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Suggestion of Cognitive Enhancement Improves Emotion Regulation

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Cognitive training seems a promising approach to enhance emotion regulation. To establish a causal connection, researchers must compare the training intervention with a control group that accounts for improvements induced by some factors other than the training. Despite this familiar methodology, the influence of expectations on the transfer effects of training remains poorly understood. We tested this possibility in 2 experiments, where a procedure was designed to intentionally induce a placebo effect via the suggestion of cognitive enhancement to evaluate the role of expectation in emotion regulation gains from cognitive training. Both the Placebo and Control groups completed the identical short-term working memory training (20 min) in Experiment 1. New participants were recruited to complete a long-term pseudotraining program (7 days) in Experiment 2. The results from the 2 experiments consistently showed that the Placebo group, who expected benefits from the training, unlike the Control group, showed less negative emotion and better regulatory effects after pseudotraining, irrespective of the duration of the training. Thus, inadequate control of expectation is a fundamental design flaw that potentially undermines any causal inferences. These findings also suggest a novel perspective for optimizing the experimental designs in psychological interventions and advancing the understanding of emotion regulation enhancement.

Keywords: emotion regulation, suggestion, expectation, placebo effect, cognitive training

One of our crucial survival skills is to flexibly regulate emotion according to environmental requirements. In contrast, deficient regulation of emotion is a core syndrome across psychiatric disorders (Beck, 2008; Gross, 2013). Researchers have made efforts to develop better and more effective interventions aimed at improving emotion regulation abilities. Recently, cognitive training, such as working memory training, inhibitory control training, has been considered a promising approach and used to enhance emotion regulation (Beauchamp, Kahn, & Berkman, 2016; Cohen et al., 2016; Cohen & Ochsner, 2018; Hoorelbeke, Koster, Demeyer, Loeys, & Vanderhasselt, 2016; Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013). A typical example is the study by Schweizer and colleagues in 2013, showing that the benefits of short, inexpensive and easy-to-implement emotional working memory training could transfer to emotion regulation, indexed by the enhanced efficiency of the frontoparietal demand network implicated in emotional control. Nevertheless, despite a growing body of these studies, there is little consensus regarding the efficacy of cognitive training (Cristea, Kok, & Cuijpers, 2015; Hoorelbeke & Koster, 2017; Sala & Gobet, 2019), raising the important question about the role of placebo/expectation effects on emotion regulation.

Indeed, the simple act of receiving any intervention may, in itself, be effective due to expectations of benefits (Boot, Simons, Stothart, & Stutts, 2013; De la Fuente-Fernández et al., 2001; Foroughi, Monfort, Paczynski, McKnight, & Greenwood, 2016; Wager & Atlas, 2015). To establish a causal connection, researchers have to compare the intervention with the control condition to exclude placebo effects. In clinical trials, double-blind, placebo-controlled designs are used to rule out placebo effects, in which control group receives a "sugar pill" that is similar in all respects to a real treatment, resulting in same expected benefits to treatment which make it possible to obtain reliable conclusions (Bruix et al., 2017; Escudier et al., 2007).

Unlike clinical trials, psychological interventions, such as cognitive training, face a serious challenge in controlling placebo effects (De Simoni & von Bastian, 2018; Katz, Shah, & Meyer, 2018). The double-blind, placebo-controlled design is hard to conduct in these interventions and is determined by the specialty of

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psychological intervention. One of possible reasons for this is that the intervention tasks between training and control groups are usually different (Beauchamp et al., 2016; Hu, Wang, Zhang, Hu, & Chen, 2017; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Jaeggi, Buschkuehl, Jonides, & Shah, 2011; Schweizer et al., 2013), which in turn make the two groups likely to expect different amounts of improvement from the intervention tasks (Boot et al., 2013). Furthermore, another additional reason is the different expectations sourced from distinct intervention contexts (verbal suggestions, place cues, treatment cues, etc.) that are caused by non-double-blinded designs. For example, the overt and suggestive words (e.g., 'brain training') were frequently used in training paradigms (Foroughi et al., 2016), which may produce strong expectations contributing to positive results reported in these studies. Although expectation/placebo effects are well established in placebo analgesia (Wager & Atlas, 2015), it is presently not known whether expectations could induce the enhancement of emotion regulation similar to actual cognitive training.

