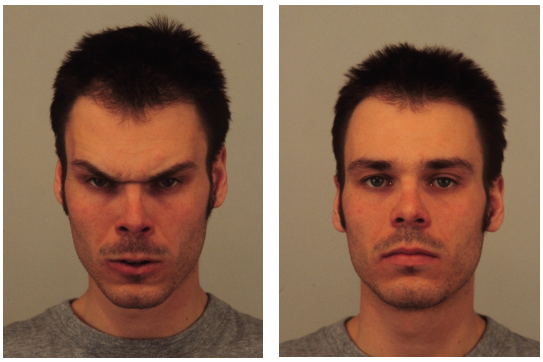
SUPPLEMENTARY MATERIAL

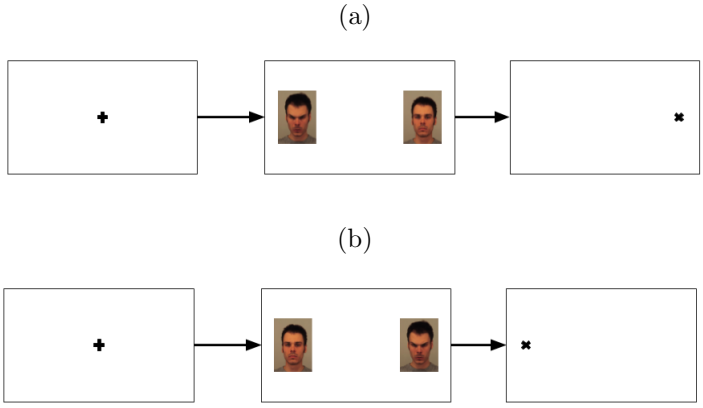
FIGURES

Figure SM.1: Example of a face pair



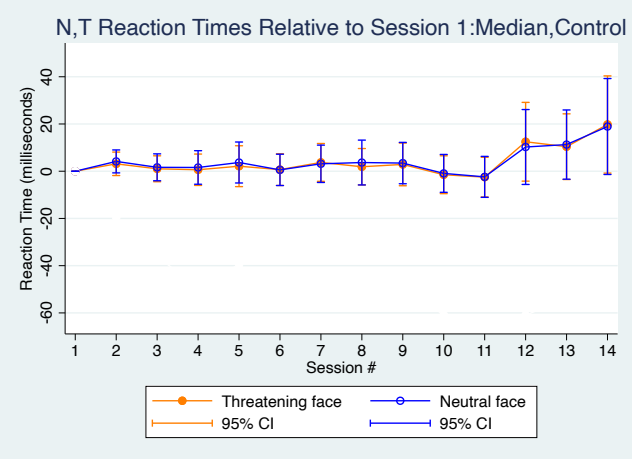
Note: From left to right, photo with angry expression and photo with neutral expression. The sample consisted of 70 amateur actors, 35 females and 35 males, of ages between 20 and 30 years taken from the Karolinska Directed Emotional Faces database.

Figure SM.2: Sequences of screens in the treatment condition of CBM



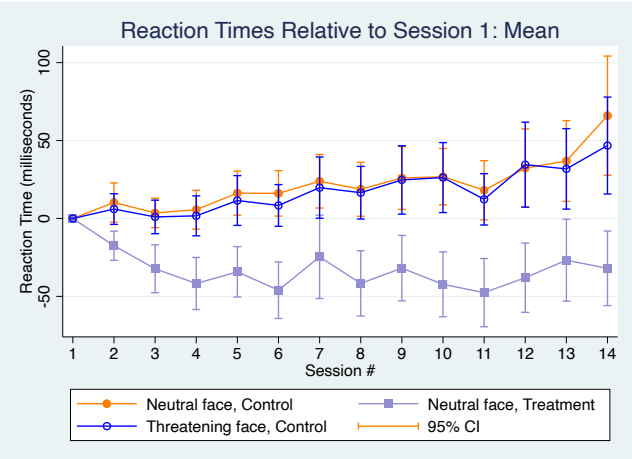
Note: The two stimuli differing in emotional valence - neutral vs. threat - are presented simultaneously following the centering of the field of vision indicated by a fixation cross. Each image appears randomly on either the left or right side of the screen. Both images (a) and (b) here show that probe appears behind the neutral facial expression, but in different locations.

Figure SM.3: Response time to threatening and neutral faces relative to the first assessment session, Median (Control Group)



Note: The figure shows the median reaction time towards threatening (orange circle) and neutral (blue hollow circle) stimuli in each session relative to the initial median reaction time (session 1 in laboratory) for the control group. Threatening faces appear only to participants in the control group.

