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Single-Session Cognitive Bias Modification of Interpretations Training in High-Anxious Adolescents

Xiaoxue Fu, MSc
Department of Psychology, Pennsylvania State University, University Park, United States

Yasong Du, MD, PhD
Department of Child and Adolescent Psychiatry, Shanghai Mental Health Center, China

Shun Au, MPhil, MBA
Chinese Mental Health Association, London, United Kingdom

Jennifer Y. F. Lau, PhD
Department of Experimental Psychology, University of Oxford, United Kingdom
Institute of Psychiatry, Psychology and Neuroscience, King's College London, United Kingdom

Anxiety disorders in youths are globally prevalent and carry impairing, long-lasting effects. Interpreting ambiguous cues negatively may be causally related to adolescent anxiety. Extending cognitive bias modification of interpretations (CBM-I) training, which counters anxiety by encouraging positive interpretations, to anxious adolescents could inform the design of new interventions. The study investigates whether single-session CBM-I training (a) altered interpretation biases and negative mood in adolescents selected for high anxiety and (b) whether these training-associated changes were larger than those reported in low-anxious adolescents. Seventy-seven Chinese adolescents received either positive or control training. Positive training encouraged endorsement of positive interpretations of ambiguous scenarios while on control training trials, half of the scenarios were resolved positively and half negatively. A single session of CBM-I altered interpretation biases across all individuals, $F(1, 52) = 10.63$, $p < .01$, $\eta^2 = .17$. However, no training effects on mood measures emerged (all $ps > .05$). Training effects were not consistently moderated by baseline trait anxiety. Multisession CBM-I may be needed for mood changes to occur.

Keywords: cognitive bias modification; adolescence; interpretation bias; anxiety

Anxiety disorders in youths are prevalent and debilitating in both western (Merikangas et al., 2010; Woodward & Fergusson, 2001) and non-western societies (Li, Ang, & Lee, 2008). Untreated, adolescent anxiety increases risks for adult anxiety and mood disorders (Pine, Cohen, Gurley, Brook, & Ma, 1998) as well as substance dependence (Buckner et al., 2008). Cognitive behavioral therapy (CBT) is a frontline treatment for adolescent anxiety disorders. Evidence shows that although CBT can yield variable outcomes in pediatric anxiety disorders

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(James, Soler, & Weatherall, 2005), treatment efficacy of some forms of CBT is reduced for adolescents compared to children and adults (Drysdale et al., 2014). Another form of treatment relies on serotonin reuptake inhibitors—which combined with CBT, appears effective in the short term (Walkup et al., 2008). However, there are still concerns over long-term use particularly the possibility of side effects in nonadult samples. These include increased stimulation effects (aggression and hostility) and suicidality (Muris, 2012). Because access to frontline treatments more generally are also rather limited, there is a need for fresh, innovative, and widely accessible therapeutic strategies.

Cognitive bias modification of interpretations (CBM-I) training is grounded in cognitive theories suggesting that threat-related biases in interpretation of ambiguity play a central role in the genesis and maintenance of anxiety in adults (e.g., Mathews & Mackintosh, 1998) but also in children and adolescents (Cannon & Weems, 2010; Miers, Blöte, Bögels, & Westenberg, 2008). Across a range of studies using different methodologies for the assessment of threat biases, anxious children and adolescents have been found to endorse negative interpretations of ambiguity more than their nonanxious peers (e.g., Muris, Merckelbach, & Damsma, 2000; Taghavi, Moradi, Neshat-Doost, Yule, & Dalgleish, 2000). Although informative, these studies have been limited in their capacity to demonstrate causal relationships between interpretation biases and symptoms.

CBM-I training programs were first developed to address this gap. The rationale was that if interpretation biases were causally linked to symptoms, then experimental generation of positive and negative interpretative styles through training would result in training-congruent mood changes. In a pioneering study by Mathews and Mackintosh (2000), participants were trained to adopt negative or positive resolutions of ambiguity by completing a word fragment at the end of a hypothetical scenario (see Figure 1 for an example). Completion of the word encouraged participants to draw positive or negative meanings of the situation—a tendency that was reinforced by the completion of a comprehension question (with feedback). After repeated training trials, participants in the negative training condition were found to endorse more negative interpretations of ambiguous scenarios than positively trained participants—while endorsing fewer positive interpretations (Mathews & Mackintosh, 2000). On a measure of state anxiety, negatively trained participants also reported a significant increase in anxiety levels. These data were taken to support a causal link between interpretations and anxious mood.

More recent CBM-I studies have considered the interventive potential of these training procedures in modifying biases and reducing symptoms among analogue and clinical samples of adults (see Beard, 2011 for a review). Although most studies have reported alterations in interpretation bias, across individual studies, data have been more mixed in showing changes on various measures of anxiety or negative mood (Amir & Taylor, 2012; Hirsch, Mathews, & Clark, 2007; Salemink, van den Hout, & Kindt, 2009; Yiend, Mackintosh, & Mathews, 2005). Pooling data across studies, at least two meta-analyses have now been performed (Hallion & Ruscio, 2011; Menne-Lothmann et al., 2014), although the first of these analyzed CBM-I together with attention bias modification procedures. In the first, larger training effects on anxiety and mood measures occurred in response to a psychological challenge (Hallion & Ruscio, 2011), that is, when participants' anxiety and mood were assayed in response to a stressful situation. In the second, significant reductions also emerged on mood measures across time as a function of training, although not specifically in response to a psychological challenge (Menne-Lothmann et al., 2014). Both studies, however, suggested that changes in anxiety and mood may be more consistent in high-anxious individuals than nonanxious individuals (Menne-Lothmann et al., 2014).

An evolving number of studies have extended CBM-I to adolescents to explore whether benign interpretative styles and anxiety and mood changes can also be produced in this age range (see Lau, 2013 for a review). These consist largely of studies with unselected adolescents (Lau, Belli, & Chopra, 2012; Lau, Molyneaux, Telman, & Belli, 2011; Lothmann, Holmes, Chan, & Lau,

