

The evidential value of research on cognitive training to change food-related biases and unhealthy eating behavior: A systematic review and *p*-curve analysis

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Summary

Cognitive bias modification (CBM), which retrains implicit biases towards unhealthy foods, has been proposed as a promising adjunct to improve the efficacy of weight loss interventions. We conducted a systematic review of research on three CBM approaches (i.e., cue-specific inhibitory control, approach bias modification, and attentional bias modification) for reducing unhealthy eating biases and behavior. We performed a *p*-curve analysis to determine the evidential value of this research; this method is optimally suited to clarify whether published results reflect true effects or false positives due to publication and reporting biases. When considering all CBM approaches, our results suggested that the findings of CBM trials targeting unhealthy eating are unlikely to be false positives. However, only research on attentional bias modification reached acceptable levels of power. These results suggest that CBM interventions may be an effective strategy to enhance the efficacy of weight loss interventions. However, there is room for improvement in the methodological standards of this area of research, especially increasing the statistical power can help to fully clarify the clinical potential of CBM, and determine the role of potential moderators.

KEYWORDS

cognitive training, obesity, *p*-curve analysis, systematic review

1 | INTRODUCTION

The prevalence of obesity has rapidly grown worldwide and is expected to be on the rise in the near future.^{1,2} Excess weight is related to an increased likelihood of suffering a wide range of physical illnesses, as well as emotional distress and related mental health disorders.³ Lifestyle and weight management interventions based on dietary and physical activity counseling, delivered either in isolation or in combination with pharmacological or cognitive-behavioral interventions, are the most widely used treatments for

excess-weight.^{4,5} For people with severe obesity, when other approaches do not lead to significant weight loss, bariatric surgery is the treatment of choice.⁶ However, the success of these interventions is highly variable and there is mixed evidence regarding their long-term benefits.^{4,7,8} The development of less invasive and more sustainable weight-loss interventions is thus a priority for public health systems.

Obesity is a multifactorial and heterogeneous condition, but consistent evidence suggests that overeating of energy-dense food is the main driver of the current obesity problem^{1,3} (henceforth, we use

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the term energy-dense food to refer to highly palatable foods with excessive caloric content and poor nutrient density, including ultra-processed foods). Energy-dense food stimulates the brain's reward circuit and may promote persistent habits.^{9,10} However, current interventions for obesity do not directly target habit formation and modification mechanisms. This may be one of the reasons for their limited efficacy in the long run. In this context, cognitive bias modification (CBM) interventions have emerged as promising add-on treatments to remodel eating habits and thereby promote long-lasting changes in eating behavior.^{11,12} In addition, they can be easily implemented in eHealth applications for computers and smartphones, which facilitates their tailoring to individual patients' characteristics¹³ and broadens the population that can be reached in a cost-effective way.¹⁴ An additional advantage of CBM is that they reduce the invasiveness and potential side effects of some of surgery or medication-based treatments.

CBM interventions are grounded in dual-process models which posit that choice behavior is determined by two separate, but interconnected systems. The terminology to refer to both systems varies across different models,¹⁵ but all of them assume that one of these systems is unconscious, automatic, and impulsive, while the other is conscious, deliberate, and reflective. To ensure clarity and consistency, we will follow Strack and Deutsch's terminology¹⁶ and refer to these systems as impulsive and reflective, respectively. While the former is fast, relatively rigid, requires no higher order cognitive resources and relies on associative processes, the latter processes information slowly, is flexible but resource-demanding, and influences decisions by weighting the value and probability of potential consequences.¹⁶ CBM interventions primarily target the impulsive system.¹² In the domain of eating behavior, they aim to help individuals overcoming the influence of food cues that signal availability of energy-dense food.

1.1 | Cognitive bias modification interventions

Cognitive bias modification (CBM) encompasses different interventions aimed at modifying eating behavior by retraining food-related biases.^{11,12} More specifically, they target two key biases, namely, "go" or approach responses. These responses are triggered by energy-dense food stimuli (i.e., approach/response bias) and the automatic attentional capture by such stimuli (i.e., attentional bias). CBM includes cue-specific inhibitory control (henceforth, INH), approach bias and attentional bias modification training (APP and ATT respectively).¹¹

INH training is intended to override response biases produced by appetitive stimuli, by extinguishing associations between energy-dense food stimuli and motor-response (i.e., "go") tendencies. Note the difference with general inhibitory control training,¹² which aims to improve overall response inhibition capabilities by using affectively neutral stimuli. INH training tackles the impulsive system while general inhibitory control training focuses on the reflective system. Two explanatory mechanisms have been proposed for the efficacy of INH.

On the one hand, food-related stimuli may end up producing inhibition by themselves rather than a "go" response.¹⁷ On the other hand, such stimuli may lose incentive value.¹⁸ Most studies on this type of training have used modified versions of the Go/No-go and Stop Signal tasks, where unhealthy food stimuli are massively paired with stopping signals to favor behavioral inhibition.¹²

The goal of APP is to modify impulsive approach tendencies towards affective stimuli. In the food domain, this training usually implies either associating unhealthy food stimuli with avoidance-related words and healthy food stimuli with approach-related words (i.e., implicit association training),¹⁹ or practicing approach and avoidance movements in response to healthy and unhealthy visual food cues, respectively (i.e., approach and avoidance training).²⁰ The latter is designed to emulate the action of pulling and pushing away food as it occurs in real-life environments.

