City Research Online

City St George's, University of London

Citation: Madan, R. & Martinelli, C. (2026). Food-related attentional biases in restrained eaters: A meta-analysis. International Journal of Eating Disorders, 59(7), pp. 1426-1444. doi: 10.1002/eat.70090

This is the accepted version of the paper.

This version of the publication may differ from the final published version. To cite this item please consult the publisher's version.

Permanent repository link: https://openaccess.city.ac.uk/id/eprint/37067/

Link to published version: https://doi.org/10.1002/eat.70090

Copyright and Reuse: Copyright and Moral Rights remain with the author(s) and/or copyright holders. Copies of full items can be used for personal research or study, educational, or not-for-profit purposes without prior permission or charge, unless otherwise indicated, provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way. For full details of reuse please refer to City Research Online policy.

City Research Online: http://openaccess.city.ac.uk/ publications@citystgeorges.ac.uk

Food-related attentional biases in restrained eaters: A meta-analysis

[1]Rio Madan (ORCID: https://orcid.org/0009-0008-6619-8546) and [1,2]Cristina Martinelli (ORCID: https://orcid.org/0000-0002-4686-572)

[1]City St George's, University of London

[2]Kingston University

Declaration of competing interest: *We declare no conflicts of interest.*

Role of funding sources: *We declare that no funding was received for this research.*

Data Availability: *Data and materials will be made available on request by the corresponding author.*

Use of Artificial Intelligence (AI): *Use of AI was not involved in any component of preparation of this manuscript.*

Persons with lived experiences: *Due to the nature of the work, persons with lived experiences were not involved in the study design or execution, or in the preparation of this manuscript.*

Author Contributions:

Rio Madan: *Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review and editing.*

Cristina Martinelli: *Supervision, Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review and editing.*

Keywords: *meta-analysis; attentional biases; dietary restraint; food stimuli; response task; eye-tracking; eating disorders; disordered eating*

Rio Madan (Corresponding Author)

City St George's, University of London

Northampton Square, London, EC1V 0HB

Rio.Madan@citystgeorges.ac.uk

Cristina Martinelli

Cristina.Martinelli@citystgeorges.ac.uk

Abstract

Objective: Dietary restraint may contribute to the development and maintenance of eating disorders (EDs), with food-related attentional biases (ABs) as a key underlying mechanism. We examined associations between dietary restraint and ABs and explored how several methodological factors (i.e. AB mechanism, mode of AB investigation, response task type, stimulus task relevance, type of food stimulus) might influence these associations.

Method: Database searches followed the guidelines set by the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA; Page et al, 2021). We included empirical studies that measured both dietary restraint and ABs, excluding studies involving participants with clinical diagnoses or below 16 years of age. Fifty-one eligible articles were identified, of which 29 unique samples were included in the final analyses. The protocol for this meta-analysis was preregistered at: https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=532562

Results: We first examined associations between dietary restraint and attentional maintenance and orienting, separately. This was followed by subgroup analyses to examine whether these associations varied based on the chosen methodological factors. Our findings revealed significant associations between dietary restraint and attentional maintenance in studies that used response tasks (other than the dot probe task), and where the food stimuli were relevant to the task instructions.

Discussion: Collectively, these findings suggest that dietary restrainers activated strategic top-down processing of foods cues, rather than the reflexive orienting linked to ED-driven saliency processing. Overall, this may be interpreted as more purposeful monitoring to facilitate restraint when food is relevant to the goals and actions of dietary restrainers.

Key Points

- Dietary restraint may contribute to the development and maintenance of eating disorders, with food-related attentional biases as a key underlying mechanism.
- Current literature on food-related attentional biases and dietary restraint is contradictory.
- Different methodological approaches used to capture attentional biases may account for some of this divergence.
- Our meta-analysis revealed that associations between dietary restraint and attentional biases varied based on the specific attentional bias investigated, the mode of AB investigation, the response task type and the relevance of food stimuli to the task.

Introduction

Dietary restraint involves exercising cognitive control to override physiological and environmental cues that signal food intake (Polivy and Herman, 2020). With the abundance of ultra-processed and high energy dense food promoting overeating and hedonic eating styles (Calcaterra et al, 2023; LaFata et al, 2024) dietary restraint is now a prevalent tool for weight loss or maintenance across cultures (Olea Lopez and Johnson, 2016; Alqahtani, and Alhazmi, 2025; Yong et al, 2021).

However, Restraint Theory argues that repeatedly exercising cognitive control over food intake can have a rebound effect, leading to increased preoccupation with food and greater susceptibility to external food cues (Herman and Polivy, 1975). This can result in lapses in dietary control, which may trigger counterregulatory eating (Walilko et al, 2021) and other maladaptive eating tendencies (Meule et al, 2012), thereby contributing to disordered eating. Consistent with this, dietary restrainers are more likely to be overweight (Ramirez-Contreras et al, 2021), experience more episodes of disinhibited eating (Walilko et al, 2021) and binge eating (Linardon et al, 2020), have negative thinking patterns around food (Walilko et al, 2021) and report more body dissatisfaction (Kong et al, 2013), than their unrestrained counterparts. Furthermore, dietary restraint has been shown to be a robust predictor and risk factor for clinical eating disorders (EDs; Racine et al, 2011; Yamamiya and Stice, 2024).

Mechanisms thought to underlie food preoccupation and susceptibility to overeating in dietary restrainers relate to the cognitive processing of food-related cues. Particularly, attentional biases (ABs) – defined as the selective allocation of attention toward specific stimuli whilst ignoring others – toward food have been observed in dietary restrainers (e.g., Hepworth et al, 2010; Veenstra et al, 2010; Dondzilo et al, 2022; Chen et al, 2023). It has been proposed that such ABs could drive the rebounding effect of dietary restraint and contribute to maladaptive eating behaviours (Polivy and Herman, 2020). Consistent with this, food-related ABs have been linked to higher cravings (Hardman et al, 2021), greater food intake (Hardman et al, 2021; Werthmann et al, 2014), higher

BMI (Brand et al, 2024), and increased disinhibited (Seage and Lee, 2017) and external eating (Hou et al, 2011).

In clinical ED groups, increased attention to food cues has been linked to binge-eating disorder (Schmidt et al, 2016; Deluchi et al, 2017; Stott et al, 2021), bulimia nervosa (Stott et al, 2021; Albery et al, 2016) and food addiction (Liu et al, 2025). In anorexia nervosa, where refusal to eat an adequate intake is the hallmark of the illness, ABs are characterised by an initial attentional orienting towards food cues – reflecting heightened threat detection (Neimeijer et al, 2017) – followed by attentional avoidance of food cues (Meregalli et al, 2023) – thought to reflect top-down goal-driven processing that maintains severe energy restriction.