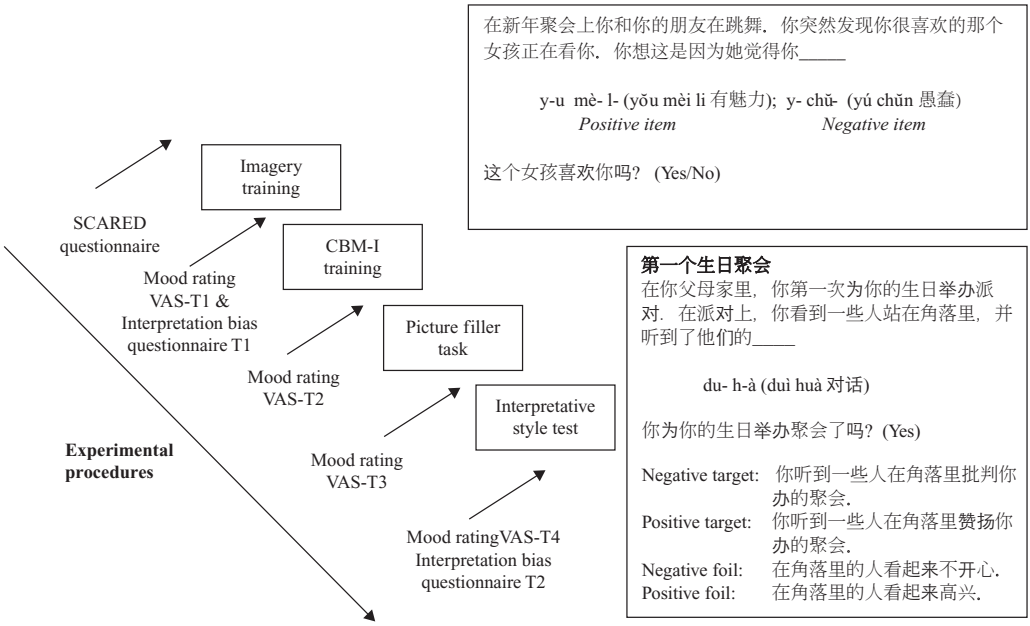

Figure 1. Overview of experimental procedures. Training scenarios depicted social (interpersonal relationships) or nonsocial (educational and sport/recreational achievements) concerns. An example social scenario was (Chinese translation is presented above) "At a New Year party you are dancing with your friends. You suddenly notice that the girl you quite like is looking at you. You think this is because she finds you ___." Pinyin fragment "y-u mè- l- (cute)" was provided for the positive item and "y- chǔ- (foolish)" for the negative item. The subsequent comprehension question was "Does the girl like you?" The correct answer was "Yes" for positively trained adolescents and "No" for the negative training condition. The pronoun used in the situations was sex-matched to the participant (same sex for scenarios depicting peer relationships and opposite sex for romantic relationships). The test scenario "You are organizing your first real party for your birthday at your parents' basement. At the party, you see some people in the corner and hear them ___ (du- h-à, talking)" was presented under the title "First birthday party." The comprehension question was "Did you organize a party for your birthday? (Yes)." The following four statements were "You hear some people in the corner praising the party" (positive target), "you hear some people in the corner criticizing the party" (negative target), "the people in the corner are looking pleased" (positive foil), "the people in the corner are looking miserable" (negative foil). An example nonsocial scenario was "Your father helps you to study for your mathematics test. When your teacher hands back the exams and you see the grade you know that your father will be very ___." The Pinyin fragment was "z- há- (pound)" for the positive item and "sh- w-ng (disappointed)" for the negative item. CBM-I = cognitive bias modification of interpretations training; SCARED = Screen for Child Anxiety Related Emotional Disorders; VAS = visual analogue scale; T1 = Time 1; T2 = Time 2; T3 = Time 3; T4 = Time 4.

2011; Salemink & Wiers, 2011, 2012; Telman, Holmes, & Lau, 2013) with a few studies describing training in clinical samples (Fu, Du, Au, & Lau, 2013; Micco, Henin, & Hirshfeld-Becker, 2014). Because adolescence is a period of heightened sensitivity to motivational cues and vulnerability to intensive negative affect (Somerville, Jones, & Casey, 2010), many anxiety problems can emerge in this age range and persist into adulthood. Implementing effective interventions in this age range

can therefore attenuate long-term negative outcomes. It has also been suggested that adolescence is a period of heightened learning and flexibility (Crone & Dahl, 2012), and that clinically, it may provide a window of opportunity for the positive effects of intervention to take place (Pine, Helfinstein, Bar-Haim, Nelson, & Fox, 2008). Because adolescence is characterized by protracted maturation of frontal regulatory control networks (Casey, Tottenham, Liston, & Durston, 2005), many emotion regulation strategies may emerge and stabilize at this developmental juncture. Interventions that target maladaptive strategies for regulating emotions, or which teach more adaptive strategies, may therefore be especially helpful in reducing anxiety. We have also previously argued that CBM-I in particular may be suitable. Unlike traditional therapies that employ top-down, explicit emotion regulation strategies, CBM-I relies on simple, reinforcement learning. Specifically, participants learn to pair ambiguous scenarios with benign or positive outcomes. This may be more appropriate for targeting biases because these learning mechanisms are not dissimilar to how interpretative styles during development are first acquired (Muris & Field, 2010). It has been suggested that youth learn cognitive styles by modeling those of their parents or peers (Lester, Seal, Nightingale, & Field, 2010; Rose, 2002; Stevens & Prinstein, 2005). Through observational or vicarious learning, youth learn to associate negative explanations with ambiguous situations. During CBM-I training, we try to mimic this type of learning but by pairing ambiguous situations with benign explanations instead.

CBM-I studies with children and adolescents have adapted the content of the training scenarios, and in some cases, with younger children, the method by which training materials are delivered (e.g., Muris, Huijding, Mayer, & Hameetman, 2008). However, training paradigms applied to adolescents have been based on Mathews and Mackintosh's (2000) procedures and parameters but with age-appropriate scenarios incorporated. Studies with unselected adolescents, and more recently with clinically anxious adolescents (Fu et al., 2013) and clinically depressed adolescents (Micco et al., 2014), suggested that interpretation biases are malleable: They can be trained in the intended direction in most cases, even after a single session of CBM-I. However, akin to adult findings, training effects on anxiety and mood measures are mixed. In an unselected sample, Salemink and Wiers (2011) found no effects of training on their state anxiety measure, whereas another study reported decreased negative mood (assessed using a simple visual analogue scale [VAS]) following positive CBM-I (Lothmann et al, 2011). To complicate findings, training-induced mood alterations were moderated by gender (Lothmann et al., 2011), self-efficacy (Lau et al., 2011), and regulatory control (Salemink & Wiers, 2012). Extending interpretation bias training to adolescents with clinical anxiety or depression, neither Fu et al. (2013) nor Micco et al. (2014) found training-induced reduction on their measures of anxiety and/or depression.

To shed light on the absence of training effects on measures of anxiety and mood in single-session training, the moderating effects of adolescents' trait anxiety levels on training efficacy need to be examined. High-anxious individuals might be more susceptible to CBM-I training effects than low-anxious individuals—a finding that characterizes adults in recent meta-analyses (Hallion & Ruscio, 2011; Menne-Lothmann et al., 2014). High-anxious individuals might display more biased interpretations and negative mood at baseline, leaving more room for improvement from such training interventions (Salemink & Wiers, 2011). However, these assumptions have not been directly tested. Some studies have compared training effects in high- and low-anxious participants in unselected participants (e.g., Telman et al., 2013). However in this study, group categorization was determined based on median split of the anxiety scores of participants in that sample. Thus, the categorization might be biased by the anxiety levels of the study sample. In contrast, here, we specifically screened and recruited adolescents who scored above a cutoff of on an anxiety questionnaire that had been determined from data collected from a much larger population-based community sample. Thus, participants who scored above this cutoff are likely to present a more extreme group in the population. Using this sample, we investigated the

effectiveness of positive CBM-I training in ameliorating interpretation biases and negative mood in Chinese adolescents. We defined high- and low-anxious groups based on trait anxiety rather than presence/absence of clinical diagnosis for two reasons. First, adolescents with clinical anxiety present as a heterogeneous group, varying in primary anxiety and secondary anxiety disorders, comorbid nonanxiety conditions (e.g., depression), and also past treatment history; these effects could confound effects of training. Second, high trait anxiety may operate on a continuum of severity with pathological anxiety (Mineka & Oehlberg, 2008), demonstrating that CBM-I can alter biases, and negative mood in an at-risk sample may inform its usage as a preventative tool.