Therefore, given the possible influence of expectations, some placebo effects may have been confounded with actual training effects in previous interventions. Although controlling expectations is crucial to rule out placebo effects, few published studies have investigated whether the training and control conditions create the same expectations (Beauchamp et al., 2016; Cohen et al., 2016; Dahlin, Neely, Larsson, Bäckman, & Nyberg, 2008; Schweizer et al., 2013). Even though researchers noted limitations in their designs, they tended to ignore them and drew causal conclusions about the effectiveness of cognitive training (Katz et al., 2018). The answer to the effectiveness is the fundaments of subsequent training studies (why it works; under what conditions). Thus, the failure to control expectations is a fundamental design flaw that potentially undermines any causal inference.

The Present Study

The current study was driven by concerns about pervasive placebo effects and the fundamental design flaw in psychological intervention studies. Specifically, we kept the intervention task consistent between training and control groups, but changed the intervention context to induce different expectations on improvement. Moreover, to illustrate how expectations influence the observed results, we conducted two experiments with different aspects of cognitive training. First, to simulate the experimental task, the training task was the same as in previous training studies, while the training time was short enough so that we can obtain the immediate effects of expectation before producing actual training effects. Second, to simulate the time course of cognitive training, a long-term pseudotraining procedure was conducted so that we could obtain the delayed effects of expectations, but the used training task did not have any actual training effects.

In Experiment 1, we tested the influence of expectations on emotional reactivity and emotion regulation in a short-term working memory training context (immediate effect). Here, we had three considerations regarding the experimental parameters. Initially, working memory training is commonly used in cognitive training research (Jaeggi et al., 2008; Schweizer et al., 2013; Shipstead, Redick, & Engle, 2012), and accordingly has strong operability. In addition, the use of a working memory task is to maintain the credibility of the suggestion words, which is similar to the effect of placebo pain medication appearing identical to the real intervention (Benedetti et al., 2003). Very importantly, the duration of the short-term training can avoid the actual training effect.

Furthermore, in Experiment 2, we investigated whether expectation effects still existed after a long-term pseudotraining (delayed effect). Considering that the traditional training procedure needed to seven or even more hours of training (Cohen et al., 2016; Schweizer et al., 2013), we conducted a seven days pseudotraining procedure to simulate the time course of real training as much as possible. Importantly, the experimental task used in the training stage did not have any training effects, which ensured that the effects we obtained were the delayed effects of expectation rather than the training effects.

Usually, people can form different expectations with different verbal instructions (Benedetti et al., 2003). In the current study, the placebo group received a placebo-forming stage that served to create links between cognitive training and emotion regulation gains by using suggestive words, and then the placebo and active control groups were instructed to complete the same training task. It is worth noting that expectations have a lasting influence on cognition and emotion (Schwarz, Pfister, & Büchel, 2016). For instance, participants experience more angry or excited emotions when they expect those emotions to promote performance (Tamir & Bigman, 2018). Thus, we predicted that expectations induced by suggestive words would modulate subsequent emotion and behavior in an improved manner, irrespective of the duration of the training.

Experiment 1: The Immediate Effects of Expectations on Emotional Reactivity and Emotion Regulation After the Short-Term Working Memory Training

Method, Materials, and Participants

We determined the sample sizes for both groups based on two criteria: (a) published training studies had sample sizes of 20 or fewer; and (b) a priori statistical power analyses (power ≥ 0.9) on within-between interaction designs, assuming a small-to-medium effect size f of 0.25, revealed a sample size of 15 per group, which was performed by G*power 3.1.9.2 software (Faul, Erdfelder, Lang, & Buchner, 2007). Due to variability in participant scheduling reliability, we ended up with $N = 56$ in Experiment 1, and $N = 37$ in Experiment 2. All participants signed written informed consent to the experimental procedure in accordance with the ethical principles of the 1964 Declaration of Helsinki. This study was approved by the local ethical committee of Southwest University (China).

Fifty-six undergraduates from Southwest University (40 females, age from 17 to 24 years) completed Experiment 1. They were randomly assigned to the Control ($N = 27$) and Placebo groups ($N = 29$). The two groups were similar in age, gender, and emotion-related states (the Spielberg State-trait Anxiety Scale; the Beck Depression Inventory) ($p_s > .05$).