However, the current evidence for food-related ABs in dietary restrainers is equivocal, and the link to disordered eating remains largely unexplored. This gap is important to address as ABs toward food stimuli are known to contribute to EDs in clinical populations (Mercado et al, 2020; Flynn 2023; Werle et al, 2024) and may also play a role in maladaptive eating among dietary restrainers. (Walilko et al, 2021). Thus, it remains unclear whether food-related ABs exist and contribute to ED risk in non-clinical yet vulnerable groups such as dietary restrainers. To date, only one study has attempted a systematic review of the literature. Watson and Le Pelley (2021) examined associations between dietary restraint and several cognitive biases but reported inconclusive results regarding the relationship between dietary restraint and ABs. Furthermore, the review did not investigate links between dietary restraint and disordered eating.

We here propose that the inconsistent findings in the literature on associations between ABs and dietary restraint may be attributable, at least in part, to heterogenous methodological approaches. One major source of this heterogeneity lies in the different types of ABs that have been examined. The literature typically distinguishes between attentional maintenance (van Ens et al, 2019), attentional orienting (van Ens et al, 2019), distraction (Neimeijer et al, 2013), interference (Neimeijer et al, 2013), switching (Dondzilo et al, 2022) and disengagement (Veenstra et al, 2010)

processes, each assessed using varying methodological approaches. A second source of heterogeneity relates to the measurement of ABs. Studies have employed both reaction time (RT) based tasks (Ahern et al, 2010; Meule et al, 2012) and eye-tracking methods, with the latter further subdivided into instructed (Liu et al, 2021; Werthmann et al, 2013) and free-viewing paradigms (Hummel et al, 2018; Graham et al, 2011). Additionally, tasks vary in the food-related stimuli used (Dondzilo et al, 2022; Brignell et al, 2009), and in whether these stimuli are relevant to task instructions (Donofry et al, 2019; Jiang et al, 2024).

To address these issues, we conducted a series of meta-analyses examining how these methodological factors influence the relationship between food-related ABs and dietary restraint. Our work builds on the review by Watson and Le Pelley (2021) by 1) focussing exclusively on ABs, rather than a broader range of cognitive biases, 2) including eye-tracking data, which were largely overlooked in their work, 3) isolating distinct AB mechanisms that were not differentiated in their analyses, 4) investigating specific methodological factors not previously considered, and 5) exploring associations between ABs and ED symptoms. In addition, we further reduced heterogeneity present in their investigation by restricting inclusion to studies using pictorial stimuli only (rather than combining pictorial and linguistic stimuli), by excluding studies where main findings were based on experimental manipulations of mood or hunger which may have biased results, and controlling (where possible) for whether studies screened out clinical EDs. This led to the inclusion of 8 samples from Watson and Le Pelley's (2021) review and 21 new samples they did not include. Overall, our goal was to determine whether dietary associations between dietary restraint and ABs are tied to specific methodological factors, and whether such associations are also related to disordered eating in undiagnosed, yet ED-vulnerable populations, such as dietary restrainers.

Research Questions

1) Does the relationship between ABs and dietary restraint vary as a function of attentional mechanisms (i.e., orienting vs maintenance), modes of AB investigation (i.e., eye-tracking vs response tasks; free-viewing vs instructed-viewing eye-tracking tasks), the response task used (i.e., dot probe vs other tasks), the relevance of food stimuli to task instructions (i.e., task relevant vs task irrelevant), and type of food stimuli (i.e., high calorie [HC] vs mixed foods)?

2) Is the association between dietary restraint and ABs linked to disordered eating?

Research question 1 focuses on potential sources of heterogeneity in the association between dietary restraint and ABs. Given the methodological diversity of AB paradigms and evidence that different tasks and attentional indices capture distinct cognitive processes, it is important to examine whether observed associations vary systematically across attentional mechanisms, task characteristics, and stimulus properties. On the basis of the literature we hypothesised that stronger associations between restraint and ABs would be found for i) eye-tracking versus response tasks, as gaze indices have been found to be more reliable in inferring attentional allocation (Waechter et al, 2014); ii) irrelevant versus relevant task stimuli, as irrelevant stimuli have been shown to carry more bottom-up saliency (Neimeijer et al, 2017) and to easily elicit ABs in clinical populations (Sablottny et al, 2025; Neimeijer et al, 2017; Meregalli et al, 2023) – we predicted dietary restrainers to behave similarly; iii) HC versus mixed foods, as HC cues may carry more reward- or threat-related saliency for dietary restrainers (Wang et al, 2016); iv) dot-probe tasks versus alternative tasks, given the task homogeneity of the dot-probe group.

Method

Search strategy

Literature searches were guided by the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA; Page et al, 2021). Our search was conducted on April 2024 (updated on October 2024, July 2025 and December 2025) on Web of Science, PsycINFO, PubMed, CINAHL Plus and Medline. In addition, we searched the references of all selected articles and relevant published reviews. Grey literature and unpublished articles were searched via ProQuest Dissertations, SocArXiv Papers, Web of Science and Medline. These were included to account for potential publication bias (Hopewell et al, 2007). The search terms for each database consulted can be found in the *Supplementary Materials*. For each concept, relevant search terms were chosen, guided by the literature, as well as the index terms and synonyms in database thesauri. The protocol for this meta-analysis was preregistered at: https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=532562. Note that contrary to what was reported in the protocol, we were unable to examine dietary restraint in relation to approach versus avoidance biases due to insufficient studies measuring such biases. We were also unable to proceed with secondary study aims due to insufficient studies measuring any one type of experimental manipulation and insufficient studies measuring ED symptoms in the high dietary restraint group. Instead, we conducted an exploratory analysis of ED symptoms and AB associations unstratified by restraint. Finally, we conducted a univariate rather than a multivariate meta-analysis due to the high degree of heterogeneity across studies and the risk that aggregating multiple correlated outcomes into composite effect sizes could mask distinct effects (Borenstein et al, 2021; please see *Supplementary Materials*).