Figure SM.4: Response times relative to the first assessment session, Mean



Note: The figure shows the mean reaction time towards neutral stimuli in each session relative to the initial mean reaction time (session 1) in the treatment group (purple square) and control group (orange circle). It also shows the mean reaction time towards threatening stimuli in each session relative to the initial mean reaction time (session 1) for the control group (blue hollow circle). Threatening faces appear only to participants in the control group.

TABLES

Table SM.1: Attrition analysis

CBM	-0.286	-0.385	-0.388
	(0.465)	(0.494)	(0.561)
Male		0.710	0.705
		(0.439)	(0.485)
Age			-0.015
			(0.102)
Constant	-2.220***	-2.633***	-2.298
	(0.274)	(0.403)	(2.173)
N	289	288	288
R^2	0.003	0.021	0.021

Note: The table shows logistic regressions where the dependent variable is equal to 1 if the subject was present in the first experimental session but drops from the sample afterwards (and zero otherwise). Estimations are based on OLS regressions. Standard errors are bootstrapped with 150 replications and reported in brackets. Levels of significance: $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

Table SM.2: Balance table: female sample

	(1) TG		(2) Control		(3) Test	
	Mean	S.D.	Mean	S.D.	T test/Chi2♯	P-value
N	65		66		131	
Age	20.81	(2.105)	21.13	(2.794)	0.741	0.459
Grade (past year)	4.606	(0.540)	4.537	(0.639)	-0.659	0.510
Trait anxiety (pre-treatment)	43.092	(8.742)	43.681	(9.978)	0.3594	0.719
N-T (baseline)	6.968	(29.18)	-2.916	(32.90)	-1.819	0.071
Attempted questions (pre-treatment)	8.738	(3.649)	10.12	(3.764)	2.134	0.034
Correct answers (pre-treatment)	5.908	(2.199)	6.576	(2.113)	1.773	0.078
Field of studies:						
Humanities	0.475	(0.503)	0.428	(0.498)	0.274♯	0.600
Economics/Technical	0.229	(0.424)	0.238	(0.429)	0.012♯	0.910
Sciences	0.295	(0.459)	0.333	(0.475)	0.210♯	0.647
Year of study:						
BSc year 1	0.415	(0.496)	0.424	(0.498)	0.010	0.918
BSc year 2	0.230	(0.424)	0.181	(0.388)	0.479	0.489
BSc year 3	0.076	(0.268)	0.090	(0.289)	0.083	0.773
MSc year 1	0.200	(0.403)	0.136	(0.345)	0.949	0.330
MSc year 2	0.076	(0.268)	0.121	(0.328)	0.718	0.397
Other years	0.000	(0.000)	0.045	(0.209)	3.023	0.082

Note: The table shows the means and standard deviations (S.D.) of listed variables for the female sample. The final columns report the T-tests (for continuous variables) and Chi-squared tests (for binary variables) for equality of means between treatment arms and the test's p-values. Humanities includes degrees in Literature, Law, Political Sciences; Economics/Technical includes degrees in Business and Economics, Management and Technology; Sciences includes degrees in Biology, Medicine, Life Sciences, Geology, Architecture, Engineering, Computer Science.

Table SM.3: Balance table: male sample

	(1) TG		(2) Control		(3) Test	
	Mean	S.D.	Mean	S.D.	T-test/Chi2♯	P-value
N	67		63		130	
Age	20.74	(2.186)	21.13	(2.587)	0.913	0.362
Grade (past year)	4.659	(0.560)	4.568	(0.518)	-0.963	0.337
Trait anxiety (pre-treatment)	41.552	(8.733)	39.301	(8.329)	-1.501	0.135
N-T (baseline)	1.187	(26.926)	1.628	(28.006)	0.091	0.927
Attempted questions (pre-treatment)	9.575	(3.258)	8.190	(2.401)	-2.386	0.0071
Correct answers (pre-treatment)	6.462	(2.30)	6.206	(1.676)	-0.721	0.472
Field of studies:						
Humanities	0.129	(0.337)	0.193	(0.398)	0.953♯	0.329
Economics/Technical	0.403	(0.494)	0.354	(0.482)	0.308♯	0.579
Science	0.467	(0.503)	0.451	(0.501)	0.032♯	0.857
Year of study:						
BSc year 1	0.318	(0.469)	0.412	(0.496)	1.243	0.265
BSc year 2	0.257	(0.440)	0.142	(0.352)	22.635	0.104
BSc year 3	0.181	(0.388)	0.126	(0.335)	0.739	0.390
MSc year 1	0.166	(0.375)	0.158	(0.368)	0.0149	0.903
MSc year 2	0.030	(0.172)	0.126	(0.335)	0.4213	0.040
Other years	0.045	(0.209)	0.0317	(0.176)	0.162	0.687