Procedure. The Placebo group completed an individual pretest followed by the placebo-forming stage that was designed to intentionally induce an expectation of benefits by viewing a leaflet for 5 min (Figure 1A). Participants completed a 20-min pseudotraining task (working memory task), after which a posttest was required on the following day. To control the natural history of

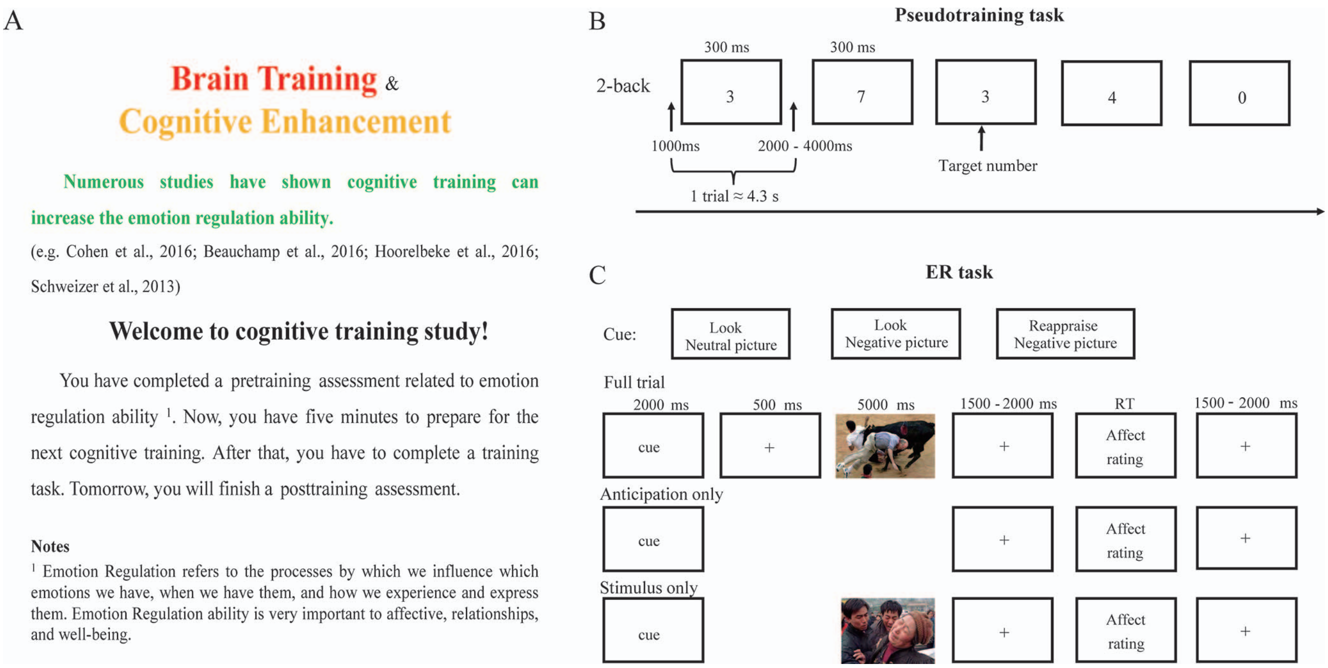

Figure 1. A. The placebo-forming stage was used to intentionally induce an expectation of improvement. B. Pseudotraining task: participants decide whether the current number matches the number that was presented *n* items ago. C. ER task: the task includes three trial types: Full trial, Anticipation only, and Stimulus only, for each of the three experimental conditions (Cue). The photos are taken from the Chinese Affective Picture System (CAPS; Bai et al., 2005), which are published with permission from correspondence. See the online article for the color version of this figure.

emotion, the time course of the Control group was equal to Placebo group, in which Control group had a 5-min break followed by the same pseudotraining. Aside from the placebo-forming stage, all participants completed an identical procedure. The same Emotion Regulation (ER) task was presented at both pretest and posttest.

Pseudotraining task. Participants completed a working memory task: the *n*-back task, which had been used in cognitive training research (Jaeggi et al., 2008; Schweizer et al., 2013; Shipstead et al., 2012). As shown in Figure 1B, participants were presented with a stream of numbers at a mean rate of 4.3 s per stimuli (fixation, 1000 ms; stimulus length, 300 ms; interstimulus interval, 2000–4000 ms). Participants decided whether the current number (target number) matched the number that was presented *n* items ago ("F" for the mismatch, "J" for the match).

Pseudotraining procedure comprised 5 blocks consisting of 48 + *n* trials, and each block represented one level of *n*-back. There were 16 matching targets per block. The sequence of matching targets or blocks was pseudorandom.

ER task. The ER task has been commonly used in previous studies (Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008). Ninety-six aversive images (valence = 2.17, arousal = 5.83) and 48 neutral images (valence = 5.11, arousal = 4.25) were selected from the Chinese Affective Picture System (CAPS) (Bai, Ma, Huang, & Luo, 2005). All images were randomly assigned to two image sets (pre- and posttest images sets). Both sets were similar in valence ($F_{(1,140)} = 0.009$, $p = .93$) and arousal ($F_{(1,140)} = 0.11$, $p = .74$); the difference in valence/arousal between aversive and neutral images was significant ($p_s < .001$). An additional set of 8 aversive images and 4 neutral images was used during a practice procedure. Participants viewed each image only once during the ER task.