Eligibility Criteria

To be included, studies had to i) be empirical in nature, ii) use a validated measure of dietary restraint (self-reported or interviewed), and iii) assess ABs to pictorial or video food stimuli. We

included food stimuli of unspecified caloric value as well as food stimuli from a specific caloric category (high or low). Linguistic stimuli were excluded because they may be less ecologically valid for food-specific investigations (Freijy et al, 2014), and their inclusion would have increased heterogeneity, as ABs are known to differ across stimulus modalities (Freijy et al, 2014; Stormark and Torkildson, 2004). To capture ABs in dietary restrainers, a population known to be at risk for EDs, we excluded studies involving clinical samples. We also excluded samples below 16 years of age, as feeding practices are largely shaped by parental influence in childhood and early adolescence (van Strien and Bazelier, 2007), and dieting behaviours typically emerge in middle to late adolescence (Field et al, 2003). Reviews, meta-analyses, qualitative studies and study protocols were omitted. We excluded articles which assessed ABs after any experimental induction but included control group data if this was collected prior to manipulation. We also excluded data from any collapsed experimental and control conditions, to avoid food related ABs being confounded by specific manipulations such as those linked to negative mood (Hepworth et al, 2010) and hunger (Forestell et al, 2012). It was agreed to exclude studies using inhibitory control tasks due to a lack of consensus on whether these tasks can isolate ABs (Kakoschke et al, 2015). We also excluded tasks measuring any other type of cognitive bias, such as memory bias or impulsivity. Our primary outcome data were statistical associations between dietary restraint and ABs.

Data selection and extraction

The study inclusion process is shown in the PRISMA Flow Diagram (Page et al, 2021) in *Figure 1.* Searches were conducted by one researcher. All retrieved studies were uploaded to Rayyan and duplicate studies were removed, leaving 9682 studies for screening. Two researchers independently screened studies, first by title and abstract and then by full text. Disagreements were resolved upon discussion. The results of a Cohen's Kappa test revealed good inclusion agreement between researchers ($k=0.720$, $P<0.001$; Landis and Koch, 1977). This database search resulted in 36 eligible articles. The screening of 24 reviews on attentional and cognitive

biases, and eye-tracking research, in general and ED populations, yielded another 12 eligible studies. An additional 3 studies were identified by searching the references of all studies included. A final citation search of these three studies was carried out with no eligible studies identified.

Of the 51 total studies, 27 provided the quantitative data needed for the meta-analyses, for some or all reported outcomes. Of these 27 studies, eleven authors provided this data via email correspondence (Nannt et al, 2025; Xu et al, 2023; Meule et al, 2012; Sambal et al, 2021; Chen et al, 2023; Werthmann et al, 2013, 2014; Garcia-Burgos et al, 2017; Wilson and Wallis, 2013; Kim et al, 2014; Hummel et al, 2018; Donofry et al, 2019). Of the 51 total studies, 24 had missing data required for the meta-analyses (i.e., did not report stats on the association between AB and dietary restraint) that could not be retrieved from email correspondence - authors were contacted up to four times over a five-month period (Soetens et al, 2008; Burmester et al, 2022; Jonker et al, 2019; Kochs et al, 2022; Loeber et al, 2013; 2012; Stamataki et al, 2020; Valenzuela, 2019; Seo and Lee, 2021; Seage and Lee, 2017; Hardman et al, 2014; Broadley et al, 2019; Baldofski et al, 2018; Hege et al, 2017; Geyskens et al, 2010; Smeets et al, 2009; Hou et al, 2011; Leppanen et al, 2017; Gearhardt et al, 2012; Higgs et al, 2012; Frayn et al, 2016; Sperling et al, 2017; Bongers et al, 2015; Hummel et al, 2017). As Wilson and Wallis (2013) contributed three separate samples, this resulted in a total of 29 included samples across 27 articles.

We extracted the following study and sample characteristics: year of publication, sample size, recruitment setting and country, ethnicity, socioeconomic status, gender, mean age, mean BMI, dietary restraint scale used, ED measures and whether participants were screened for EDs. Task-related information was also extracted, including food type (e.g., HC food), comparator stimuli, stimuli relevance to task instructions, mode of AB investigation (response task vs eye-tracking), task type used, and, for eye-tracking studies, whether paradigms involved free- or instructed-viewing. We also extracted information on the AB mechanism investigated, the type of index used, and the relevant computation method. Extracted statistical data included F-values or correlations between dietary restraint and ABs, means and standard deviations of the AB outcomes (separately

for high restraint and low/no restraint in group comparison studies), mean ED scores and correlations between ABs and ED symptoms. Data collection took place between 2024 and 2025.

Figure 1. PRISMA Flow Diagram of study inclusion *(insert Figure 1. here).*

Effect Size Selection Criteria

We used the following criteria to select one effect size per study (see *Supplementary Materials* for selected effect sizes):

- When studies examined HC and low calorie (LC) food stimuli separately, HC outcomes were prioritised being the most common stimuli among our studies. If studies compared HC food stimuli to both LC and non-food stimuli, we prioritised LC comparator outcomes, as these capture a more nuanced effect of energy density, which is relevant to dietary restraint.
- If multiple modes of AB investigation were used, we used the following order of selection: free-viewing gaze indices, instructed-viewing gaze indices, and response task indices. This order reflects evidence that gaze patterns more directly index attentional allocation and demonstrate greater internal reliability compared to response tasks (Duc et al, 2008), and that free-viewing paradigms provide greater ecological validity than instructed viewing tasks (Puttevils et al, 2023; Pasqualette and Kulke, 2024).

Maintenance Criteria – Primary Analysis

- Outcomes from trials of 500ms or more; shifts in attention can occur as early as 500ms (Field and Cox, 2008). If more than one trial presentation time at 500ms or more was investigated, the longer trial outcome was chosen, as these are deemed to be more reliable in capturing maintained attention (Skinner et al, 2018).
- Eye-tracking indices reflecting maintenance: total dwell time or total fixation duration. If both indices were investigated, we prioritised total dwell time, being the most common in our studies. No current evidence suggests one is more reliable than the other.

Orienting Criteria – Exploratory Analysis

- Outcomes from trials of 200ms or less, as this timeframe is thought to capture initial orienting (Field and Cox, 2008).
- Eye-tracking indices typically used to measure orienting: gaze direction bias or first fixation location. If both indices were investigated, we prioritised first fixation location with previous evidence supporting good reliability (Soleymani et al, 2022) versus gaze direction bias (Van Ens et al, 2019).

ED Symptoms Criteria – Exploratory Analysis

- We prioritised attentional maintenance being the most common outcome investigated in relation to ED symptoms.
- If more than one ED outcome measure was used, we prioritised general over specific symptom measures, being the most common in included studies.