Single sessions of positive training and control training were implemented. The reason for implementing this protocol is that most adolescent studies (with exception of Micco et al. 2014) used single-session training. Thus, this allows us to directly compare our findings of Chinese adolescents with those from western samples. Given also that we are uncertain of the effects of CBM-I training on mood, we thought that it was premature to expend time and energy of our young participants. Training effects on interpretation biases were assessed using two measures. The first was the interpretational style test (IST) that has been adopted in other studies of unselected and clinical adolescent samples. The second measure was the interpretation bias questionnaire (IBQ) administered before and after training. The IST has the advantage of being more covert, but the disadvantage of being similar in structure and format to the training task, which may increase demand characteristics (even though items across training and test are different). Hence, a questionnaire measure of interpretation biases (the IBQ), with a distinct format and content to training and the recognition test, was used to measure changes in interpretation bias from pre- to posttraining. Because the IST relies on responses to negative and benign interpretations measured during a surprise memory test, we only administered it after training (although others have differed in their use of this test at several time points [e.g., Salemink & Wiers, 2011]). Simple indices of negative and positive mood were assessed before and after training.

Consistent with prior data supporting an association between anxiety symptoms and interpretation biases in Chinese youths (Lu, Daleiden, & Lu, 2007), we hypothesized that high-anxious adolescents would show more interpretation biases, more negative and less positive mood than the low-anxious counterparts at baseline. Based on single-session CBM-I studies in both adults and adolescents, we hypothesized that positive training would alter interpretational style across the IST and IBQ. Tentatively, we hypothesized that for the test, adolescents receiving positive training would show a reduced tendency to select negative interpretations and an enhanced tendency to select benign/positive interpretations compared to those receiving control training, and for the questionnaire (which is administered twice), there would be a reduction in interpretation bias across time in the positive group only. We hypothesized that these effects would be greater in high-anxious positively trained adolescents than low-anxious adolescents. We also hypothesized that there will be training-induced changes in mood after positive training across all participants, but these would be greater for high-anxious adolescents.

Method

Sample

One hundred and seven adolescents randomly selected from three public secondary schools in Shanghai, China, completed the Chinese version of the Screen for Child Anxiety Related Emotional Disorders (SCARED; Birmaher et al., 1997; Wang, 2005). All participants were native Mandarin Chinese speakers. Adolescents younger than 16 years old provided written assent and parental consent. Those older than 16 years provided their own written consent. This research was approved by the Ethics Committees of the Shanghai Mental Health Center.

A total score of 23 was used to define the high-anxious group. This figure represents the score corresponding to that of the top 20% of a community sample of 2,019 healthy children from 14 major cities of China (Wang, 2005). Of 43 adolescents who were categorized as high-anxious, 40 adolescents agreed to take part in the training portion of the study and did not experience reading difficulties and/or current or past clinical diagnoses of mental disorders (including anxiety disorders) based on self-reports on the participant information form, consistent with previous research (Fu et al., 2013). All adolescents younger than 23 years were assigned to the low-anxious group. Within this group of 64 adolescents, only 37 agreed to take part in the training portion of the study and who also did not have reading difficulties/mental health diagnoses. Across groups, those who agreed to take part in training did not differ in anxiety scores to those who did not want to take part ($p = .137$). Thus, there were 77 adolescents (49% female; aged 12–18 years, $M_{age} = 14.06$ years, $SD_{age} = 1.61$) participated. To ensure that the high-anxious adolescents showed stable anxiety symptoms, the SCARED questionnaire was administered again on the day of testing (approximately 7 days later). All high-anxious adolescents again scored above the cutoff and scored higher than the low-anxious group, $t(56.2) = 11.3$, $p < .001$. The SCARED scores obtained on the second testing day were used for analyses.

Adolescents in both anxiety groups were allocated to receive positive or control CBM-I using a random number sequence. Four participants showed poor performance in comprehending training scenarios defined as accuracies below two standard deviations of the group mean. Hence, their data was excluded from all data analyses, leaving data from 73 participants (Table 1). Post hoc power analysis was conducted with 37 adolescents in the positive and 36 adolescents in the control training groups. Using the more conservative effect size estimate previously reported (Lothmann et al., 2011; Cohen's $d = 0.716$) for group differences in positive interpretation endorsement, the power to detect training-group differences with the present sample size was 0.916. However, it must be recognized that this study compared training effects between positive and control training that was mixed valence (half the items were resolved positively and half, negatively), whereas this earlier adolescent study used a negative training condition as the comparison condition. The power to find in training-induced interpretation bias change among anxious participants who received positive CBM-I compared to those in the control condition was 0.864 based on the effect size (Cohen's $d = 0.92$) reported in Amir and Taylor (2012). It should also be noted that this study involved only clinically anxious adults, whereas this study compares training effects between both training conditions and anxiety groups. Adolescents allocated to the positive versus control training did not differ significantly in terms of SCARED scores or by age or gender ($ps > .05$; Table 1).

Procedures

Details of the procedures and parameters adopted in this study (see Figure 1) are described in Fu et al. (2013). Before CBM-I training, participants reported anxiety symptoms on the SCARED for the second time. The IBQ was administered to assess interpretation bias at baseline. Participants were then given imagery training to enhance the effect of training followed by the CBM-I training. Posttraining interpretation bias was then examined after a filler task using the computerized IST and the IBQ that contained a different set of questions from the baseline IBQ. Negative and positive mood were measured pretraining (T1), immediately after training (T2), immediately before the computerized test (T3), and after the test (T4) using VASs. Upon completing all assessments, participants were debriefed about the study.

Two Chinese-English bilingual researchers translated all stimuli for computerized training and test tasks, the VASs and IBQ because their Chinese version was not readily available. We piloted all translated materials with three Chinese teenagers from one of the participating schools

TABLE 1. Means (Standard Deviations) of Participant Characteristics and Training Performance Indices

	Positive CBM-I			Control CBM-I		
	Low-Anxious	High-Anxious	Training Group Mean	Low-Anxious	High-Anxious	Training Group Mean
Demographics						
Sample size (predeletion)	18	20		19	20	
Sample size (postdeletion)	18	19		18	18	
Age (years)	13.83(1.58)	13.79(1.62)		14.61(1.75)	14.39(1.42)	
Female (%)	55.60	47.40		44.40	50.00	
SCARED score[a]	12.22 (4.88)	28.32 (4.60)	20.49 (9.40)	13.94 (4.82)	35.61(10.71)	24.78 (13.70)
Training performance						
Word fragment RT (ms)			8,647.29 (3,567.67)			11,741.5 (4,151.28)***
Comprehension questions accuracy (%)			91.71 (5.64)			88.30 (6.46)*
Comprehension question RT (ms)			2992.79 (756.35)			3223.04 (786.98)

Note. CBM-I = cognitive bias modification of interpretations; SCARED = Screen for Child Anxiety Related Emotional Disorders; RT = reaction time.