Finally, ATT aims to reduce the attention-grabbing effect of energy-dense food stimuli.²¹ For this purpose, people are trained to withdraw their attention from such stimuli and directed it towards healthy foods or neutral stimuli, usually by means of a modified dot-probe task.²² Such training is believed to produce lasting changes in attentional processing and, therefore, in affective and overt behavioral responses to environmental cues.

1.2 | Aims of the present study

Two recent systematic reviews have thoroughly examined the benefits of CBM interventions.^{12,23} Both reviews concluded that CBM may be effective in modifying some automatic food-related processes (i.e., food-related biases) and clinical outcomes (e.g., weight loss), but they also raised concerns about the existence of null-findings and inconsistencies across studies. Complementarily, the most recent meta-analyses on this topic suggest that inhibitory control training (including both general and INH) and ATT may have a small but significant effects in changing eating behavior, while APP is not effective to this end²⁴ (see Box 1 for an overview of methodological aspects and main findings of these studies). However, several questions remain unexplored. These meta-analyses^{24,25} made no distinction between cue-specific and general inhibitory control, which prevents unraveling the distinctive benefits of both interventions. Furthermore, both meta-analyses used a popular method known as "trim-and-fill" to correct for publication bias, but the results of these analyses are inconsistent. One of them suggests that there is no publication bias in research on CBM,²⁴ while the other one casts doubts at this respect.²⁵ Given that trim-and-fill returned a significant bias-corrected effect size in the meta-analysis conducted by Yang et al.,²⁴ these authors concluded that the observed effects must be real, that is, they cannot be solely due to the selective publication of significant findings. Unfortunately, trim-and-fill is known to undercorrect for publication bias²⁶ and shows alarmingly high false-positive rates.²⁷ Given the shortcomings of this method, at least some of the conclusions of Yang et al.²⁴ might be premature and should be confirmed with alternative methods.

Box 1. Brief overview of the most comprehensive meta-analytic studies on CBM interventions targeting eating behavior.

Yang et al (2019)²⁴

This study examined whether several cognitive training interventions, i.e., inhibitory control (INH), approach (APP), attention bias modification (ATT), and episodic future thinking (EFT), are effective in changing healthy or unhealthy eating behavior and calorie intake. For this purpose, 153 effect sizes from 66 studies were meta-analyzed. INH, ATT and EFT produced changes in eating behavior, but APP did not: INH, $g = 0.226$, 95% CI [0.098, 0.354]; APP, $g = 0.064$, 95% CI [-0.150, 0.278]; AAT, $g = 0.191$, 95% CI [0.062, 0.319]; EFT, $g = 0.708$, 95% CI = [0.224, 1.19]. The effect of INH was moderated by the type of training task (Go/No-go training was superior to training with modified Stop Signal Task) and also food novelty. The effect of APP was moderated by the type of food (healthy vs. unhealthy). The effect of EFT was moderated by the type of training. Egger's test for funnel plot asymmetry showed no evidence of publication bias for APP, ATT, and EFT but there was significant evidence of bias for INH. However, the effect of INH training on eating behavior remained significant after correcting for publication bias with trim-and-fill.

Aulbach, Knittle & Haukkala, (2019)²⁵

The aim of this study was twofold. First, it examined the evidence for potential benefits of implicit process interventions in modifying eating behavior. And second, it examined whether stimulus devaluation could explain changes in implicit bias towards food stimuli and, in this way, influence eating behavior. In this case, three interventions were considered: INH (but separate for Go/No-go and modified Stop-Signal tasks), APP and evaluative conditioning (EC). The selected dietary outcomes were amount of consumed food in taste tests, snack choices and/or food diaries or questionnaires. Forty-seven effect sizes from 30 studies were included in the meta-analysis. Considering all interventions together, small but significant beneficial changes were found in dietary outcomes, $g = -0.17$, 95% CI [-0.29, -0.05], and implicit biases towards food stimuli, $g = -0.18$, 95% CI [-0.34, -0.02]. The type of task moderated effects on dietary outcomes: INH using Go/No-go produced larger effects, $g = -0.38$, 95% CI [-0.55, -0.22], than SST, $g = -0.14$, 95% CI [-0.40, 0.12], APP, $g = 0.09$, 95% CI [-0.10, 0.29], and EC, $g = -0.01$, 95% CI [-0.58, 0.56]. There were no further effects of the other moderators on dietary outcomes. In addition, the change in implicit bias was related to changes in dietary behavior, $B = 0.42$, 95% CI [0.02, 0.81]. Regarding publication bias, trim-and-fill suggested that all the effects on dietary outcomes might be nonsignificant after adjusting for publication bias, $g = -0.02$, 95% CI [-0.15, 0.11], with

the only exception of response inhibition training with Go/No-go, $g = -0.25$, 95% CI [-0.42, -0.09]. However, a selection model suggested the opposite, that is, that there was no significant publication bias.