Note: The table shows the means and standard deviations (S.D.) of listed variables for the male sample. The final columns report the T-tests (for continuous variables) and Chi-squared tests (for binary variables) for equality of means between treatment arms and the test's p-values. Humanities includes degrees in Literature, Law, Political Sciences; Economics/Technical includes degrees in Business and Economics, Management and Technology; Sciences includes degrees in Biology, Medicine, Life Sciences, Geology, Architecture, Engineering, Computer Science.

Table SM.4: Descriptive statistics by sex

	Females	Males	Total	T-Test/Chi2♯
Age	20.977	20.908	20.943	0.230
Grade (past year)	4.572	4.615	4.593	-0.622
N-T (pre-treatment)	1.989	1.401	1.696	0.161
Percentage of subjects with (N-T)>0	54.200	53.850	54.020	0.057
Attention bias (ms)	21.090	20.390	20.743	0.232
Trait anxiety (pre-treatment)	43.389	40.462	41.931	2.634***
Attempted questions (pre-treatment)	9.435	8.885	9.161	1.318
Correct answers (pre-treatment)	6.244	6.338	6.291	-0.362
Field of study:				
Humanities	0.452	0.160	0.305	5.246***
Economics/Technical	0.233	0.376	0.014	-2.454**
Sciences	0.314	0.464	0.389	-2.437**

Note: The table shows the means of listed variables for the entire sample by gender. The final columns report the T-tests (for continuous variables) and Chi-squared tests (for binary variables) for equality of means between genders and the conventional stars symbol for test significance. Humanities includes degrees in Literature, Law, Political Sciences; Economics/Technical includes degrees in Business and Economics, Management and Technology; Sciences includes degrees in Biology, Medicine, Life Sciences, Geology, Architecture, Engineering, Computer Science.

Table SM.5: Control Group's reaction times by session

Panel A: Subjects in the Control Group with Attention Bias at Baseline, N-T>0

		Pre-treatment	CBM sessions															Post-treatment
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Female	N	371.4	368.3	366.2	363.2	365.6	380.2	369.4	370.8	374.8	374.8	375.6	365.8	370.8	382.9	402.6	378.5	346.2	340.7
	T	356.3	369.1	368.0	362.6	363.2	383.6	367.7	370.5	372.7	371.3	376.3	363.1	371.4	382.5	402.8	376.7	344.0	339.1
	N-T	15.1	-0.8	-1.8	0.6	2.3	-3.4	1.8	0.3	2.1	3.5	-0.8	2.7	-0.6	0.4	-0.2	1.8	2.2	1.6
Male	N	386.6	361.7	370.8	367.2	366.6	372.3	369.7	376.9	372.9	381.2	373.1	374.4	375.1	377.9	391.1	393.9	338.1	338.9
	T	366.1	357.9	370.2	365.4	368.2	367.2	370.4	374.9	371.7	379.5	371.3	371.9	379.9	376.9	390.3	390.2	339.5	343.4
	N-T	20.5	3.8	0.6	1.9	-1.6	5.1	-0.7	2.1	1.2	1.7	1.8	2.5	-4.7	0.9	0.9	3.6	-1.4	-4.4

Panel B: Everyone in the Control Group

		Pre-treatment	CBM sessions															Post-treatment
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Female	N	378.9	378.0	371.4	370.1	369.9	379.0	372.0	375.6	377.7	376.8	377.1	373.1	379.4	384.6	395.0	379.2	349.8	345.1
	T	381.8	378.1	371.3	369.1	368.4	380.5	371.3	374.8	376.8	374.5	375.2	372.8	379.5	383.2	392.8	378.4	348.0	343.0
N-T		-2.9	-0.1	0.1	1.0	1.5	-1.5	0.7	0.8	0.9	2.3	1.9	0.2	-0.1	1.4	2.2	0.9	1.8	2.1
Male	N	368.8	359.4	371.6	370.3	370.9	375.1	377.9	382.6	378.7	386.7	377.4	374.7	382.3	382.2	389.8	390.5	336.8	333.3
	T	367.1	356.8	370.0	368.6	371.0	372.2	375.6	379.3	378.1	385.3	375.2	371.5	386.5	381.5	389.8	389.6	337.4	335.2
N-T		1.6	2.6	1.6	1.7	-0.1	2.8	2.3	3.3	0.6	1.4	2.2	3.2	-4.1	0.7	-0.1	0.9	-0.6	-1.9

Note: The table shows the control group's reaction times to neutral ($\bar{N}$) and to threat ($\bar{T}$) stimuli in the pre-treatment session, each of the CBM sessions, the post-treatment session.