[a]SCARED scores collected on the day of testing are displayed. Sample sizes before and after the deletion of participants who showed unacceptable performance on the comprehension questions are presented.

*$p = .034$. ***$p = .001$.

to ensure their readability, age appropriateness, and relevance. Because training involves the completion of word fragments, any that pilot participants all found difficult were reworded. One scenario described in the pretraining IBQ was not appropriate for youths in China because it involved driving a car and our sample was younger than the legal driving age. Instead, we replaced this with a scenario about retrieving a missing wallet.

Training Protocols

Imagery Training. This involved asking participants to close their eyes and imagine coming home after school. They were then asked to describe what they could see, hear, smell, taste, and feel. Research has indicated that imagery enhances the overall emotional experience, particularly in the context of training, compared to verbal processing, strengthening the therapeutic effects of CBM-I (Holmes, Lang, & Shah, 2009; Holmes & Mathews, 2005). Once participants had confirmed that they could "picture events and feelings in their mind," they were asked to apply these imagery procedures during the training task.

CBM-I Training. The Chinese version of CBM-I was adapted from the training paradigm previously used in adolescents (Lothmann et al., 2011)—and reported in Fu et al. (2013). Half of the scenarios related to social concerns (within interpersonal relationships) and the other half on nonsocial worries (about educational and sport/recreational achievements). Because the study aimed to investigate training effect on negative mood, the content of the training scenarios was not tailored to the concerns relating to any specific anxiety phenotype. During training, participants completed 60 trials that were presented in 5 blocks of 12 items. Although the block order was not randomized, the scenarios in each block were presented in a random order for each participant. Each trial presented an ambiguous situation followed by a word fragment that completed the scenario. Participants were instructed to identify the word from the fragment as quickly as possible by typing in the first missing letter. Completing this fragment resolved the ambiguity of the scenario, giving positive, negative, or neutral valence to the situation. In the Chinese version, the scenario was described using Chinese characters, whereas the word *fragment* was presented using Pinyin. Pinyin denotes the pronunciation of Mandarin Chinese and is used to transcribe the logographic form of Chinese into Roman alphabets (Snowling & Hulme, 2005). Upon successful completion of the fragment, participants were required to respond to a comprehension question as quickly and accurately as possible by entering "Y" (for "yes") or "N" (for "no"). "Correct" or "Wrong" feedback followed. The response was only correct if the situation was interpreted correctly according to its emotional implications. A sample training trial (in English) is written in the footnote of Figure 1. The positive training group in each block received 10 scenarios, which were resolved positively; one scenario that was resolved negatively; and one scenario in which resolution resulted in a neutral description. Inclusion of training-incongruent items and scenarios without emotional content masked the purpose of training. A control training condition controlled for the effects of exposure to daily situations and completing word fragments. Participants in the control condition completed five positively valenced and five negatively valenced scenarios in each block (Steinman & Teachman, 2010). Two additional neutral items were included as fillers (Mathews & Mackintosh, 2000).

Measures

Trait Anxiety. The Chinese version of the SCARED (Birmaher et al., 1997; Wang, 2005) was administered twice: for screening and allocation of individuals into high- and low-anxious groups and then again on the day of the training to assess the stability of these categories. The Chinese SCARED has good internal consistency (Day 1: Cronbach's $\alpha = .84$; Day 2: Cronbach's $\alpha = .90$).

It also has good test–retest reliability (r = .57–.61) as well as high sensitivity (.74) and specificity (.79) in diagnosing anxiety disorders (Wang, 2005).

Participant Information. Participants completed questions on their gender, date of birth, school year, and also checked boxes (yes/no) over whether they experienced reading difficulties or were diagnosed with mental health problems currently or in the past.

Mood. To investigate changes in mood, participants completed simple VASs at four time points throughout the study. Adolescents reported how much of each negative or positive emotion they were feeling at that moment by marking on a line between "not (emotion) at all" (0 mm) and "very (emotion)" (100 mm). Eight items for negative mood (nervous, sad, upset, worried, anxious, miserable, scared, and gloomy) and four items measuring positive mood (happy, calm, cheerful, and energetic) were taken from the Positive and Negative Affect Scales for Children (Laurent et al., 1999) to make up the completed VASs. The length of the marked line segment is recorded to index the level of each mood item participants reported. Negative mood and positive mood scores are the sum of the item scores. The VASs have been used in previous studies to measure training effects on mood in adolescents (Fu et al., 2013; Lau et al., 2012; Lau et al., 2011; Telman et al., 2013). In one of our previous studies, pretraining negative mood correlated with the questionnaire measure of anxiety symptoms administered before training (Fu et al., 2013). In this study, the range of scores for negative mood was 0 and 690 and for positive mood, 49 and 400. Items contributing to each mood scale were internally consistent (T1: Cronbach's α = .87; T2: Cronbach's α = .92; T3: Cronbach's α = .89; T4: Cronbach's α = .71). Of note, only T1 and T2 scores are analyzed in relation to study hypotheses. T3 and T4 measures were conducted as checks that (a) mood differences as a result of training did not persist to influence the test and questionnaire of interpretation bias/style and (b) mood differences did not persist beyond the testing session for ethical reasons.

Interpretation Bias. Two outcome measures were used to investigate training effects on interpretation bias. The first was the 26-item IBQ modified from an adult questionnaire (Stopa & Clark, 2000). Items consisted of vignettes describing ambiguous social (e.g., "You walk past a group of tourists and they start laughing") and nonsocial scenarios (e.g., "You reach for your wallet and cannot find it. What has happened to it?"). These were followed by three alternative interpretations, with one always being negative and two were benign (both neutral or one neutral and one positive). Participants were asked to select the most likely explanation for the situation. The number of negative interpretations selected was summed. Thus, higher scores indicate a more negative interpretative style. Half of the items were completed before training and the other half completed posttraining to measure training-induced alterations in interpretation bias (possible score range: 0–13; range in this study for Time 1: 0–6; range in this study for Time 2: 0–7). We modified an adult questionnaire rather than use questionnaires already developed for use in children and adolescents because the latter contained too few items for us to administer the questionnaire twice but with different items. Although the IBQ showed acceptable internal consistency in this study (pretraining: Cronbach's α = .68; posttraining: Cronbach's α = .74), our previous study with clinically anxious adolescents revealed poorer reliability (Fu et al., 2013; pretraining: Cronbach's α = .50; posttraining: Cronbach's α = .66).