Coding of data

We coded the data so that positive effect sizes reflected a stronger AB towards food stimuli (versus comparator stimuli) as dietary restraint increased or in the high dietary restraint group. Negative effect sizes reflected a stronger AB towards food stimuli (versus comparator stimuli) as dietary restraint decreased or in the low dietary restraint group. When there was no inclusion of a comparator stimulus, we included associations between restraint and response task data or gaze data for the food stimuli only (Jiang et al, 2024; Husted et al, 2016). For one study (Donofry et al., 2019), we recoded the AB score of food minus instrument trials so that a positive AB score reflected a stronger bias towards food versus non-food.

Risk of Bias

The risk-of-bias assessment was carried out by two independent assessors. The Newcastle-Ottawa quality assessment scale (NOS; Wells et al, 2000) was adapted to encompass factors relevant to our study, such as sample representativeness, the exclusion of conditions affecting eating behaviours, validity of the restraint outcome measure, sample size justification, the control of confounding variables, paradigm conditions, practice effects and randomisation, and statistical analysis and reporting of results (see *Supplementary Materials*). Studies could score in the following categories: unsatisfactory (0-6 points), satisfactory (7-9 points), good (10-12 points) or very good (13-14 points). Discrepancies between scores in each of these domains were addressed by a third independent assessor.

Data Analysis

To account for smaller sample sizes, we selected Hedge's G as our standardised effect size (Taylor and Alanazi, 2023). We first explored ROB using meta-regression to determine whether to include high ROB studies in our analyses. ROB was added as an independent variable and associations between dietary restraint and ABs were the dependent variable. If no significant association was found, we included all studies in our analyses (Page et al, 2021).

We conducted univariate analyses to explore each of our research questions. Mode of AB investigation was explored in two ways: 1) with two subgroups, comparing response tasks to all viewing paradigms (instructed and free-viewing) and 2) with three subgroups, comparing response tasks, instructed-viewing and free-viewing. Type of response task had two subgroups comparing the dot probe task to all other tasks collectively, due to the low study number in each alternative task. Free-viewing paradigms were excluded from this analysis as no specific task is used. Stimuli task relevance also had two subgroups: task relevant and task irrelevant stimuli, and again we excluded

free-viewing paradigms from this analysis as they do not include specific task instructions. Type of stimuli included two subgroups: mixed food and HC food. Finally, associations between ABs and ED symptoms were explored both collectively and across three subgroups of outcome measure used: Eating Disorder Examination Questionnaire (EDE-Q), Eating Disorder Inventory (EDI-2) and all other outcome measures collectively. For all subgroup analyses, we used meta-regression models to adjust for potential confounders. These were whether clinical EDs were screened out, and the type of restraint scale used. We did not run meta-regression analyses if heterogeneity within subgroups was high, as this level of variability among studies can obscure true effects and lead to incorrect conclusions (Zhou and Shen, 2022). We chose random effects models for all analyses, to account for unexplained heterogeneity among effect sizes, and we used the following control variables in meta-regression models: 1) whether clinical EDs were screened out; and 2) the type of restraint scale used. In line with Cochrane guidelines, we did not include control variables in meta-regressions if heterogeneity was already low in the unadjusted models (Chandler et al, 2019). We used the I-squared statistic and the following cut-offs to assess heterogeneity; Low: 25%, Moderate: 50% and High: 75% (Higgins et al, 2003).

Attentional maintenance outcomes were examined in the primary analysis, as this was the most frequently reported AB in the included studies. Attentional orienting outcomes were examined in a secondary exploratory analysis, as this was the second most commonly reported AB. There were insufficient studies reporting on other types of ABs to warrant further meta-analyses.

Results

The 29 included samples had a total of 1727 participants, who were mainly adult females, mostly recruited via UK and European based universities. Their mean age range was 19-34 years, and most reported a healthy BMI. *Table 1* shows the information extracted from all studies included in the meta-analysis and our ROB final score.

Table 1. Study Characteristics

(Insert Table 1. here)

Primary Analysis: Maintenance

General associations between dietary restraint and attentional maintenance

ROB did not influence associations between dietary restraint and maintenance (B=0.084 [-0.271 0.439] Q=0.21) P=0.644; K=25), so all studies were kept in our meta-analysis. This revealed no significant associations between restraint and attentional maintenance (HG =0.100 [-0.054, 0.254] P=0.201; Heterogeneity: Q=47.65 P=0.003 I^2=49.6%) – see *Supplementary Materials* for forest plot *(Fig. 1)*.

Mode of AB investigation

Eye-tracking vs Response Tasks

We compared all response tasks to all eye-tracking paradigms (i.e., instructed and free-viewing) and found that response tasks demonstrated positive associations between restraint and attentional maintenance, shown in *Figure 2* (HG = 0.253 [0.078, 0.428] P =0.005), but eye-tracking paradigms did not (HG = -0.129 [-0.370, 0.112] P=0.295; K=10; *Supplementary Material Fig. 2)*. Furthermore, the comparison test for associations between restraint and maintenance across each group was

significant (Q= 6.306, P=0.012), and heterogeneity was low-moderate for response task studies (Q= 20.714 P=0.109 I^2 =32.4%) and moderate for eye-tracking paradigms (Q= 18.262 P=0.032 I^2 =50.7%).

Figure 2. Meta-analysis of associations between attentional maintenance and dietary restraint in studies using response tasks (K=15)

(insert Figure 2 here)

In the unadjusted meta-regression, the mode of AB investigation coefficient was significant (B= 0.377 [0.087, 0.668], R^2=0.28) and the model explained a significant amount of the variance (Q=6.47 P=0.011). Heterogeneity reduced from 49.6% (null model) to 41.0%. Adjusting for clinical ED screening and type of restraint scale improved the precision of the coefficient and heterogeneity (B= 0.494 [0.195, 0.793] P=0.001; R^2=0.51; Q=13.36 P=0.010 I^2=31.9%).

Overall, response tasks elicited stronger associations between eating restraint and attentional maintenance compared to all eye-tracking paradigms, with stronger effects when the variance from type of restraint scale and clinical ED screening were accounted for.

Instructed Viewing vs Free-viewing

We sub-grouped eye-tracking studies into instructed viewing and free-viewing to explore differences between all three experimental paradigms. We found no significant associations between restraint and attentional maintenance among free-viewing studies (HG = -0.162 [-0.733, 0.409] P=0.578; Q=16.733 P=0.001 I^2=82.1%; K=4; *Supplementary Material Fig. 3*) nor among instructed viewing studies (HG = -0.116 [-0.352, 0.120] P=0.544; Q=1.308 P=0.934 I^2=0%; K=6; *Supplementary Material Fig. 4)*. Given the high heterogeneity in the free-viewing paradigms, we did not run any further analyses using this subgroup.