Images were grouped into three *experimental conditions* (cues; Figure 1C): Neutral (Look neutral picture): participants viewed neutral images. Attend (Look negative picture): participants viewed aversive images. In both conditions, participants were instructed to understand their content and were allowed to experience any emotional response that it might elicit. Regulate (Reappraise negative picture): participants viewed aversive images and were instructed to cognitively down-regulate their emotional experience by using a reappraisal strategy (Gross & John, 2003). A practice procedure was used to assure that participants understood the cue-task associations and the reappraisal strategy.

Within each *experimental condition*, three different trial types were used (Figure 1C): full trials, anticipation only trials, and stimulus only trials. In the full trials, a 2000 ms cue was followed by a 500 ms anticipatory interval during which a fixation cross was presented on the screen. The image was presented for 5000 ms followed by a 1500–2000 ms interval. Then, participants were instructed to rate their emotional experience which referred to how negative they felt to the negative stimulus on a five-point scale (1-not at all; 5- extremely negative). Rating was terminated by a number key. Finally, an intertrial interval was presented for 1500–2000 ms. Anticipation-only trials consisted of the cue, anticipatory (1500–2000 ms), and rating intervals. Stimulus-only trials were identical to the full trials, except that the anticipation interval was omitted. A random sequence was used in the ER task.

At the pretest or posttest, participants completed 3 blocks of 36 trials each for a total of 108 trials. In this report, to clarify the theme of this article, subsequent analyses of affect ratings were conducted on averages of the full trials and stimulus only trials.

Data analysis. In the current two experiments, all statistical analyses were performed using SPSS Statistics 20.0 (IBM, Somers, U.S.A.). First, two-way repeated measure ANOVAs were performed on emotional experience at the pretest, with *experimental condition* (Neutral, Attend, Regulate) as a within-subject factor, and *group* (Placebo, Control) as the between-subjects factor. Second, training-related changes in the pseudotraining task were tested. Third, to test the change in emotional reactivity across time, three-way ANOVAs were performed on emotional reactivity, with *time* (pretest, posttest) and *experimental condition* (Neutral, Attend) as two within-subject factors, and *group* as a between-subjects factor. Additionally, three-way ANOVAs were performed on emotion regulation, with *time* and *experimental condition* (Attend, Regulate) as two within-subject factors, and *group* as a between-subjects factor. Post hoc multiple comparisons were conducted using the Bonferroni test. Degrees of freedom were corrected by Greenhouse-Geisser correction whenever appropriate.

Results

Pretest ER task performance. At the pretest, participants in both groups felt the comparable negative emotional experience (Figure 2A). Pretest assessment showed that the main effect of *group* ($F_{(1,\ 54)} = 0.39$, $p = .54$) and the interaction of *group* × *experimental condition* ($F_{(2,\ 102)} = 0.34$, $p = .70$) were not significant.

Additionally, there was a notable main effect of *experimental condition* ($F_{(2,\ 108)} = 208.52$, $p < .001$, $\eta_p^2 = 0.794$, 95% confidence interval [CI] [0.72, 0.84]), with more negative experience in the Attend condition than in the Neutral condition ($p < .001$), as well as less negative experience in the Regulate condition than in the Attend condition ($p < .001$).

Training-related changes in the pseudotraining task. All subjects completed five blocks of the pseudotraining task. The training performance of the two groups was similar (Figure 2B): both the Placebo and Control groups completed a pseudotraining task with a similar degree of success in five blocks ($t(54)_{\max} = 1.12$, $p = .27$). The expectation did not significantly improve the performance on the Pseudotraining task.

Changes in ER: Behavioral effects after the expectation of cognitive improvement.

Emotional reactivity. The results showed that there was a significant *time* × *group* × *experimental condition* interaction ($F_{(1,\ 54)} = 13.45$, $p = .001$, $\eta_p^2 = 0.20$, 95% CI [0.04, 0.37]) (Figure 2C). We deconstructed this interaction in each group separately. The Placebo group was associated with a significantly greater pre- to posttest decrease in the Attend condition relative to the Neutral condition ($F_{(1,\ 28)} = 7.18$, $p = .012$, $\eta_p^2 = 0.204$, 95% CI [0.01, 0.43]). In contrast, the Control group showed a significant pre- to posttest increase in the Attend relative to the Neutral condition ($F_{(1,\ 26)} = 6.30$, $p = .019$, $\eta_p^2 = 0.195$, 95% CI [0.004, 0.43]). Additionally, there was a statistically marginally significant difference in emotional experience between the Placebo and Control groups (2.17 vs. 1.99; $F_{(1,\ 54)} = 3.18$, $p = .08$, 95% CI [0.00, 0.20]). No significant effects were observed for the main