The second measure was the IST, which has been used in previous adult CBM-I studies (Mathews & Mackintosh, 2000), but here, we altered the content so that it was appropriate for adolescents (Lothmann et al., 2011). The IST comprised two parts. First, participants viewed 10 ambiguous scenarios in a randomized order, each containing a title. Similar to training, these scenarios were also followed by completion of a Pinyin word fragment. Unlike training scenarios, completing the Pinyin fragments did not disambiguate the situations. The subsequent comprehension questions also had no reference to the emotional content of the vignettes. In the second part of the assessment, the title of the previously displayed scenario was presented in a randomized

order, followed by four statements resembling the scenario. Two of the sentences were "targets," conveying either a positive or a negative interpretation of the story. Two were "foils," which were positively and negatively valenced sentences but did not contain an interpretation of the previously viewed scenario. These were included to assess whether training induced a general response bias toward valenced sentences. Presentations of the four statements were randomized. An example of the test trial is presented in Figure 1. Participants were asked to rate, using a 4-point scale, how similar each statement was to the scenario presented in the first part (1 = *not similar at all*; 4 = *very similar*). Higher similarity ratings to positive targets versus negative targets indicate a more positive interpretative style. Because this measure involves a "recognition test" phase (i.e., in the second part of the assessment)—from which the outcome measure is comprised—we only administered the IST at posttraining to minimize demand characteristics; however, others (e.g., Salemink & Wiers, 2011) have administered this test twice.

Of note, in this study, posttraining IBQ score positively correlated with similarity ratings of negative targets ($r = .35$, $p < .01$) and negatively related to similarity ratings of positive targets in the IST ($r = -.28$, $p < .05$). Higher SCARED scores correlated with both greater endorsement of negative interpretations in the IBQ ($r = .42$, $p < .001$) and negative targets in the IST ($r = .31$, $p < .01$). Hence, the two measures appear to tap into the common construct of interpretation bias that is associated with heightened anxiety symptoms—and as such, we expect a similar pattern of results.

Filler Task. Prior to completion of the IST, a 10-min picture filler task was administered to remove possible group differences in mood that might arise from training, thus, avoiding confounding any training-related effects on interpretative style (Mathews & Mackintosh, 2000). In the task, participants rated the pleasantness of 60 neutral pictures on VASs ranging from *very unpleasant* (0 mm) to *very pleasant* (100 mm). The VASs were administered immediately after the filler task to verify that there were indeed no group differences in mood (T3, see Table 2).

TABLE 2. Negative and Positive Mood Ratings (Log-Transformed) Obtained at the Three Time Points of the Experiment

		Ms (*SDs*)[a]			
		Pretraining	Posttraining	Postfiller	Posttest
Positive CBM-I					
Negative mood	All	−2.09 (0.40)	−1.82 (0.69)	−1.78(0.63)	−1.62 (0.72)
	Low-anxious	−2.02 (0.39)	−1.70 (0.83)	−1.7(0.69)	−1.55 (0.71)
	High-anxious	−2.16 (0.41)	−1.93 (0.53)	−1.86 (0.57)	−1.69 (0.74)
Positive mood	All	2.43 (0.12)	2.44 (0.12)	2.42 (0.17)	2.44 (0.17)
	Low-anxious	2.47 (0.08)	2.46 (0.09)	2.49 (0.08)	2.49 (0.08)
	High-anxious	2.39 (0.14)	2.42 (0.15)	2.36 (0.21)	2.23 (0.22)
Control CBM-I					
Negative mood	All	−2.14 (0.50)	−2.02 (0.65)	−1.68 (0.70)	−1.60 (0.85)
	Low-anxious	−2.05 (0.28)	−1.83 (0.61)	−1.53 (0.55)	−1.35 (0.78)
	High-anxious	−2.22 (0.65)	−2.20 (0.65)	−1.83 (0.81)	−1.84 (0.88)
Positive mood	All	2.34 (0.21)	2.35 (0.18)	2.37 (0.19)	2.39 (0.18)
	Low-anxious	2.40 (0.20)	2.42 (0.16)	2.46 (0.09)	2.47 (0.10)
	High-anxious	2.28 (0.20)	2.27 (0.18)	2.28 (0.21)	2.32 (0.21)

Note. CBM-I = Cognitive bias modification of interpretations.
[a]Ratings were evaluated in millimeters on visual analogue scales. Higher values represent more intense emotion.

Statistical Analyses

All statistical analyses were performed using SPSS Statistics Version 20. Log-transformed data (IBQ scores; negative and positive affect VAS scores, similarity ratings to both targets and foils) were used wherever assumptions of normality were violated. A series of mixed design analyses of variance (ANOVAs) were used to examine our primary hypotheses that changes in interpretation bias and in mood would vary as a function of training condition and anxiety group. With the aim of examining immediate training-induced changes in mood, ratings collected at T1 and T2 were entered in ANOVAs. As preliminary analysis (Table 1) revealed training condition differences in two training performance indices: mean reaction times (RTs) to complete Pinyin word fragments, $t(71) = 3.42$, $p = .001$, and mean percentage of correct responses to comprehension questions, $t(71) = 2.38$, $p < .05$, these variables were entered as covariates. The inclusion of these variables controlled for any confounding effects of training performance across groups on training differences on interpretative style and mood. Gender and age were also entered as covariates in earlier-mentioned analyses because prior research shows that interpretation biases vary across gender (Lothmann et al., 2011) and age (Cannon & Weems, 2010). Significant interaction effects were followed up by using two-tailed paired- or independent-samples *t* tests. Effect sizes of within- and between-group differences were presented using Cohen's *d* where $d \geq 0.6$ is interpreted as a large effect, $0.3 \leq d \leq 0.5$ is a medium effect, and $d \leq 0.2$ is a small effect (Cohen, 1992). Wherever the assumption of sphericity was violated, Greenhouse-Geisser (GG) corrections were adopted.

Results

Pretraining Relationships Between Anxiety, Interpretative Style, and Mood

Before training, high-anxious adolescents made significantly more negative interpretations of ambiguous scenarios, $t(57.7) = 4.13$, $p < .001$; $M_{\text{anxious}} = 2.35$, $SD_{\text{anxious}} = 1.93$; $M_{\text{low-anxious}} = 0.83$, $SD_{\text{low-anxious}} = 1.11$; $d = 0.97$; reported greater negative mood, $t(58.2) = 3.21$, $p < .01$; $M_{\text{anxious}} = 230.95$, $SD_{\text{anxious}} = 153.38$; $M_{\text{low-anxious}} = 136.89$, $SD_{\text{low-anxious}} = 89.38$; $d = 0.75$; and less positive mood, $t(71) = 2.94$, $p < .01$; $M_{\text{anxious}} = 233.38$, $SD_{\text{anxious}} = 80.13$; $M_{\text{low-anxious}} = 285.06$, $SD_{\text{low-anxious}} = 69.37$; $d = 0.69$, compared to low-anxious individuals. Higher baseline interpretation bias scores also correlated with more negative mood ($r = .34$, $p < .01$) and less positive mood ($r = -.39$, $p = .001$) across all participants.