General conclusions

In short, results of both meta-analyses taken together suggest that INH, ATT and EFT produce small benefits in changing eating behavior. It is possible that INH using Go/No-go tasks may yield greater benefits than modified Stop-Signal tasks. This type of training seems to be effective in a wide set of populations, since no idiosyncratic characteristics of participants moderated the effect. Furthermore, the devaluation of food-stimuli may be a potential mechanism underlying the efficacy of INH. Both meta-analyses raised concerns about the efficacy of APP. Finally, there is a partial discrepancy regarding publication bias in research on the effects of CBM on eating behavior. While trim-and-fill suggested that publication bias was trivial or nonexistent in INH in Yang et al.'s²⁴ meta-analysis, the same method revealed substantial publication bias in Aulbach et al.'s²⁵ meta-analysis, except for INH using Go/No-go tasks.

The main goal of the present study is to test whether the effects of CBM interventions, both considered together and separately, are reliable using p -curve analysis, a state-of-the-art method that can handle publication bias more effectively than trim-and-fill.^{26,28} Unlike trim-and-fill, p -curve examines the distribution of significant p values within a set of studies and compares it with a worst-case scenario where all the significant effects are false positives. If the observed distribution of p values departs significantly from this scenario, it is concluded that not all the observed results can be false positives or, in other words, that the significant findings reported in that set of studies cannot be attributed solely to publication bias or questionable research practices.

The p -curve method has not been used in previous meta-analyses of CBM interventions, possibly because it is based on statistical information that is rarely coded in systematic reviews and meta-analyses. Unlike standard meta-analytic methods, p -curve analysis does not rely on effect sizes but on the crucial statistic of each experiment.²⁸ These crucial statistics are often different from the information used to compute effect sizes, and coding them is sometimes a challenging task. Because of this, most meta-analyses typically explore publication and reporting biases using methods (such as trim-and-fill or regression-based methods) that do not require this information and can be directly applied to effect sizes instead. Note also that p -curve analysis is not aimed at computing a bias-corrected estimate of the average effect size (although it can be adapted for this purpose),²⁶ but to test the hypothesis that the statistically significant results of a set of studies are not false positives. In other words, p -curve does not replace, but rather complements the analyses typically reported in standard meta-analytic reviews.

An additional advantage of p -curve analysis over other methods is that it also returns a bias-corrected estimate of the average power of the studies, which can be used to assess whether the sample sizes of the studies are sufficiently large. Such analysis is worthwhile, since much of the available evidence on CBM comes from pilot or proof-of-concept studies¹¹ that may not be sufficiently powered to detect the effects examined in this literature. Thus, our study can contribute to assess the quality of previous research on this topic.

2 | METHOD

We conducted a systematic search for intervention studies using different types of cognitive bias modification training (CBM) among participants with healthy or excess weight and/or dysfunctional excessive eating patterns. We updated the literature search of a previous systematic review on cognitive training and neuromodulation techniques in unhealthy eating and obesity, that is, Forcano et al.²³ We used the same search terms with respect to CBM and added the studies identified in this updated search to those that had already been examined in that systematic review. We followed the PRISMA guidelines for systematic review and meta-analysis protocols.²⁹

2.1 | Eligibility criteria

We selected all studies testing at least one cognitive training technique aimed to modify implicit-automatic processes, namely, cue-specific inhibitory control (INH), and approach bias (APP) and attentional bias modification training (ATT). The eligibility criteria were (1) human studies, (2) including adult participants from the normal-weight to obesity range, (3) applying any of the three types of cognitive bias modification training mentioned above, (4) including at least one comparison group or control condition, and (5) published in an international peer-reviewed journal. Studies conducted with participants with psychopathologies, including eating disorders, were excluded.

2.2 | Information sources and search strategy

The literature search was conducted in February 2021, covering the interval time since the previous review,²³ that is, in January 2017. We examined PubMed and SCOPUS databases with the following search terms: Approach bias, Attentional bias, Cognitive bias or Response Inhibition; and Modification or Training, and Body mass index, BMI, weight, obesity, food consumption, food choice, food valuation, or food craving. Search results were assessed for inclusion. After removing duplicates, abstracts were screened and those articles which clearly did not meet the inclusion criteria were removed. Afterwards, the full-text of the remaining articles were examined. In addition, citation list from the selected articles were scrutinized for potential inclusion of further studies. This procedure

was made by the first author. When there was some ambiguity in the articles to be selected, a consensus was reached between first and senior authors.