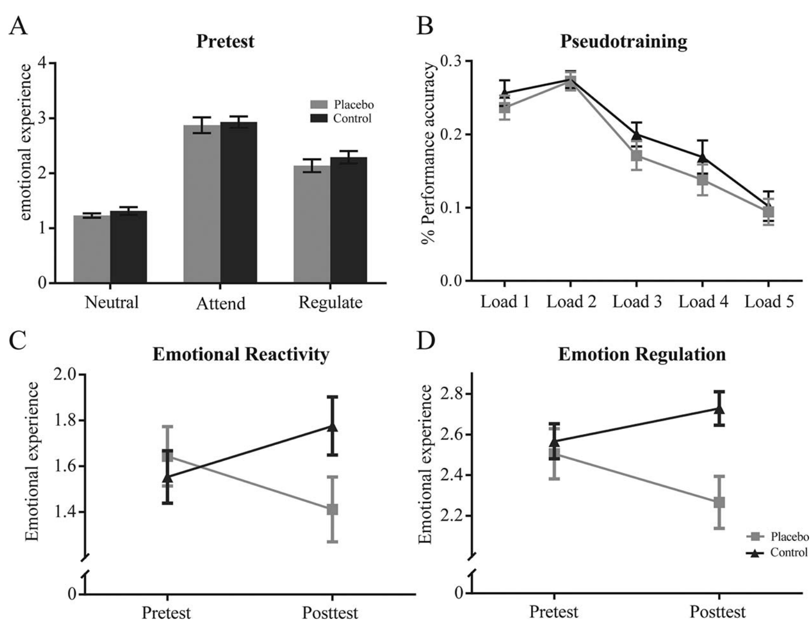

Figure 2. A. The figure shows the emotional rating of the Placebo and Control groups at the pretest. B. The graph represents mean performance accuracy (hit rates - false alarm rates) at the levels of *n*-back = 1, 2, 3, 4, and 5 in the Placebo and Control groups during the pseudotraining task. The graph reports the emotional experience (changes in reported negative emotion for the Attend compared with the Neutral condition) in Emotional Reactivity (C), and the emotional experience in Emotion Regulation (D) by time and group. Error bars denote the standard error of the mean (SEM).

effect of *time* ($F_{(1, 54)} = 0.04$, $p = .851$), the *group* × *experimental condition* interaction ($F_{(1, 54)} = 0.64$, $p = .428$), and the *time* × *experimental condition* interaction ($F_{(1, 54)} = 0.005$, $p = .944$).

Emotion regulation. We obtained a significant interaction between *time* and *group* ($F_{(1, 54)} = 16.35$, $p < .001$, $\eta_p^2 = 0.232$, 95% CI [0.06, 0.40]) (Figure 2D). The follow-up tests in separate groups revealed that the Placebo group was associated with a significant pre- to posttest decrease in emotional experience ($F_{(1, 28)} = 9.57$, $p = .004$, $\eta_p^2 = 0.255$, 95% CI [0.03, 0.47]). Nevertheless, the Control group showed a significant pre- to posttest increase in emotional experience ($F_{(1, 26)} = 7.15$, $p = .013$, $\eta_p^2 = 0.216$, 95% CI [0.01, 0.45]). Moreover, the main effect of *group* was marginally significant ($F_{(1, 54)} = 3.23$, $p = .078$, 95% CI [0.00, 0.20]), with more negative experience in the Control (2.65) than in the Placebo group (2.39). Additionally, there were no significant effects for the main effect of *time* ($F_{(1, 54)} = 0.61$, $p = .439$), *group* × *experimental condition* interaction ($F_{(1, 54)} = 0.03$, $p = .867$), *time* × *experimental condition* interaction ($F_{(1, 54)} = 2.16$, $p = .148$), and *time* × *group* × *experimental condition* interaction ($F_{(1, 54)} = 2.90$, $p = .094$).

Experiment 2: The Delayed Effects of Expectations on Emotional Reactivity and Emotion Regulation After the Long-Term Cognitive Training

Method, Materials, Participants

Forty undergraduates (30 women, age from 17 to 23 years) were randomly assigned to the Placebo group ($N = 20$) and Control group ($N = 20$). Three participants (two from the Placebo group) failed to complete the required training sessions, and their data were excluded from the analysis, which resulted in 37 participants for the analyses. Both groups were similar in age, gender, and emotion-related states (the Spielberg State-trait Anxiety Scale; the Beck Depression Inventory) ($p_s > 0.05$).