Training Effects on Changes in the Interpretation Bias Questionnaire

To test the hypotheses that training conditions would differentially influence interpretative style and that these effects may be greater in high-anxious adolescents, we used a $2 \times 2 \times 2$ mixed design ANOVA with one within-subjects factor (time: pretraining vs. posttraining) and two between-subjects factors (training condition and anxiety group) on the IBQ scores. Age, gender, mean RT to complete Pinyin fragments, and mean accuracy of comprehension question completion were included as covariates.

A time-by-training-condition interaction emerged, $F(1, 52) = 4.54$, $p < .05$, $\eta^2 = .08$ (Figure 2). Positively trained adolescents selected significantly fewer negative interpretations of ambiguous vignettes posttraining compared to pretraining, $t(36) = 3.47$, $p = .001$, $d = 0.65$, whereas the change across time was not significant in the control-training group ($p = .62$). There was a significant main effect of anxiety group, $F(1, 52) = 9.09$, $p < .01$, $\eta^2 = .15$, with high-anxious adolescents reporting higher IBQ scores across training conditions. However, anxiety

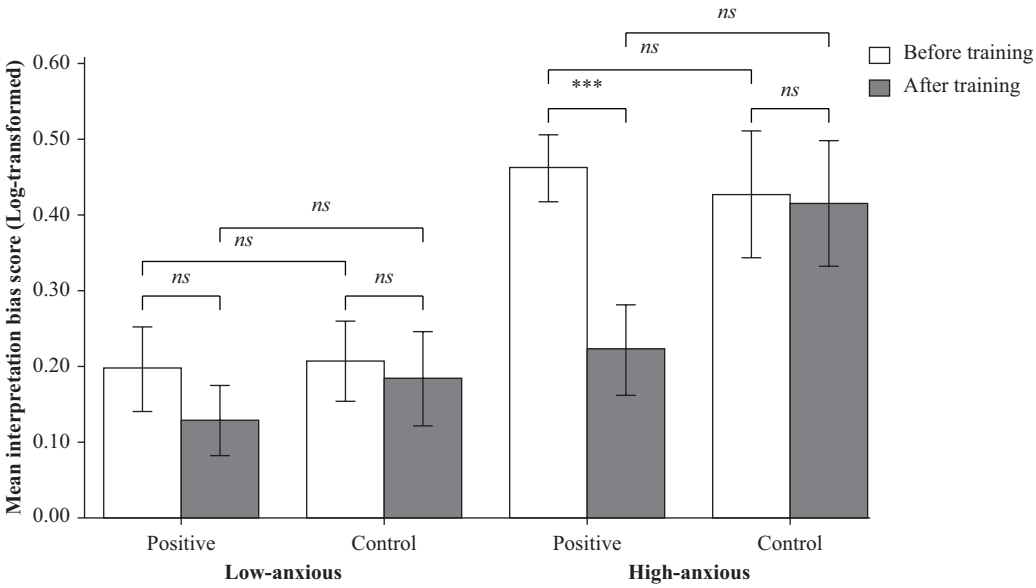

Figure 2. Mean raw scores of interpretation bias assessed using the interpretation bias questionnaire, obtained before and after training across training conditions and anxiety groups. Higher scores indicated more negative interpretations made to the ambiguous scenarios presented in the questionnaires. Error bars: ± 1 standard error. ***p < .001.

group did not moderate the time-by-training-condition interaction ($p = .31$). The 2 × 2 × 2 mixed design ANOVA did not reveal any other significant main or interaction effects.

However, because of a priori hypotheses that anxiety group could increase the effectiveness of positive training, we nevertheless performed a 2 × 2 mixed design ANOVA with time as the within-subjects factor and anxiety as the between-subjects factor in the participants who received positive training. The significant main effects of time, $F(1, 35) = 12.62$, $p = .001$, $\eta^2 = .27$, and anxiety group, $F(1, 35) = 9.27$, $p < .01$, $\eta^2 = .21$, were modified by a significant time-by-anxiety interaction, $F(1,35) = 3.96$, $p = .05$, $\eta^2 = .10$ (Figure 2). That is, high-anxious adolescents showed significantly greater interpretation bias than low-anxious participants at pretraining, $t(35) = 3.79$, $p = .001$; $M_{\text{anxious}} = 0.46$, $SD_{\text{anxious}} = 0.19$; $M_{\text{low-anxious}} = 0.19$, $SD_{\text{low-anxious}} = 0.23$; $d = 1.24$. However, interpretation bias did not differ between anxiety groups following positive CBM-I ($p = .23$). Positive training–induced reduction of interpretation bias was only significant in the high-anxious group, $t(18) = 3.76$, $p = .001$; $M_{\text{pretraining}} = 2.16$, $SD_{\text{pretraining}} = 1.30$; $M_{\text{posttraining}} = 1.00$, $SD_{\text{posttraining}} = 1.37$; $d = 0.87$, not in the low-anxious group, $t(17) = 1.07$, $p = .23$; $M_{\text{pretraining}} = 0.83$, $SD_{\text{pretraining}} = 1.25$; $M_{\text{posttraining}} = 0.50$, $SD_{\text{posttraining}} = 0.86$, $d = 0.31$. We calculated change scores between pretraining and posttraining to compare relative change of interpretation biases across anxiety groups among those who were positively trained. Interestingly, there was a nonsignificant trend of greater changes in interpretation bias postpositive training in the high-anxious than the low-anxious group, $t(35) = 1.87$, $p = .07$; $d = 0.62$; $M_{\text{anxious}} = 1.16$, $SD_{\text{anxious}} = 1.34$; $M_{\text{low-anxious}} = 0.33$, $SD_{\text{low-anxious}} = 1.33$.

Training Effects on the Interpretational Style Test

The differences in training effects on the IST between anxiety groups was examined using a 2 × 2 × 2 mixed design ANOVA with one within-subjects factor (sentence valence: positive vs.

negative sentences) and two between-subjects factors (training condition and anxiety group) on target and foil ratings separately. Sentence type (target vs. foils) was not included as an additional factor given that the present sample size may have limited power to detect a four-way interaction. For target ratings, after age, gender, mean RT to complete Pinyin fragments, and mean accuracy of comprehension question completion were included as covariates, the mixed design ANOVA revealed a sentence-valence-by-training-condition interaction, $F(1, 52) = 10.63$, $p < .01$, $\eta^2 = .17$ (Figure 3a). Although adolescents in both training conditions assigned higher similarity ratings to the positive than negative targets—positive: $t(36) = 9.11$, $p < .001$, $d = 2.37$; control: $t(35) = 4.80$, $p < .001$, $d = 1.22$—positively trained adolescents rated positive targets as more similar, $t(71) = 2.51$, $p < .05$, $d = 0.58$, and negative targets as less similar, $t(71) = 3.79$, $p < .001$, $d = 0.88$, to the previously viewed scenarios than participants who had received control training. There was also a significant sentence-valence-by-anxiety-group interaction, $F(1, 52) = 4.08$, $p < .05$, $\eta^2 = .07$ (Figure 3b). Although adolescents in both anxiety groups reported higher similarity ratings to the positive than negative targets—high-anxious: $t(36) = 5.77$, $p < .001$, $d = 1.54$; low-anxious: $t(35) = 7.32$, $p < .001$, $d = 1.96$—collapsed across training conditions, high-anxious adolescents endorsed more negative targets than low-anxious individuals, $t(71) = 2.11$, $p < .05$, $d = 0.49$. This between-group difference did not characterize positive target ratings ($p = .16$). The $2\times 2 \times 2$ ANOVA did not reveal additional significant main or interaction effects.