Instructed Viewing vs Response Tasks

As we previously found a significant association between dietary restraint and ABs in the response task groups, we compared effect sizes between the response task subgroup and instructed viewing subgroup. This comparison showed a significant difference (Q=6.046, P=0.014). In the unadjusted meta-regression, the mode of AB investigation coefficient was significant (B= 0.368 [0.069, 0.667], R^2=0.63) and the model explained a significant amount of the variance (Q=5.82, P=0.016). Heterogeneity reduced from 30.0% (null model) to 13.7%.

Overall, no associations between restraint and attentional maintenance were found for instructed viewing or free-viewing paradigms. However, when comparing instructed viewing to response tasks, response tasks elicited stronger associations between eating restraint and attentional maintenance.

Response Task Type

We explored whether the response task type could account for differential associations between restraint and attentional maintenance. We found no associations between restraint and attentional maintenance among dot probe studies (HG=0.001 [-0.141, 0.143] P=0.991; K=15; *Supplementary Material Fig. 5)* but significant associations among the other tasks group, shown in *Figure 3* (HG = 0.545 [0.312, 0.777] P=0.000), with the difference between these effect sizes also significant (Q=15.301, P=0.000). Heterogeneity was low in both the dot probe (Q=9.105, P=0.824 I^2=0%) and alternative tasks group (Q=4.168 P=0.526 I^2=0%).

Figure 3. Meta-analysis of associations between attentional maintenance and dietary restraint in studies using alternative tasks to the dot probe task (K=6)

(Insert Figure 3 here)

In the unadjusted meta-regression, the task type coefficient was significant (B=0.544 [0.271, 0.816]; R^2=1.00) and the model explained a significant amount of the variance (Q=15.30 P=0.000) Heterogeneity was 0% (30.0% in the null model).

Collectively, the alternative tasks were able to capture significant positive associations between restraint and attentional maintenance compared to the dot probe task.

Food Stimuli Relevance

We investigated whether the relevancy of food stimuli to the response task could influence associations between restraint and attentional maintenance. The irrelevant stimuli group included the same studies as in the dot probe subgroup, with the addition of one study (Veenstra et al, 2010). The relevant stimuli group included the same studies as the other tasks subgroup minus Veenstra et al (2010). We found no associations between restraint and attentional maintenance among irrelevant studies (HG=0.009 [-0.131, 0.148] P=0.904; K=16 *Supplementary Material Fig. 6)* and significant associations among the relevant group, shown in *Figure 4* (HG = 0.576 [0.332, 0.820] P=0.000), with the differences between these effect sizes also significant (Q=15.644, P=0.000). Heterogeneity was low in the irrelevant group (Q=9.452 P=0.853 I^2=0%) and low in the relevant group (Q=3.478 P=0.481 I^2=0%).

Figure 4. Meta-analysis of associations between attentional maintenance and dietary restraint in studies using relevant food stimuli (K=5)

(Insert Figure 4 here)

In the unadjusted meta-regression, the stimuli relevancy coefficient was significant (B=0.567 [0.286, 0.848]; R^2=1.00) and the model explained a significant amount of the variance (Q=15.64, P=0.000). Heterogeneity was 0% (30.0% in the null model).

Overall, task-relevant food stimuli elicited stronger associations between restraint and attentional maintenance compared to irrelevant food stimuli.

Type of Food Stimuli

We investigated whether the type of food stimuli could influence associations between restraint and attentional maintenance. We found no significant associations among HC studies (0.086 [-0.107, 0.278] P=0.382; K=19; *Supplementary Material Fig. 7)* nor among mixed food studies (HG = 0.136 [-0.092, 0.364] P=0.243; K=6; *Supplementary Material Fig. 8)*. The difference between these effect sizes was also non-significant (Q=0.108, P=0.743). Heterogeneity was moderate-high in HC group (Q=43.087, P=0.001 I^2=58.2%) and low in the mixed food group (Q=4.455 P=0.486 I^2=0%).

The stimuli type coefficient was non-significant in the unadjusted meta-regression (B=-0.056 [-0.424, 0.312] R^2=-0.09; Q=0.09 P=0.766 I^2= 51.6%; I^2=49.6% in null model). We adjusted for clinical ED screening only, given the smaller study number in the mixed food group, with no change in significance (B=-0.032 [-0.148, 0.512] P=0.865, R^2=-0.10; Q=1.26 P=0.532 I^2=51.8%).

Exploratory Analyses

General associations between dietary restraint and attentional orienting

We assessed ROB using a meta-regression model and included ROB as the independent variable. ROB was not associated with dataset (B=0.058 [-0.421 0.536], Q=0.06, P=0.813) so we included all studies in analyses (K=18). The meta-analysis of the whole dataset revealed no significant associations between restraint and orienting, shown in *Figure 5* (HG=0.013 [-0.170, 0.196] P=0.888; Q=36.754 P=0.004 I^2=53.75%). Heterogeneity was moderate.

Figure 5. Meta-analysis of associations between dietary restraint and attentional orienting (K=18)

(Insert Figure 5 here)

Furthermore, we found no significant associations between dietary restraint and orienting in any subgroups of mode of AB investigation, type of response task or stimuli task relevance. Nor did we find any relative differences in restraint-orienting associations across these subgroups. The mixed food subgroup for type of stimuli only had two samples so we were unable to complete the subgroup analysis and meta-regression. The HC subgroup showed no significant associations between restraint and orienting *(Please see Supplementary Material for effect sizes and forest plots, Fig. 9-17).*

ABs and ED symptoms

We ran an exploratory analysis to investigate whether ED symptoms may be associated with ABs in the ten samples that reported or provided data to calculate these associations. Included studies investigated attentional maintenance, mostly captured by the dot-probe task and two studies used free-viewing paradigms (Garcia-Burgos et al, 2017; Xu et al, 2023), shown in *Table 2.*

Table 2. Studies included in ED symptoms analysis (K=10)

(Insert Table 2 here)

We found no associations between ABs and ED symptoms: HG=0.042 [-0.237, 0.321] P=0.767; Q=24.499 P=0.004 I^2=63.26%, shown in *Figure 6*. Heterogeneity was moderate-high amongst studies. We explored whether controlling for whether clinical EDs were screened out could reveal an association between attentional maintenance and ED symptoms. The overall model and coefficient remained non-significant (B=0.025 [-0.613, 0.662] P=0.939, R^2=-0.28; Q=0.01 P=0.939 I^2=66.8%).