Procedure. All procedures were identical to Experiment 1, except that all participants had to complete 7 days of pseudotraining task (Search task) with a daily training time of 20 min.

The Search task was used in the previous study (Anderson, Laurent, & Yantis, 2011). Each trial started with a randomly chosen interval of 400, 500, or 600 ms, followed by a search screen that remained until a response or after 1500 ms. This screen consisted of a diamond among circles, and participants made a choice target identification by pressing the F and J for the horizontally and vertically orientated targets, respectively. Importantly, this task makes minimal demands on working memory resources, which often served as an active control task in cognitive training studies.

Results

Pretest ER task performance. Both groups were similar in emotional experience at the pretest (Figure 3). *The main effect of group* ($F_{(1, 35)} = 2.08$, $p = .159$) and the interaction of *group* × *experimental condition* ($F_{(2, 61)} = 1.24$, $p = .293$) were not significant.

A significant effect was observed for the *experimental condition* main effect ($F_{(2, 61)} = 119.28$, $p < .001$, $\eta_p^2 = 0.773$, 95% CI [0.69, 0.85]). The pretest assessment showed increased levels of reported emotional experience to negative stimuli in the Attend condition compared to the Neutral condition ($p < .001$). Participants downregulated their emotions effectively in the Regulate condition relative to the Attend condition ($p < .001$).

Training-related changes in the pseudotraining task. The Placebo and Control groups completed 7 days of pseudotraining and showed a linear improvement across the training sessions on their respective training tasks (Figure 4). Two-way ANOVAs were performed on reaction time (RT) and accuracy and showed that the interaction between *time* and *group* was not significant for RT ($F_{(1, 34)} = 2.95$, $p = .095$) or for accuracy ($F_{(1, 34)} = 0.83$, $p = .368$). All participants revealed a significant pre- to posttest improvement in RT ($F_{(1, 34)} = 222.13$, $p < .001$, $\eta_p^2 = 0.867$, 95% CI [0.77, 0.91]) and accuracy ($F_{(1, 34)} = 33.36$, $p < .001$, $\eta_p^2 = 0.495$, 95% CI [0.24, 0.65]).

Taken together, training performance was not affected by the expectation: the Placebo and Control groups completed a pseudotraining task with a similar degree of success.

Changes in ER: Behavioral effects after placebo.

Emotional reactivity. We obtained a significant main effect of *group* ($F_{(1, 35)} = 5.24$, $p = .028$, $\eta_p^2 = 0.130$, 95% CI [0.00, 0.33]), with more negative experience in the Control group (2.27) than in the Placebo group (1.93). Also, a significant *group* × *time* interaction was observed ($F_{(1, 35)} = 11.51$, $p = .002$, $\eta_p^2 = 0.247$, 95% CI [0.04, 0.45]) (Figure 3B). The follow-up tests in separate groups showed that the Placebo group was associated with a significant pre- to posttest decrease in emotional reactivity ($F_{(1, 17)} = 5.04$, $p = .038$, $\eta_p^2 = 0.229$, 95% CI [0.00, 0.49]). In contrast, the Control group showed a significant pre- to posttest increase in emotional reactivity ($F_{(1, 18)} = 6.85$, $p = .017$, $\eta_p^2 = 0.276$, 95% CI [0.01, 0.53]). In addition, there were no significant effects for the main effect of *time* ($F_{(1, 35)} = 0.045$, $p = .833$) and the *time* × *experimental condition* interaction ($F_{(1, 35)} = 0.001$, $p = .984$).

Emotion regulation. The results revealed a significant main effect of *group* ($F_{(1, 35)} = 6.05$, $p = .019$, $\eta_p^2 = 0.147$, 95% CI [0.003, 0.35]), with more negative experience in the Control group (2.90) than in the Placebo group (2.37). There was a significant *time* by *group* interaction ($F_{(1, 35)} = 11.65$, $p = .002$, $\eta_p^2 = 0.250$, 95% CI [0.04, 0.45]) (Figure 3C). We deconstructed this interaction in each group separately. The Placebo group showed a significant pre- to posttest decrease in emotional experience ($F_{(1, 17)} = 7.89$, $p = .012$, $\eta_p^2 = 0.317$, 95% CI [0.02, 0.56]). In contrast to the Placebo group, the Control group showed a marginally significant pre- to posttest increase in emotional experience ($F_{(1, 18)} = 3.66$, $p = .072$, 95% CI [0.00, 0.44]). No significant effects were observed for the main effect of *time* ($F_{(1, 35)} = 1.12$, $p = .297$), the *group* × *experimental condition* interaction ($F_{(1, 35)} = 0.23$, $p = .632$), the *time* × *experimental condition* interaction ($F_{(1, 35)} = 1.73$, $p = .197$), and the *group* × *time* × *experimental condition* interaction ($F_{(1, 35)} = 1.31$, $p = .260$).