2.3 | Data collection

A key point in p -curve analysis is the selection of contrasts of interest to be included from each study. The selection should focus on the statistical contrasts that are most directly related to the main hypothesis and should also depend on the studies' design. In all cases, we followed the guidelines for p -curve analysis provided by Simonsohn, Nelson, and Simmons.²⁶ When two or more contrasts were eligible for the analysis, we selected the first one presented by the authors for the main analysis, and the second one for a robustness test. P -curve analysis ignores nonsignificant results. However, to avoid introducing any bias in our selection, we selected statistical contrasts based on the predictions of the authors and the experimental designs of the studies, ignoring whether or not they turned out to be statistically significant. For exploratory studies without clearly defined hypotheses, we applied the same method. As our selection was based on the focal hypothesis made by the authors, we did not distinguish between different types of outcome measures, that is, between near transfer outcomes (i.e., response, approach, and attentional biases as directly addressed in the training protocols) and far transfer outcomes (i.e., outcomes that are intended to be indirectly modified such as eating behavior and its proximal determinants).

For the sake of transparency, the reader can find a p -curve disclosure table at <https://osf.io/cdqj5/>, where we describe in detail each selection and also justify any departure from the recommended guidelines. Broadly, five studies did not report sufficient information to include the key contrasts of the main hypotheses in our analysis. In those cases, we selected information from the following hypothesis (or aim, in the case of exploratory studies) that was available. In seven studies, the crucial eligible statistics were not reported for any of the main hypotheses, and thus we selected the results that, in our opinion, deviated less from the p -curve analysis guidelines (e.g., an omnibus test comparing the experimental group vs. two control groups instead of a comparison between just two groups). In the disclosure table, we also explain the rationale behind our selection of crucial contrasts for complex designs not covered in the p -curve guidelines (e.g., studies with more than three factors).

2.4 | Data analysis

All the analyses reported below were carried out with the p -curve web application (<http://www.p-curve.com/app/>). P -curve analysis is based on the fact that the distribution of p values is different when the null hypothesis is true and when the alternative hypothesis is true. If a set of studies is exploring true nonzero effects, then very small p values (e.g., .0001) are more likely than higher p values (e.g., .045),

even if we consider only significant p values lower than .05. In contrast, if all those studies are exploring a null effect, then all p values are equally likely and the distribution of p values becomes flat. Following this logic, it is possible to know whether a set of studies is exploring true effects or null effects by simply testing whether the distribution of p values is skewed or flat.

The web application for p -curve analysis first runs a test for right-skewness. The crucial question for this analysis is whether the distribution of p values departs significantly from a flat distribution. If this is the case, it can be concluded that at least some of the studies included in that distribution must be exploring true effects. Then, the online application runs a test for flatness. Specifically, this analysis tests whether the distribution is flatter than what would be expected if the studies were exploring a true effect but with a very low power (33%). If the distribution is significantly flatter than this benchmark, it can be concluded that the studies lack any evidential value: they are either exploring a null effect or they are too underpowered to detect a true effect. The distribution of p values can also be used to estimate the average power of the studies included into the analysis. P -curve analysis runs these analyses using only significant p values and, most importantly, their results are unaffected by publication bias.

3 | RESULTS

3.1 | Search results

The results of the updated literature search are displayed in Figure 1. The initial search yielded 636 entries. Four additional articles were identified by other sources (e.g., inspecting reference lists). After screening the titles and abstracts of all the entries, 38 full texts were examined, but 17 were excluded because they did not meet the inclusion criteria. Thus, 21 articles were added for analyses to those already identified by Forcano et al.²³ Among the 45 selected articles,^{13,17,19,20,21,30–69} 12 included multiple studies, we therefore considered the results of 61 studies, (mean sample size = 115.84, SD = 109.53; range = 18–561).

Of the 61 studies, 29 used cue-inhibitory control training (INH), 14 approach bias modification training (APP), 12 attentional bias modification (ATT), and 6 used a combination of several CBM interventions. All studies included a near transfer measure of food-related biases. The most common far transfer outcomes assessed in the revised literature were food consumption (in taste tests or in real-life), hypothetical and real food choices, strength of induced craving and self-reported craving state or trait, and a range of food