Table SM.6: CBM impact on changes in attention bias by severity of (pre-treatment) attention bias: female sample

			Conditional on Attention Bias, N-T>0	
Female sample	Low bias	High bias	Low bias	High bias
CBM	-8.167	-20.837**	-7.401	-19.149*
	(7.511)	(9.465)	(8.221)	(11.241)
Age			-1.269	1.265
			(1.705)	(2.023)
Trait anxiety (pre-treatment)			-1.499	-4.229
			(2.889)	(6.154)
Trait anxiety (squared)			0.017	0.046
			(0.032)	(0.068)
Pre-treatment				
Mean Attention Bias (ms)	7.65	33.43	7.65	33.43
R^2	0.043	0.105	0.091	0.141
N	33	36	33	36

Note: The table shows the CBM impact on changes in attention bias between pre- and post-treatment (equation 2) by severity of attention bias at baseline in the female sample only. Attention bias is measured as the difference in response latency to neutral versus threat stimuli. The sample includes females who display positive (pre-treatment) attention bias. 'Low bias' indicates pre-treatment attention bias lower than the median values; 'high bias' indicates attention bias higher than the median value. Estimations are based on OLS regressions. Standard errors are bootstrapped with 150 replications and reported in brackets. Levels of significance: $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

Table SM.7: Robustness: CBM impact on pre-post treatment changes in attempted questions, trimmed sample

	(1)	(2)	(3)	(4)
	Male	Female	Male	Female
CBM	-0.055	0.982*	0.189	0.929*
	(0.515)	(0.564)	(0.481)	(0.514)
Age	0.312***	-0.001	0.287***	-0.033
	(0.097)	(0.139)	(0.098)	(0.136)
Trait anxiety (pre-treatment)	0.409*	-0.352*	0.381**	-0.320*
	(0.219)	(0.198)	(0.193)	(0.194)
Trait anxiety (squared)	-0.005**	0.004*	-0.005**	0.003
	(0.002)	(0.002)	(0.002)	(0.002)
Attempted questions (pre-treatment)			-0.396***	-0.337***
			(0.140)	(0.096)
Constant	-11.706**	10.319**	-7.506	13.591***
	(5.040)	(4.216)	(4.819)	(4.064)
R^2	0.113	0.051	0.197	0.147
N	109	106	109	106

Note: The table shows the CBM impact on changes in attempted questions in the Raven's Matrices test by gender (equation 2 in the manuscript) in a trimmed sample where observations below or equal to the 5^{th} and above or equal the 95^{th} percentile have been dropped. Estimations are based on OLS regressions. Standard errors are bootstrapped with 150 replications and reported in brackets. Levels of significance: $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

Table SM.8: Omitted Variable Bias: Oster (2019)/ Altonji (2005) ratios

	Control set	Oster (2019) bias-adjusted test	Oster (2019) bounds for β	Altonji, Elder, Taber (2005) test
Female	as in Table 2	[<0]	[1.10, 3.77]	[<0]
Male	as in Table 2	[<0]	[0.14, 1.59]	[<0]

Note: The table reports the degree of selection on unobservables relative to observables which is required to produce a treatment effect of zero, using the methods of Altonji et al. (2005) and Oster (2019) (the δ in their papers). The entry [<0] indicates that the respective ratios are negative. This is because the observable controls are on average positively correlated with the outcome variable and negatively with the treatment, suggesting a downward bias in the OLS estimates (provided the unobservables have similar correlation patterns with the outcome and the treatment as the included observables). The control variables included are those presented in Table 2 of the paper. The *bounds* for β are calculated according to Oster (2019), page 18, using the conservative assumption that the maximum explainable variation is 1 ($R_{max} = 1$) and $\delta = 1$.