General Discussion

The present research serves to highlight the influence of expectations in psychological interventions. As expected, regardless of the duration of the training, the participants who were instructed that cognitive training could improve emotion regulation showed less emotional reactivity and better regulatory effects than those who did not receive these instructions. In other words, expectations induced by the suggestion of cogni-

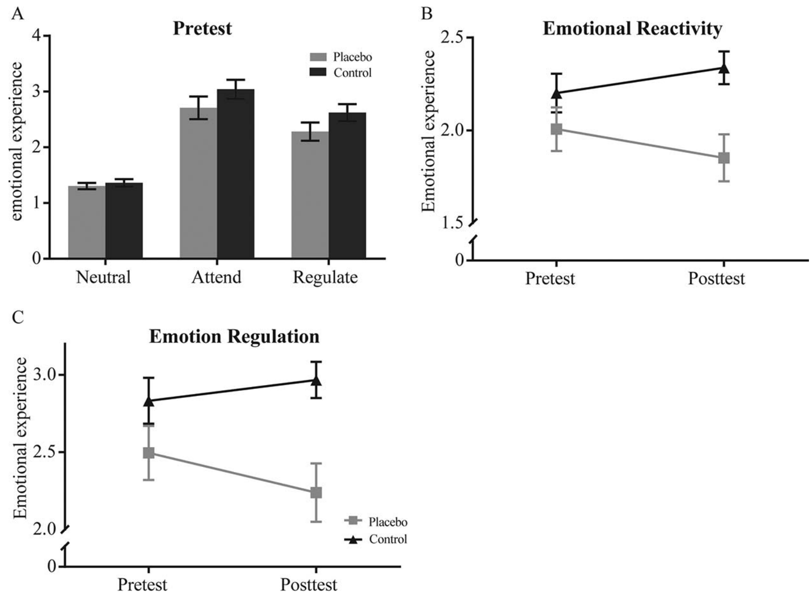

Figure 3. A. The figure shows the emotional rating of the Placebo and Control groups at the pretest. The graph reports the emotional experience in Emotional Reactivity (B) and Emotion Regulation (C) by time and group. Error bars indicate the SEM.

tive enhancement can significantly improve subsequent emotion and behavior. These results support the concern about inadequate experimental control, which fails to eliminate placebo effects and underlies positive results reported in cognitive training studies (Boot et al., 2013; De Simoni & von Bastian, 2018; Foroughi et al., 2016; Shipstead et al., 2012). Thus, an active control can rule out placebo effects only when intervention and control groups share the same expectations, especially at the same intervention context.

Now, it seems that emotion regulation is truly changed by short- or long-term training. However, it is impossible that participants have less negative emotion after the pseudotraining procedure due to the negative bias (Long, Yang, Lou, Cai, & Yuan, 2015; Yuan et al., 2009). We suggest that the improvement in the Placebo group may be fully attributed to expectancy effects instead of training effects. Here are several reasons for this claim. First, the manipulation of the pseudotraining task can exclude the actual training effects. Only 20 min of training in Experiment 1 is far less than the traditional seven or more hours commonly used in published studies (Cohen et al., 2016; Diamond & Lee, 2011; Schweizer et al., 2013). Meanwhile, the search task used in Experiment 2 usually served as the training task of an active control group in prior studies, which makes minimal demands on working memory resources. Second, the Placebo and Control groups had the same baseline on emotion regulation at the pretest, suggesting that any changes at the posttest cannot be attributed to the baseline difference. Third, both groups completed the pseudotraining task with a similar degree of success in both experiments.

How can expectations improve one's behavioral performance? Based on clinical research, placebo effects were shown to be mediated by the brain reward circuitry in which reward expectations played a significant role in dopamine release in the nigrostriatal system (De la Fuente-Fernández et al., 2001; Enck, Benedetti, & Schedlowski, 2008). In this case, the expectation has the motivational function, predicting high effort and successful performance (Oettingen & Mayer, 2002), in which individuals are mobilizing cognitive control to attend to the desired outcome, and