The same analyses were conducted on foils, with one male participant (positive condition; low-anxious group) excluded as an outlier (similarity ratings for negative items > $M + 2\ SD$). With the covariates entered in the analyses, the training-condition-by-sentence-type interaction was significant, $F(1, 51) = 11.88$, $p = .001$, $\eta^2 = .19$ (Figure 3c). Although adolescents in both training conditions perceived the positive foils as more similar to the test scenarios than the negative foils—positive: $t(35) = 12.65$, $p < .001$, $d = 2.58$; control: $t(35) = 5.58$, $p < .001$, $d = 1.28$—positively trained adolescents assigned higher ratings to positive foils, $t(70) = 2.31$, $p < .05$, $d = 0.54$, and lower ratings to negative foils, $t(70) = 4.05$, $p < .001$, $d = 0.95$, compared to those receiving control training. No additional main or interaction effects were significant.

Changes in Mood Measures

Ratings of negative and positive mood at T1 and T2 are presented in Table 2. A time (within-subjects: pretraining, posttraining)-by-training-condition (between-subjects: positive, control)-by-anxiety-group (between-subjects: high-anxious, low-anxious) mixed design ANOVA was conducted on negative mood ratings. With age, gender, mean RT to complete Pinyin fragments, and mean accuracy of comprehension question completion included as covariates, significant main effects of anxiety, $F(1, 52) = 4.97$, $p < .05$, $\eta^2 = .09$; gender, $F(1, 52) = 10.23$, $p < .01$, $\eta^2 = .16$; and Pinyin fragment completion RTs, $F(1, 52) = 5.32$, $p < .05$, $\eta^2 = .09$, emerged. Collapsed across both time points, negative mood was stronger in high-anxious than low-anxious adolescents ($M_{\text{anxious}} = 2.13$, $SD_{\text{anxious}} = 0.53$; $M_{\text{low-anxious}} = 1.91$, $SD_{\text{low-anxious}} = 0.47$; $d = 0.46$); girls had more negative mood than boys ($M_{\text{girl}} = 2.16$, $SD_{\text{girl}} = 0.32$; $M_{\text{boy}} = 1.88$, $SD_{\text{boy}} = 0.62$; $d = 0.57$); and adolescents who completed Pinyin fragments faster showed less negative mood than those with longer RTs. No additional main effects or interactions were found significant.

For positive mood, there was a significant difference between anxiety groups, $F(1, 52) = 10.04$, $p < .01$, $\eta^2 = .16$, with low-anxious adolescents reporting more positive mood than high-anxious counterparts across both time points ($M_{\text{low-anxious}} = 2.44$, $SD_{\text{low-anxious}} = 0.11$; $M_{\text{anxious}} = 2.34$, $SD_{\text{anxious}} = 0.16$; $d = 0.72$). There were no other significant main effects or interactions.

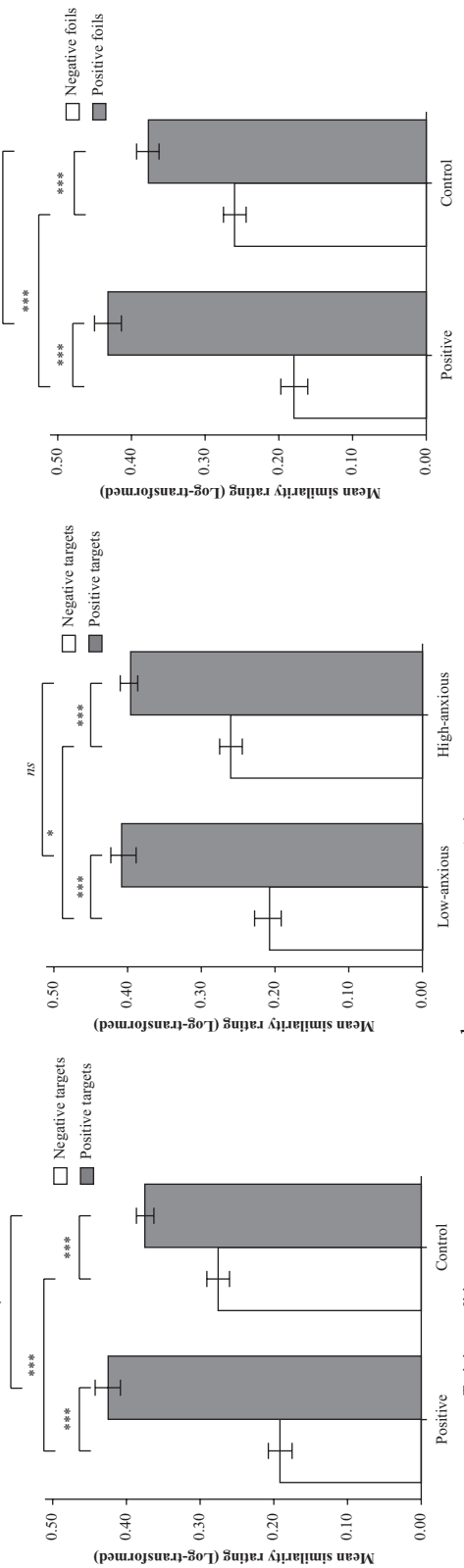

FIGURE 3. Log-transformed raw scores from the posttraining interpretative style test. Higher ratings represented greater similarity of the description to the ambiguous scenario. (a) Similarity ratings assigned to positive and negative targets by positive and control training groups. (b) Similarity ratings assigned to positive and negative targets by anxiety groups. (c) Similarity ratings for positive and negative foils across training conditions. Error bars: ± 1 standard error. $^{\star}p < .05$. $^{\star\star\star}p < .001$.

Discussion

This study extended prior findings supporting the effectiveness of positive CBM-I in modifying interpretation biases in subclinically anxious adults (Beard, 2011) to adolescents preselected for high trait anxiety. Both interpretation bias measures yielded similar results: Questionnaire data from the IBQ showed that the positive CBM-I, but not control training, reduced the number of negative interpretations adolescents made from pre- to posttraining. This appeared to be driven by positively trained high-anxious adolescents because they showed elevated interpretation bias at baseline but made comparable numbers of negative interpretations posttraining, relative to low-anxious adolescents. Results from the posttraining IST showed that positively trained adolescents endorsed positive interpretations more and negative interpretations less than adolescents receiving control training. High-anxious adolescents endorsed more negative interpretations than nonanxious individuals. However, unlike the IBQ, the training effects on the IST did not vary significantly across anxiety groups. Because we used an additional questionnaire measure of interpretation biases, which is procedurally distinct from the training task, our result suggests that the training-induced improvements in interpretation biases were unlikely to be because of demand characteristics and can be generalized to different contexts. Despite changes in interpretation biases, no training effects on positive or negative mood were found in either anxiety group.