Table SM.9: Robustness: CBM impact on pre-post treatment changes in correct answers

	(1)	(2)	(3)
Panel A: Female			
	All	Low anxiety	High anxiety
CBM	0.595*	-0.564	1.646***
	(0.412)	(0.550)	(0.619)
Trait anxiety (pre-treatment)	-0.169	-0.692	1.009
	(0.161)	(0.899)	(0.860)
Trait anxiety (squared)	0.002	0.008	-0.009
	(0.002)	(0.013)	(0.008)
Age	-0.080	-0.132	-0.066
	(0.087)	(0.150)	(0.124)
Constant	7.722**	19.167	-24.547
	(3.751)	(15.935)	(23.424)
R^2	0.035	0.091	0.153
N	131	69	62
Panel B: Male			
	All	Low anxiety	High anxiety
CBM	-0.187	0.019	-0.453
	(0.382)	(0.485)	(0.447)
Trait anxiety (pre-treatment)	0.194	0.124	0.441
	(0.162)	(1.017)	(0.481)
Trait anxiety (squared)	-0.002	-0.001	-0.005
	(0.002)	(0.015)	(0.005)
Age	-0.078	-0.003	-0.154
	(0.061)	(0.112)	(0.105)
Constant	-0.217	-1.050	-4.842
	(4.169)	(16.642)	(12.039)
R^2	0.033	0.013	0.085
N	130	65	65

Note: The table shows the CBM impact on changes in correct answers among female participants (Panel A) and male participants (Panel B). A subject is classified in the group of 'High anxiety' if their trait anxiety score is higher than the median trait anxiety within their gender group, otherwise the subject is classified in the group 'Low anxiety'. Estimations are based on OLS regressions. Standard errors are bootstrapped with 150 replications and reported in brackets. The stars indicate the statistical significance of the one-sided test H_0: $\beta_{CBM} \leq 0$, H_A: $\beta_{CBM} > 0$ using the convention $^*p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

Table SM.10: Robustness: CBM impact on pre-post treatment changes in attempted questions, degree types and first year of studies

	Male	Female	Male First Year	Female First Year
CBM	0.159	1.133**	-0.099	2.092**
	(0.499)	(0.500)	(0.731)	(0.861)
Age	0.292***	-0.011	0.329*	0.389
	(0.111)	(0.131)	(0.179)	(0.465)
Trait anxiety (pre-treatment)	0.384**	-0.453**	0.844**	-0.391
	(0.188)	(0.210)	(0.355)	(0.341)
Trait anxiety (squared)	-0.005**	0.005**	-0.010**	0.005
	(0.002)	(0.002)	(0.004)	(0.004)
Science degree (=1)	-1.257**	0.529		
	(0.603)	(0.550)		
Constant	-9.988**	12.100**	-20.491***	2.530
	(4.934)	(4.853)	(7.232)	(10.019)
R^2	0.138	0.084	0.260	0.145
N	130	131	48	55
Mean Δ Attempted (control)	2.84	2.69	3.42	2.57
Mean Attempted at baseline (Science degree)	8.97	8.97		
Mean Attempted at baseline (Humanities)	8.52	9.93		

Note: The table shows the CBM impact on changes in attempted questions in the Raven's Matrices test between pre- and post-treatment by gender estimated according to equation (2). The estimation sample of columns 3 and 4 is restricted to first year bachelor students. 'Science degree' indicates enrollment into a quantitative study program, including Biology, Medicine, Life Sciences, Geology, Architecture, Engineering, Computer Science, Business and Economics, Management and Technology. Estimations are based on OLS regressions. Standard errors are bootstrapped with 150 replications and reported in brackets. Levels of significance: $^*p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

Table SM.11: Mean value of attention bias, attempted questions and correct answers: pre-treatment, post-treatment and change

	Attention bias (mean)			Attempted questions (mean)			Correct answers (mean)		
	(1) Pre-treatment	(2) Post-treatment	(3) Change (post-pre)	(1) Pre-treatment	(2) Post-treatment	(3) Change (post-pre)	(1) Pre-treatment	(2) Post-treatment	(3) Change (post-pre)
Panel A: Female									
Treatment group	6.969	-8.176	-15.145	8.738	12.431	3.692	5.908	8.431	2.523
Control group	-2.916	-0.352	3.224	10.121	12.818	2.697	6.576	8.500	1.924
Difference-in-Difference			-18.369			0.995			0.599
Panel B: Male									
Treatment group	1.188	1.718	1.329	9.537	12.373	2.836	6.463	8.075	1.612
Control group	1.629	-0.859	-2.640	8.190	11.032	2.841	6.206	8.000	1.794
Difference-in-Difference			3.969			-0.005			-0.182