Figure 6. Meta-analysis of associations between ED symptoms and attentional maintenance (K=10)

(Insert Figure 6 here)

We also explored whether associations between ABs and ED symptoms may differ across ED outcome measure. We created three subgroups so that each group had a minimum of three samples to analyse: *EDEQ (K=4), EDI-2 (K=3), Other (K=3)*. No significant associations were found between ABs and ED symptoms in each subgroup: *EDEQ* HG=0.275 [-0.203, 0.752] P=0.259, Q=6.792 P=0.079 I^2=55.83%; *EDI-2* HG= -0.243 [-0.603, 0.118] P=0.187, Q=2.402 P=0.301 I^2=16.734; K=3; *Other* HG=0.022 [-0.531, 0.575] P=0.939, Q=9.369 P=0.009 I^2=78.654% (Please see *Supplementary Materials Fig. 18-20*).

Publication Bias

Although some subgroups had less than ten studies (Page et al, 2021), we still checked for publication bias in each of our subgroups using Egger's Test and visual inspections of funnel plots. We found no evidence of publication bias (Please see *Supplementary Materials* for funnel plots and Egger's Test P-values*, Fig. 21-30*).

Discussion

Existing evidence indicates that dietary restraint may contribute to the development and maintenance of EDs, with food-related ABs as a key underlying mechanism. So far, only one study provided a systematic synthesis of the literature on ABs and dietary restraint, which was largely inconclusive due to high statistical heterogeneity between studies (Watson and Le Pelley, 2021). To reduce such heterogeneity, our work focused on one cognitive bias – i.e., ABs – and isolated its different mechanisms by distinguishing between orienting and maintenance processes. In addition, we conducted analyses to assess how various factors, including the mode of AB investigation, the type of response task, the relevance or irrelevance of stimuli to the task, and the characteristics of food-related stimuli, may influence the link between ABs and dietary restraint.

When investigating the type of AB mechanism across each dataset, we found no significant associations between restraint and attentional maintenance or attentional orienting. These results were unsurprising, as we hypothesised that different methodological features could contribute to the inconsistent findings observed in previous studies. This aligns with the conclusions of Watson and Le Pelley (2021), who suggested that unaccounted heterogeneity could be masking these associations.

When investigating the influence of our chosen methodological factors, we only found significant associations between dietary restraint and ABs for attentional maintenance indices, but not for orienting indices. The absence of preferential orienting to food-related cues among dietary restrainers suggests a lack of a bottom-up, stimulus-driven processing of food cues. This contrasts with findings in those with clinical EDs, who consistently demonstrate food-related orienting ABs (Meregalli et al, 2023; Schmitz et al, 2014). Such orienting biases have been interpreted as evidence of reward- (Schag et al, 2013) or threat-driven vigilance (Booth, 2014; Radix et al, 2023), which may either encourage binge eating (Schag et al, 2013), or drive severe energy restriction (Meregalli et al, 2023). Although this pattern might initially appear inconsistent with the conceptualisation of dietary restraint

as a risk factor for EDs, it does align with some evidence suggesting that subclinical disordered eating may be more strongly associated with attentional maintenance (Jin et al, 2023; Soleymani et al, 2022) than orienting (Freccero et al, 2025), possibly reflecting better self-regulatory control over food cues in those below a clinical threshold for EDs. As a result, ABs in ED-vulnerable groups, such as dietary restrainers, may still predominantly manifest as maintenance rather than orienting, reflecting purposeful, top-down processing (Grubb et al., 2015) and a more goal-directed attentional strategy.

Furthermore, we found significant associations between dietary restraint and attentional maintenance when stimuli were relevant, rather than irrelevant, to the task. This corroborates the idea that dietary restrainers activate self-regulatory processes when food is relevant to their current goals and actions (Papies and Hamstra, 2010).

Taken together, our findings suggest that such top-down processing in food-relevant contexts could indicate more strategic monitoring that facilitates dietary restraint (Johnson et al, 2012; Moore et al, 2022). The degree of success in dietary restraint may indeed be influential in our findings. While successful restrainers (i.e., maintaining restraint without periods of disinhibited eating; Johnson et al, 2012) may bypass bottom-up, stimulus driven attention (i.e., orienting), in favour of more purposeful monitoring in relevant contexts, unsuccessful restrainers, who tend to show higher ED pathology and maladaptive regulation of eating behaviours (Meule et al, 2012), may manifest both more orienting (Jiang et al, 2024; Alblas et al, 2020) and maintenance (Weng et al, 2012) regardless of context. In line with this reasoning, we found no associations between dietary restraint and attentional maintenance across HC or mixed food stimuli, nor any relative group differences. This could reflect strategic downregulation of the motivational salience system (Xie and Chen, 2025), reducing ABs to diet-incongruent cues (Weng et al, 2012; Higgs et al, 2015). In turn, this may facilitate successful, rather than unsuccessful restraint, whereby heightened motivational salience to HC cues can override

energy homeostasis (Xie and Chen, 2025) and reinforce the counterregulatory eating (Hagerman et al, 2021) that contributes to binge-eating pathology (Schag et al, 2013).

We tried to confirm whether the degree of success in dietary restraint influenced our findings, however not enough papers made this distinction. Instead, we ran a meta-analysis of correlations between ED symptoms and ABs in the hope to indirectly gauge maladaptive forms of dietary restraint. However, we found no associations between maintenance and global ED symptoms. It is possible that a threshold effect may exist, whereby associations are more likely to emerge when ED symptoms reach a certain level of severity (Soleymani et al, 2022), perhaps not captured if more successful restrainers were included in our samples (Meule et al, 2012). Global ED symptom scores may have also masked more specific associations between attentional maintenance and dietary restraint which may have emerged if considering specific ED profiles such as binge-eating (Sablottny et al, 2025) or restrictive symptoms (Mercado et al, 2020; Meregalli et al, 2023). In addition, as attentional orienting is linked to disorder-driven saliency processing across different EDs (Meregalli et al, 2023; Schmitz et al, 2014; Sablottny et al, 2025), this AB mechanism may instead show stronger associations with global ED pathology.

The body of literature on dietary restraint and ABs also diverges in the way in which ABs are investigated, which may account for some of the conflicting findings. Specifically, we investigated AB investigation mode and type of response task. We found significant dietary restraint and maintenance associations in the response tasks group versus the eye-tracking group One possible explanation lies in the increased AB index consistency in the response tasks compared to the eye-tracking indices. For instance, gaze fixations have no standardised definition (e.g., Hummel et al, 2018; Liu et al, 2021; Chen et al, 2023). Another source of variance was the inclusion of both free-viewing and instructed-viewing paradigms, with free-viewing being too heterogeneous to glean any meaningful differences between them.