Consistent with meta-analyses of adult training studies (Hallion & Ruscio, 2011; Menne-Lothmann et al., 2014), our data demonstrate that a single session of CBM-I can challenge interpretation biases in high-anxious as well as low-anxious adolescents. More difficult to explain is why CBM-I effects did not translate to improving mood. There are several possible reasons. First, the nonspecific VAS indices of "negative" and "positive" mood might not be sensitive enough to detect mood changes. Future studies may wish to adopt more sensitive measures of mood or anxiety. It is also possible that the positive CBM-I reduces individuals' stress vulnerability rather than mood directly (Hallion & Ruscio, 2011). Prior adolescent studies have indicated that negative training enhanced negative appraisals of stressors (Telman et al., 2013), whereas positive training attenuated anxiety after psychological challenges (Lau et al., 2012). Future studies may consider including experimental stressors to assess training effect on stress reactivity (although of note, a recent meta-analysis did not find support for finding training effects during stress reactivity; Menne-Lothmann et al., 2014). Moreover, it may be that a single session of CBM-I is insufficient for significantly reducing negative mood because previous studies that successfully modified state as well as trait anxiety symptoms in high-anxious adult populations administered multiple training sessions over an extensive time (e.g., Mathews, Ridgeway, Cook, & Yiend, 2007). A fourth possibility is that CBM-I effects on symptom reduction may only characterize those with more extreme anxiety pathology. Here, we found some support that training effects on interpretations were stronger in the high-anxious group—but yet again, these effects did not characterize our mood measures. Nor did we find in our previous report of clinical patients, benefits of CBM-I on symptom reduction (Fu et al., 2013).

Although it is tempting to discount CBM-I as a viable standalone intervention for anxiety, there have been some positive findings in the adult literature. For example, a recent study that combined CBM-I with attention bias modification procedures found both statistically and clinically significant effects on symptom reduction in clinically anxious adults (Brosan, Hoppitt, Shelfer, Sillence, & Mackintosh, 2011). CBM-I combined with imagery techniques has also been effective at reducing symptoms in depressed adult patients (Lang, Blackwell, Harmer, Davison, & Holmes, 2011). Perhaps the effects of CBM-I could be boosted by targeting more than one bias at a time, encouraging the use of mental imagery during training, or by using a more creative training interface to increase engagement by young people. Training effects could also be made

stronger if scenarios are tailored more to an individual's fears and worries, for example, using ambiguous social situations for those with social concerns and scenarios of ambiguous bodily sensations for those with symptoms of panic. Here, we also used a diverse range of situations that were general to young people from 12 to 18 years, but more age-specific scenarios for early, mid, and older adolescents could be included.

If the effects of CBM-I could be boosted in these ways to reduce anxiety symptoms or improve stress vulnerability, it is a procedure that may be particularly suitable for adolescents. Traditional face-to-face therapies such as the CBT for youths often suffer from problems with treatment compliance and accessibility (Gunter & Whittal, 2010; Kendall & Sugarman, 1997). In contrast, through repeatedly endorsing benign interpretation of ambiguous scenarios (e.g., through the use of "correct" feedback), CBM-I may tap into reinforcement learning mechanisms that are similar to how interpretative style is first acquired during childhood (Muris & Field, 2010) or maintained in adolescence (Rose, 2002). If sustained over time, reinforcement learning could make positive interpretations become more automatic. By facilitating a habitual benign interpretative style at a developmentally sensitive juncture, CBM-I might provide long-lasting benefits for adolescents at risk for anxiety problems. However, future studies need to study how the effects of CBM-I can be enhanced so that these packages can reduce anxiety symptoms.

There are several limitations to our study. First, we did not systematically assess the presence of cooccurring clinical symptoms or diagnoses (instead, relying on a simple checklist of the presence/absence of past/current psychiatric conditions) in our sample. We therefore cannot discount the possibility that the tentative trends associated with the high anxiety group were actually caused by other conditions (e.g., depression, posttraumatic stress disorder, and eating disorders) that have also been linked to negative cognitive biases. Second, although the internal consistency of the IBQ was acceptable in this study, reliability has been lower in our prior study of clinically anxious adolescents (Fu et al., 2013).

Third, training performance was not matched across groups (Table 1): Word fragment completion appeared more demanding in the control condition than the positive training condition. During positive training, adolescents may have gradually learned that they were required to generate positively valenced words, whereas for the control (mixed valence) training, the repertoire of word fragment completion was not restricted to positive words but to negative ones, too. However, if they were to have any effect, one would expect that these increased demands in the control training would have resulted in reduction in negative mood—thus enhancing group differences on mood measures (which we did not find).

Fourth, the current Chinese CBM-I training paradigm could be improved. Although the use of Pinyin fragment matches well with existing training tasks applied to western samples, the required translation from reading scenarios in Chinese characters to processing Pinyin might explain slower word fragment completion in this study ($M_{\text{positive}} = 8{,}647.29$; $M_{\text{control}} = 11{,}741.46$) compared with prior adolescents studies where all mean RTs to word fragment completion reported were shorter than 3,000 ms (Lau et al., 2012; Lau et al., 2011; Lothmann et al., 2011; Salemink & Wiers, 2011). Hence, extraneous variables such as participants' levels of Pinyin proficiency and task motivations might have confounded the training efficacy observed.

Lastly, individual differences in regulatory control at baseline were not examined. Dual process model suggests that regulatory control moderates the association between information processing biases on anxiety (Wiers et al., 2007). Evidence points to adolescents with lower regulatory control and higher state anxiety prior to training as showing greater posttraining reduction of interpretation bias (Salemink & Wiers, 2012). Hence, future studies might benefit from taking into account the role of cognitive control processes in influencing training effects on both interpretative style and state anxiety.

In summary, the study provides additional evidence supporting the ameliorating effects of a single-trial CBM-I in reducing negative interpretation bias. However, the hypothesis that CBM-I is more beneficial to high-anxious adolescents is not strongly supported. In addition, evidence on training-induced changes in mood is lacking. Before the effectiveness of CBM-I can be concluded and generalized, it is imperative for future studies to examine how individual differences in levels of negative affect and cognitive control might moderate training effects. Future research also needs to perfect CBM-I training protocols and assessments in youth. Multisession randomized controlled trials incorporating a stressor can be adopted to investigate whether CBM-I could attenuate interpretation biases, anxiety symptoms, and stress vulnerability.

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Correspondence regarding this article should be directed to Jennifer Y. F. Lau, Psychology Department, Institute of Psychiatry, King's College London, De Crespigny Park, London SE5 8AF, UK. E-mail: jennifer.lau@kcl.ac.uk