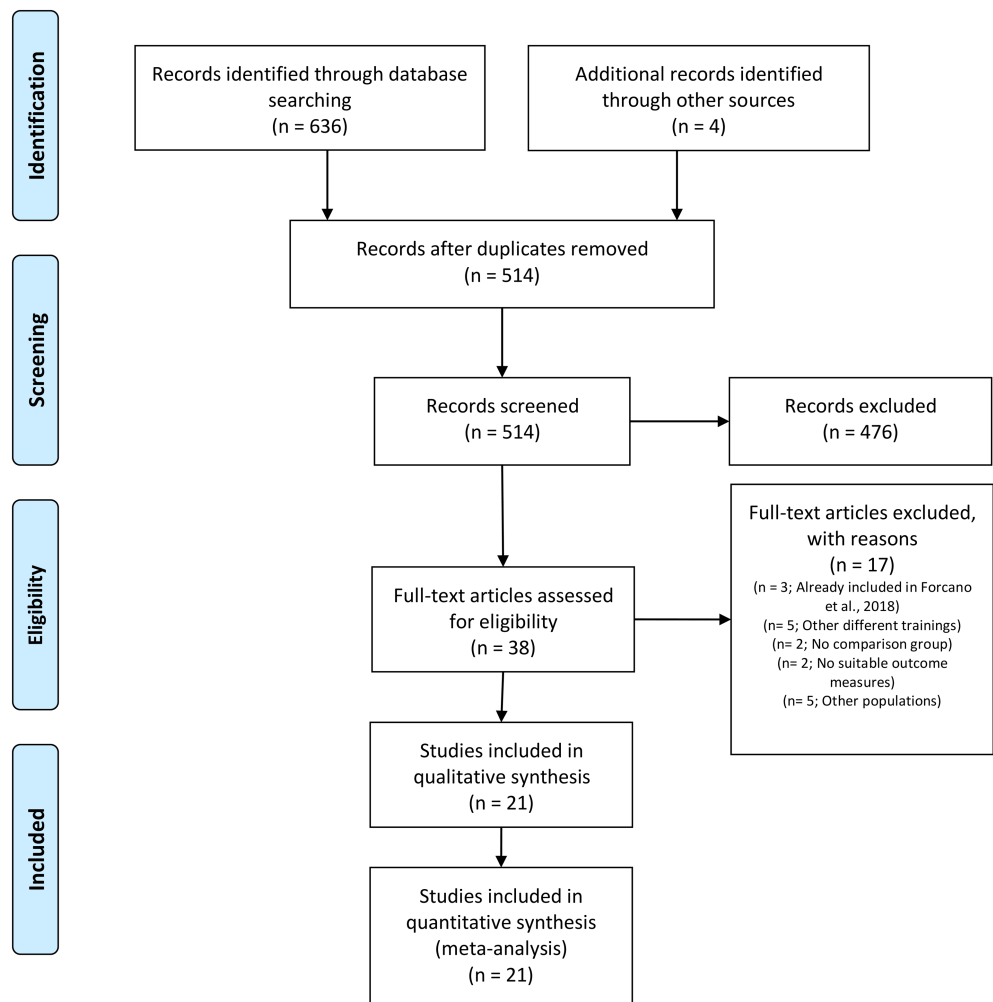


FIGURE 1 Preferred reporting items for systematic reviews and meta-analyses flow diagram: cognitive studies

incentive value indexes such as liking, wanting, or attractiveness. A brief overview of main characteristics of the samples in the included studies is shown in Table 1, while a detailed description of the main

TABLE 1 Main characteristics of samples included in the examined studies

Sex:	
Exclusively females	24
≥70% of females	18
>70% females	19
BMI:	
Normal weight ^a	23
Excess weight ^a	6
Several BMI ranges	20
BMI nonreported	12
Specific characteristics of the samples:	
Frequent consumers or people who like a specific palatable food ^b	13
People who experience craving for a specific palatable food ^b	4
Uncontrolled eaters	1
Unsuccessful/restrained/chronic dieters	6
People who wished to lose weight/change dietary behavior	5
People who underwent a bariatric surgery	1
No special characteristics	31

^aStudies which did not specify BMI range, where classified according BMI mean.

^bIn 4 studies included in Forcano et al.,²³ frequent consumers and people who experienced craving were also people who like to reduce their eating behavior (2 studies), who usually lose control over eating (1 study) or were restraint dieters (1 study).

characteristics of these studies is shown in Table S1 of the Supporting Information.

3.2 | Quantitative results

Figure 2 shows the distribution of p values entered into the main and robustness tests for the 61 studies (left and right panels, respectively). All tests for right skewness were significant, not only when all significant p values were entered into the analysis, but also when the analysis was restricted to p values lower than .025. This suggests that the results of these studies are unlikely to be false positives. In addition, all tests for flatness yielded nonsignificant results, confirming that the evidential value is not too small to matter. On the negative side, the power estimates are relatively low for both the main test, 60% (95% confidence interval [CI]: 43%,74%) and for the robustness test, 48% (CI: 30%,65%). In other words, although these studies seem to be exploring true effects, their sample sizes are, on average, too small, to such an extent that their probability of getting a significant result is around .50, far below the minimum recommended power of .80.

When analyses were performed separately for each type of training, similar results were observed with respect to right skewness and flatness tests for all training methods, although the power estimates were notably higher for ATT (Figure 3). That is, tests for right skewness were significant in all cases, while tests for flatness were nonsignificant. This confirms that the significant results observed in studies about INH, APP and ATT are unlikely to be false positives; these studies seem to be exploring true effects. Nonetheless, while the power estimates for ATT were 89% (CI: 73%,96%) and 73% (CI: 44%,90%) for the main and robustness tests, respectively (Figure 3, upper panel),