We also found significant associations between dietary restraint and maintenance in the alternative response tasks compared to the dot-probe. While this may at first be surprising, as the alternative tasks group was inevitably a less homogenous group, it is in line with what is consistently reported in the literature regarding the unreliability of the dot probe task as a measure of AB (Price et al, 2015; Chapman et al, 2019; Xu et al, 2025). Moreover, in line with the significant effects found for task-relevant food stimuli, we note that five out of six alternative-task studies used stimuli that were relevant to the task instructions. Therefore, this finding may be attributable to the relevance of the food stimuli to the task, reflecting top-down attentional processing in dietary restrainers.

Our results need to be considered in light of some limitations. Firstly, we only considered a select number of methodological factors, and other existing factors, such as the induction of certain moods (Hepworth et al, 2010) or homeostatic states (Feighan et al, 2025) could also influence associations between dietary restraint and ABs. Second, despite our efforts, we were unable to retrieve data from 24 studies, which made our results somewhat incomplete. Third, due to the constraints imposed by univariate analytical methods, we were forced to prioritise specific factors, leading to the exclusion of specific stimuli comparisons, modes of AB investigation, attentional mechanisms and gaze and performance indices. Lastly, our investigations of attentional orienting and ED symptoms were exploratory only and should be confirmed in future research. Although the following points are not directly related to this meta-analysis, they represent shortcomings in the literature that warrant consideration. First, most of our samples were young adult females from universities in Europe and the UK, and we were unable to make further inferences about race or ethnicity as only three studies reported this information. Furthermore, as only two studies reported socioeconomic information, we could not explore the potential impact of any socioeconomic variables. Hence, the generalisability of our findings remains unclear. Second, while we made efforts to screen out studies involving clinical samples exclusively, some studies did not screen for clinical EDs so may have captured individuals

above the clinical threshold. Where possible, we controlled for whether clinical ED screening took place, to extend findings to non-clinical groups who may therefore be at risk of ED development. As data on dietary restraint success level was not available, it remains unknown whether, unsuccessful dietary restrainers (i.e., a group that may be at higher risk of ED development) may show stronger associations between ABs and ED symptoms than successful restrainers.

Overall, our meta-analysis highlights that some of the inconsistencies observed in the relationship between dietary restraint and ABs could be attributable to varying methodological approaches used in the literature. Specifically, our findings suggest that dietary restrainers may show strategic top-down processing of food cues when food is relevant to their goals and actions, and certain response tasks may be more reliable in capturing this phenomenon. Furthermore, attentional orienting may not reliably characterise food cue processing in dietary restrainers. Future research should explore how dietary restraint may relate to differing AB mechanisms, and whether the degree of restraint success is influential in this. Further research is also needed to confirm whether such associations are related to ED pathology. This should be explored in populations that tend to be underrepresented in ED research, such as males and minority ethnic groups. This would help clarify whether unsuccessful restraint is more strongly associated with AB mechanisms that indicate maladaptive salience processing, and whether this contributes to higher risk of ED development across populations.

References

Ahern, A. L., Field, M., Yokum, S., Bohon, C., & Stice, E. (2010). Relation of dietary restraint scores to cognitive biases and reward sensitivity. *Appetite*, *55*(1), 61-68.

Albery, I. P., Wilcockson, T., Frings, D., Moss, A. C., Caselli, G., & Spada, M. M. (2016). Examining the relationship between selective attentional bias for food-and body-related stimuli and purging behaviour in bulimia nervosa. *Appetite*, *107*, 208-212.

Alblas, M. C., Mollen, S., Fransen, M. L., & van den Putte, B. (2020). Food at first sight: Visual attention to palatable food cues on TV and subsequent unhealthy food intake in unsuccessful restrained eaters. *Appetite*, *147*, 104574.

Alqahtani, R. M., & Alhazmi, A. (2025). Association between cognitive restraint, emotional eating, uncontrolled eating, and body mass index among health care professionals. *Scientific Reports*, *15*(1), 2570.

Baldofski, S., Lüthold, P., Sperling, I., & Hilbert, A. (2018). Visual attention to pictorial food stimuli in individuals with night eating syndrome: an eye-tracking study. *Behavior therapy*, *49*(2), 262-272.

Bongers, P., van de Giessen, E., Roefs, A., Nederkoorn, C., Booij, J., van den Brink, W., & Jansen, A. (2015). Being impulsive and obese increases susceptibility to speeded detection of high-calorie foods. *Health Psychology*, *34*(6), 677.

Booth, R. W. (2014). Uncontrolled avoidance of threat: Vigilance-avoidance, executive control, inhibition and shifting. *Cognition and Emotion*, *28*(8), 1465–1473. https://doi.org/10.1080/02699931.2014.882294

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2021). Introduction to meta-analysis. *John wiley & sons.*

Brand, J., Yeum, D., Stewart, T., Emond, J. A., & Gilbert-Diamond, D. (2024). The associations between attentional bias to food cues, parent-report appetitive traits, and concurrent adiposity among adolescents. *Eating behaviors*, *53*, 101874.

Brignell, C., Griffiths, T., Bradley, B. P., & Mogg, K. (2009). Attentional and approach biases for pictorial food cues. Influence of external eating. *Appetite*, *52*(2), 299-306.

Broadley, M. M., Bishop, T., White, M. J., & Andrew, B. (2019). The relationship between attentional bias to food and disordered eating in females with type 1 diabetes. *Appetite*, *140*, 269-276.

Burmester, V., Butler, G. K., & Terry, P. (2022). Intranasal oxytocin reduces attentional bias to food stimuli. *Appetite*, *168*, 105684.

Calcaterra, V., Cena, H., Rossi, V., Santero, S., Bianchi, A., & Zuccotti, G. (2023). Ultra-processed food, reward system and childhood obesity. *Children*, *10*(5), 804.

Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. J. H. W. (2019). Cochrane handbook for systematic reviews of interventions. *Hoboken: Wiley*, *4*(1002), 14651858.

Chapman, A., Devue, C., & Grimshaw, G. M. (2019). Fleeting reliability in the dot-probe task. *Psychological research*, *83*(2), 308-320.

Chen, Q., Peng, S., Luo, C., Zhuang, X., & Ma, G. (2023). Measuring early-stage attentional bias towards food images using saccade trajectory deviations. *Current Psychology*, *42*(34), 29838-29850.