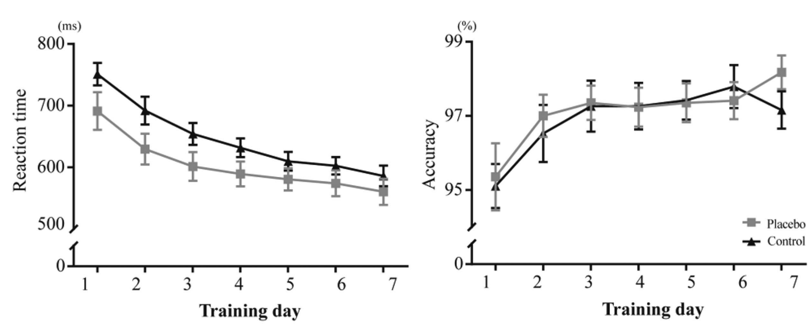

Figure 4. The graphs represent the Placebo and Control groups' performance on the pseudotraining task across training days. Error bars indicate the SEM.

to evaluate and enact goal-consistent behaviors (Botvinick & Braver, 2015). In the present study, improving emotion regulation ability is a prospective reward that attracts individuals toward that goal, which would lead to improved results in the Placebo group. Additionally, Wager and colleagues reviewed a substantial numbers of placebo studies of pain and indicated that placebo engages multiple systems in the prefrontal cortex (PFC), nucleus accumbens (NAcc), and amygdala, and influences the functional connectivity between them (Wager & Atlas, 2015). Likewise, these regions have been implicated in emotion regulation (Dixon, Thiruchselvam, Todd, & Christoff, 2017; Wager et al., 2008). Expected benefits from cognitive training are a placebo that activates these brain regions, which enhance emotion regulation at the posttest. However, given that these explanations are based on placebo studies in other fields, such inferences should be cautiously taken due to the lack of direct evidence of the neural mechanisms of the placebo-driven improvements observed in the present study.

The present study is the first direct evidence to explore the short-term and long-term effects of expectations on transfer effects in the cognitive training context. The clear implication is that these findings present a unique perspective for understanding and optimizing the experimental designs in cognitive training and other psychological interventions. The results of prior cognitive training may have been unintentionally affected by expectations derived from suggestions. For future interventions, it is an emerging imperative to measure expectations and report the detailed procedures of the intervention to evaluate the relationship between the intervention and expectancies. Researchers should take caution with overt suggestions until the placebo effects are better understood. Otherwise, strong expectations arising from these suggestions may contribute to the placebo effects, contaminating the actual intervention effects.

Another possible implication of these findings is that they promote the advancement of human cognition. Psychological science is encountering a reproducibility crisis. The published cognitive training studies and systematic reviews have provided mixed findings (De Simoni & von Bastian, 2018; Sala & Gobet, 2019). Crucially, when estimating the reproducibility of psychological science, only 36% of replications successfully reproduced results supporting the original results even if the high-powered designs and original materials were used (Open Science Collaboration, 2015). Failure to manage expectations or the experimental context may contribute to some of these inconsistent results. In any psychological study, researchers must ensure that the experimental effects we explore come from every step of the manipulations instead of other confounders.

Last but not least, we argue that these findings also bring a fresh perspective for studying the underlying mechanisms of improvement from different dimensions (e.g., expectation-driven, training-driven, reward-enhancing effects) in psychological interventions. For instance, although expectations can lead to improvement of emotional experiences, as in this study, there should be differences in the brain mechanisms between expectation-driven and training-driven improvements on emotion regulation. Exploring the similarities and differences in neural mechanisms by using functional MRI (fMRI) and electro- and magnetoencephalography (EEG and MEG) make it possible to rule out placebo effects from actual training effects. Besides, in the past few decades, research on improving emotion regulation and other cognitive abilities has emphasized the near and far effects of psychological interventions by using different training tasks (Beauchamp et al., 2016; Cohen et al., 2016; Cohen & Ochsner, 2018; Greenwood & Parasuraman, 2016; Hoorelbeke et al., 2016; Jaeggi et al., 2011; Schweizer et al., 2013). Future studies should explore the multiple mechanisms of training, expectations or other subjective variables (e.g., belief, reward), and their interactions instead of only studying the underlying mechanisms of improvement from cognitive training. A better understanding of how these effects arise and are sustained may help shed light on the mechanisms of improving emotion and cognition.

Conclusion

Taken together, regardless of the duration of the training, when individuals expected benefits from a psychological intervention, they were more likely to show improved results. An active control could eliminate placebo effects only when the intervention and active control conditions share the same expectations, especially the same intervention context, including the recruitment, instructions, and experimenters' expectations. Experimental designs that lack adequate controls will lead to inappropriate inferences, suggesting that obtaining reliable training effects requires controlling manipulations in the intervention context to match the expectation between the intervention and active control group. Additionally, these findings highlight the importance of expectation/placebo effects on emotion regulation.

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