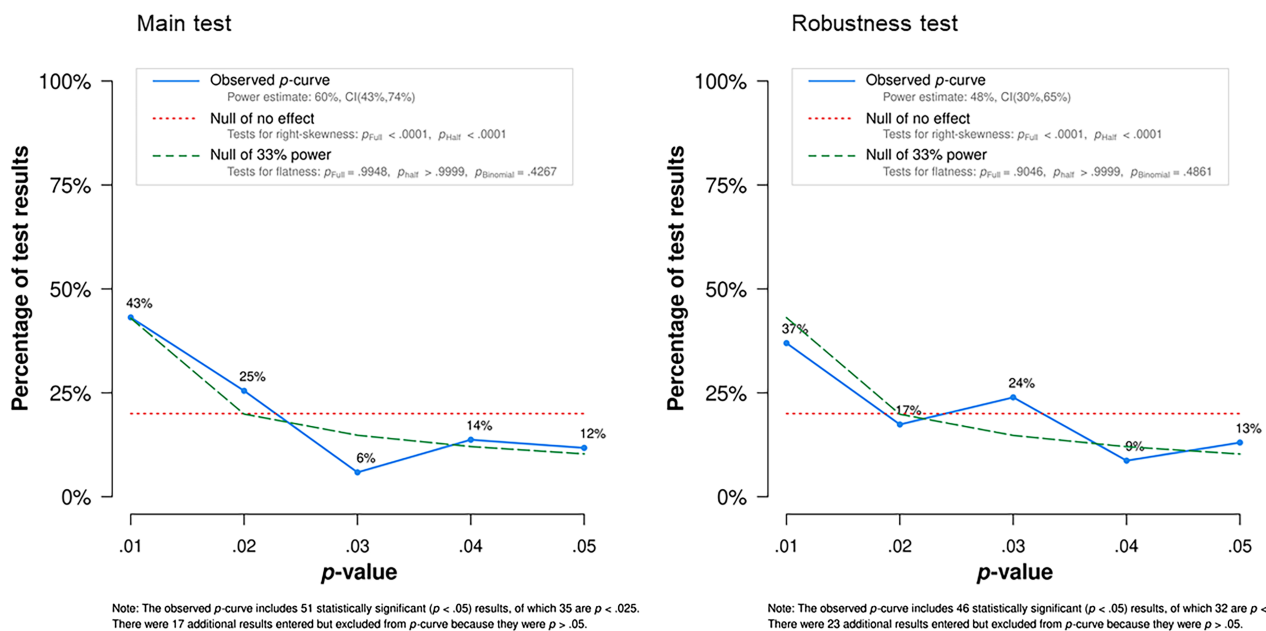


FIGURE 2 Results of p -curve analyses for all studies

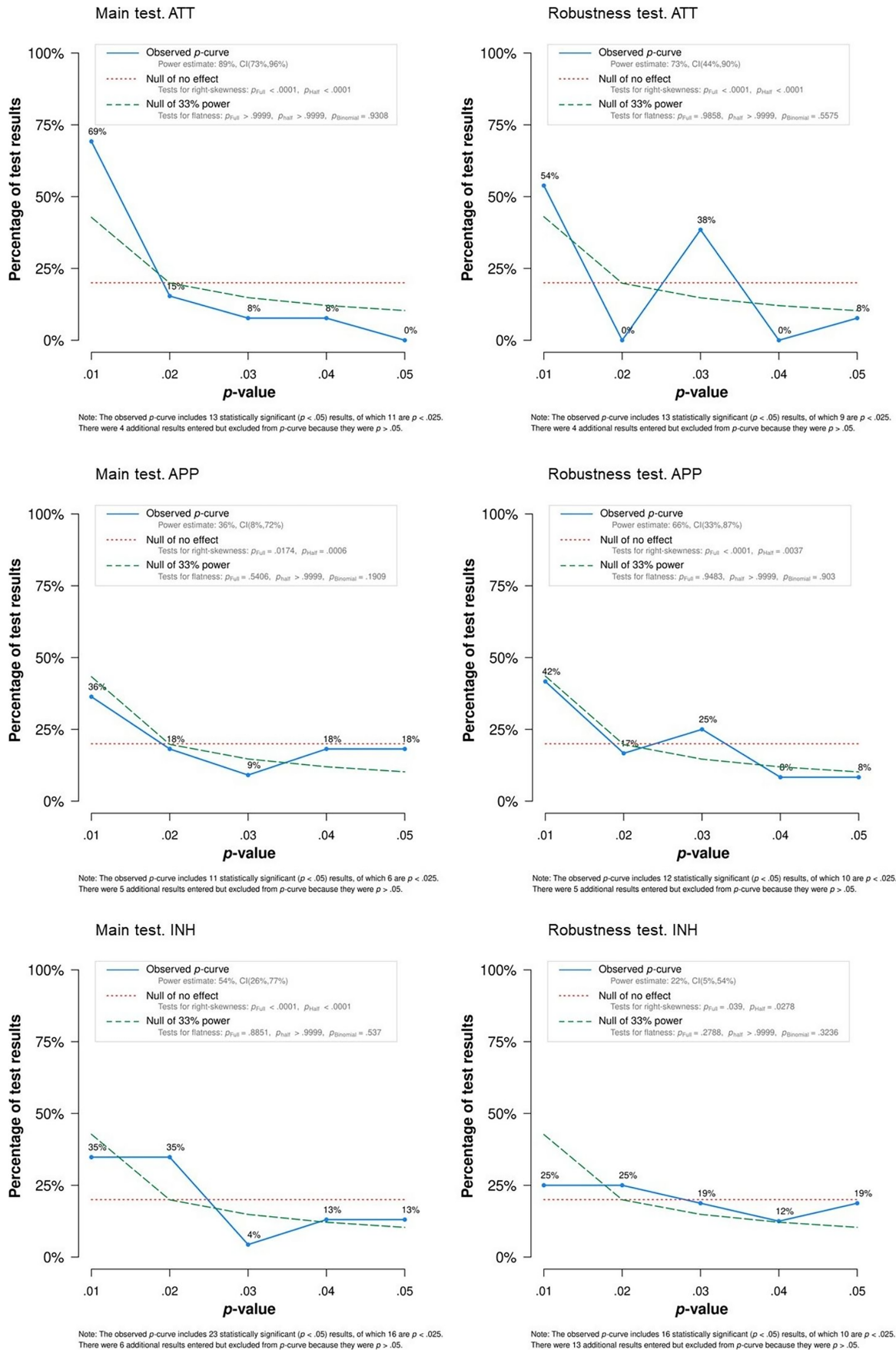


FIGURE 3 Results of p-curve analyses segregate by training type. INH, cue-specific inhibitory control training; APP, approach bias modification; ATT, attentional bias modification

for APP and INH power estimates were substantially lower: 36% (CI: 8%,72%) and 66% (CI: 33%,87%) for the main and robustness test of APP, respectively, and 54% (CI: 26%,77%) and 22% (CI: 5%,54%) for INH (Figure 3, middle and lower panel). Overall, these results suggest that only research on ATT reaches acceptable power levels. Additional analyses of the distribution of effect sizes, detailed in the Supporting Information, suggest that the higher statistical power of ATT studies is probably due to the fact that, overall, the effects explored in this literature tend to be larger than those explored in studies on INH and APP.

4 | DISCUSSION

We performed a *p*-curve analysis to examine the evidential value of research on cognitive bias modification training (CBM) for food-related biases, which are proximal factors of unhealthy eating.⁷⁰ We aimed to ascertain if the significant findings reported in this literature reflect true effects or, alternatively, may be false positives due to selective publication or reporting biases. For this purpose, we conducted a systematic review of studies that used cue-specific inhibitory control training (INH), approach bias modification (APP) and attentional bias modification (ATT) training or a combination of them.

Our results show that, overall, this research has evidential value, suggesting that the current body of significant findings on CBM cannot be entirely attributed to selective reporting or other biases. Therefore, these interventions have potential to modify the automatic process trained (i.e., food-related biases; near transfer outcomes) and other eating-related processes and behaviors, such as food incentive value, craving, dietary choices, food consumption or weight loss (i.e., far transfer outcomes). On the negative side, the average power of these studies was low, around 60%, which has important implications for the interpretation of current findings and for the planning of future research. Although most of the 61 studies examined yielded at least one significant result, the number of nonsignificant results, including main effects and potential moderators, was considerable. Given the low power of these studies, it is extremely difficult to interpret nonsignificant results; they can reflect either a genuine absence of effects or a failure to detect a positive effect.⁷¹ Some readers may interpret that if some studies find significant results in favor of these interventions and others do not, there must be unknown moderators that influence the efficacy. However, this lack of consistency might be entirely due to low statistical power.⁷² This has also important implications for future research, including attempts to replicate current evidence. If future studies do not feature considerably larger sample sizes compared to existing ones, they are likely to yield nonsignificant results, even if CBM interventions are actually effective.

Research on ATT shows the highest evidential value and estimated power among all the studies examined. This result converges with the conclusions of previous meta-analytic research, suggesting that training attention away from energy-dense food and related stimuli is a promising method to help individuals achieve their dietary

goals.^{24,73} The precise mechanisms of this training modality remain unclear, although it has been suggested that ATT may strengthen top-down control over attentional processes. Consistent with this interpretation, the clinical benefits of ATT in patients with affective disorders are associated with increased activation of cortical regions that modulate attentional biases for affective cues, such as the medial and lateral prefrontal cortex and the dorsal anterior cingulate cortex.⁷⁴ But it is also possible that ATT affects bottom-up automatic attentional processes. For example, attention retraining to avoid threat signals decreased the amplitude of P1, an evoked-related potential linked to early attentional processing, and not directly influenced by top-down control.^{74,75} Results regarding the effect of ATT in attenuating the responsiveness of the amygdala and other limbic regions, which modulate the affective salience of cues,⁷⁴ support the bottom-up influences of this type of training. Note, however, that it is also possible that the effect of ATT in modifying food-related attentional biases and eating behavior is actually a combination of top-down and bottom-up attentional processes.

Conversely, our results are more critical with current research on INH. The robustness test for this training shows the lowest power and the flattest distribution of *p* values among all the CBM interventions examined in this study. The use of relatively small samples along with the exploratory nature of several studies, which often include multiple tests of potential moderators, such as transient motivational states (e.g., appetite), cognitive functioning (e.g., inhibitory control skills) and other individual differences (e.g., dietary restraint), may explain the lower power of research on this type of interventions. Testing moderation effects, that is, two, three or four-way interactions, increases the need for larger sample sizes.⁷⁶ Our findings claim for methodological improvement of research on all CBM interventions in general, but on INH in particular.

Unlike previous findings of Yang et al.²⁴ and Aulbach et al.,²⁵ our results suggest that current research on APP has evidential value. Their analyses focused on far transfer outcomes and found no evidence of the efficacy of APP in this context. Conversely, here, we focused on the main hypotheses tested by the investigators, rather than examining intervention effects separately by outcome type. That is, we analyzed APP effects on food-related approach biases (i.e., near transfer outcomes), when the investigators focused on such hypotheses. Although, we cannot rule out the possibility that the evidential value of this research is explained by changes in near transfer outcomes, our study supports the value of further examining the direct or indirect benefits of APP on eating-related outcomes. In this regard, one of the largest studies on the effectiveness of APP to modify implicit biases in alcohol use disorder showed that changes in approach tendencies mediated the reduction of relapse rates found at 1-year follow-up.⁷⁷ Furthermore, the benefits of APP in alcohol use disorder increased as a function of the training dose.⁷⁸ Thus, it is likely that far transfer depends, at least partly, on changes in cognitive biases that would occur only after intense training. Well-powered trials that test the effects of multiple sessions of APP on eating behavior should be developed to delineate its potential direct and indirect mechanisms of action.

The present findings should be interpreted considering at least one main limitation. The studies included in this analysis tested a large number of hypotheses and, although we have followed the *p*-curve analysis guidelines to choose contrasts of interest, we also had to make several decisions about studies with complex designs or when key information was not available. Although we have disclosed them in <https://osf.io/cdqj5/>, there may be alternative ways to select contrasts that could lead to slightly different results. Nonetheless, our study has both theoretical and practical implications. Future research may benefit from addressing the methodological flaws that we have identified, especially regarding power. It is worth noting that underpowered studies contribute to the replicability crisis in science.⁷⁹ A potential solution is to conduct a priori power analyses considering all the hypotheses to be tested, including complex moderations.

On the other hand, considering the current body of research—including the results of the two meta-analyses summarized in Box 1—end-users may favor ATT over alternative CBM interventions to maximize the likelihood of intervention success. The specific relevance of ATT can also be understood considering that excessive eating behavior is increasingly viewed within an impulsive-compulsive spectrum.⁸⁰ At one end of that continuum, impulsivity, that is, the proneness to act without sufficient forethought, is considered a vulnerability factor that increases the likelihood of giving in to the temptation to eat energy-dense food. Attentional bias for food stimuli may spur craving, hindering the ability of impulsive individuals to reduce its influence on eating behavior.⁸¹ At the opposite end, compulsivity, namely, feeling compelled to repeatedly act in a certain way despite being aware that such acts do not align with intended goals,⁸² is a maintenance factor of overeating that implies maladaptive habit formation and difficulties in flexibly adapting behavior to avoid undesired consequences.⁸¹ One key cognitive component of compulsivity is attentional disengagement.⁸³ The inability to shift attention away from food-related stimuli could be especially disadvantageous in the context of heightened attentional salience of such stimuli (i.e., attentional bias). Given current evidence suggesting that people with obesity show greater attentional bias and difficulties to disengage from food-related stimuli (see Kakoschke et al.,⁸⁴ for a review of compulsive eating behavior), ATT could be especially useful to break such vicious circle. Thus, ATT may address key processes underlying impulsive and compulsive overeating, which are necessary to gain control over food-related stimuli, thereby reducing their imperative influence.

At this point, a question may arise about how to implement CBM interventions in clinical settings. In some of the largest and best-designed trials conducted with clinical populations (i.e., substance use disorders) to date, CBM interventions were applied as adjunctive rather than stand-alone treatments, yielding small but significant effects on recovery rates and relapse prevention.^{85,86} CBM can be easily implemented within existing treatment approaches and services. They can complement dietary interventions and/or psychological therapies, which tap into reflective processes (e.g., health goals), by focusing on more implicit/impulsive processes.

In our view, based on the findings of this study, the field of CBM in eating behavior is mature enough to go one step further and adopt

higher methodological standards. That is, given the existing preliminary evidence, it is time to make an effort to establish its benefits and determine its active mechanisms via gold standard methods.^{79,87} In this regard, preregistering studies may help researchers develop analytic plans in advance and not deviate from them, thus decreasing the likelihood of making strong inferences on the basis of unpowered and unplanned, post-hoc exploratory analyses. In this sense, our findings align with the call by Boffo et al.⁸⁸ to adhere to strict methodological standards in research on CBM to increase its robustness and clear up their clinical applications both as add-on and stand-alone treatments.

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CONFLICT OF INTEREST

No conflict of interest statement.

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SUPPORTING INFORMATION

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