Deluchi, M., Costa, F. S., Friedman, R., Gonçalves, R., & Bizarro, L. (2017). Attentional bias to unhealthy food in individuals with severe obesity and binge eating. *Appetite*, *108*, 471-476.

Dondzilo, L., Mills, C., Pollitt, S., & MacLeod, C. (2022). Enhanced capacity to switch but not to maintain: The basis of attentional bias to high calorie foods in restrained eaters. *Appetite*, *172*, 105969.

Donofry, S. D., Van Zoest, W., Moonen, A., Sacchetti, S., Nederkoorn, C., & Roefs, A. (2019). Effect of dietary restraint and mood state on attentional processing of food cues. *Journal of Behavior Therapy and Experimental Psychiatry*, *62*, 117-124.

Duc, A. H., Bays, P., & Husain, M. (2008). Eye movements as a probe of attention. *Progress in brain research*, *171*, 403-411.

Feighan, S. M., McArdle, K., Lisanti, L., Roche, E., Ormonde, C., Heron, E., ... & Gallagher, L. (2025). Measuring Shifts in Attentional Bias Following Satiety: A Within-Subject Eye-Tracking Study in Healthy-Weight Adults. *Physiology & Behavior*, 114993.

Field, A. E., Austin, S. B., Taylor, C. B., Malspeis, S., Rosner, B., Rockett, H. R., ... & Colditz, G. A. (2003). Relation between dieting and weight change among preadolescents and adolescents. *Pediatrics*, *112*(4), 900-906.

Field, M., & Cox, W. M. (2008). Attentional bias in addictive behaviors: a review of its development, causes, and consequences. *Drug and alcohol dependence*, *97*(1-2), 1-20.

Flynn, M. (2023). An Investigation of Concurrent Attention Bias Modification Training and Self-administered Transcranial Direct Current Stimulation in Binge Eating Disorder (Doctoral dissertation, King's College London).

Forestell, C. A., Lau, P., Gyurovski, I. I., Dickter, C. L., & Haque, S. S. (2012). Attentional biases to foods: The effects of caloric content and cognitive restraint. *Appetite*, *59*(3), 748-754.

Frayn, M., Sears, C. R., & von Ranson, K. M. (2016). A sad mood increases attention to unhealthy food images in women with food addiction. *Appetite*, *100*, 55-63.

Freccero, A., Burmester, V., Rodrigues, R., Gallucci, A., Nicholls, D., & Simplicio, M. D. (2025). Attentional Processing Biases in Young People With Binging and Purging Behavior. *Brain and Behavior*, *15*(2), e70322.

Freijy, T., Mullan, B., & Sharpe, L. (2014). Food-related attentional bias. Word versus pictorial stimuli and the importance of stimuli calorific value in the dot probe task. *Appetite*, *83*, 202-208.

Garcia-Burgos, D., Lao, J., Munsch, S., & Caldara, R. (2017). Visual attention to food cues is differentially modulated by gustatory-hedonic and post-ingestive attributes. *Food Research International*, *97*, 199-208.

Gearhardt, A. N., Treat, T. A., Hollingworth, A., & Corbin, W. R. (2012). The relationship between eating-related individual differences and visual attention to foods high in added fat and sugar. *Eating Behaviors*, *13*(4), 371-374.

Geyskens, K., Soetens, B., & Roets, A. (2010). Exposure makes the heart grow less fond! The effects of exposure to palatable foods on the subsequent attention processing of food cues. *Journal of health psychology*, *15*(2), 230-238.

Graham, R., Hoover, A., Ceballos, N. A., & Komogortsev, O. (2011). Body mass index moderates gaze orienting biases and pupil diameter to high and low calorie food images. *Appetite*, *56*(3), 577-586.

Grubb, M. A., White, A. L., Heeger, D. J., & Carrasco, M. (2015). Interactions between voluntary and involuntary attention modulate the quality and temporal dynamics of visual processing. *Psychonomic bulletin & review*, *22*(2), 437-444.

Hagerman, C. J., Stock, M. L., Beekman, J. B., Yeung, E. W., & Persky, S. (2021). The ironic effects of dietary restraint in situations that undermine self-regulation. *Eating behaviors*, *43*, 101579.

Hardman, C. A., Jones, A., Burton, S., Duckworth, J. J., McGale, L. S., Mead, B. R., ... & Werthmann, J. (2021). Food-related attentional bias and its associations with appetitive motivation and body weight: A systematic review and meta-analysis. *Appetite*, *157*, 104986.

Hardman, C. A., Rogers, P. J., Etchells, K. A., Houstoun, K. V., & Munafò, M. R. (2013). The effects of food-related attentional bias training on appetite and food intake. *Appetite*, *71*, 295-300.

763 Hardman, C. A., Scott, J., Field, M., & Jones, A. (2014). To eat or not to eat. The effects of expectancy
764 on reactivity to food cues. *Appetite*, *76*, 153-160.

765

766 Hege, M. A., Stingl, K. T., Veit, R., & Preissl, H. (2017). Modulation of attentional networks by food-
767 related disinhibition. *Physiology & Behavior*, *176*, 84-92.

768

769 Hepworth, R., Mogg, K., Brignell, C., & Bradley, B. P. (2010). Negative mood increases selective
770 attention to food cues and subjective appetite. *Appetite*, *54*(1), 134-142.

771

772 Herman, C. P., & Polivy, J. (1975). Anxiety, restraint, and eating behavior. *Journal of abnormal*
773 *psychology*, *84*(6), 666.

774

775 Higgins, J. P., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in
776 meta-analyses. *bmj*, *327*(7414), 557-560.

777

778 Higgs, S., Dolmans, D., Humphreys, G. W., & Rutters, F. (2015). Dietary self-control influences top–
779 down guidance of attention to food cues. *Frontiers in Psychology*, *6*, 427.

780

781 Higgs, S., Rutters, F., Thomas, J. M., Naish, K., & Humphreys, G. W. (2012). Top down modulation of
782 attention to food cues via working memory. *Appetite*, *59*(1), 71-75.

783

784 Hopewell, S., McDonald, S., Clarke, M. J., & Egger, M. (2007). Grey literature in meta-analyses of
785 randomized trials of health care interventions. *Cochrane Database of Systematic Reviews*, (2).

786

787 Hou, R., Mogg, K., Bradley, B. P., Moss-Morris, R., Peveler, R., & Roefs, A. (2011). External eating,
788 impulsivity and attentional bias to food cues. *Appetite*, *56*(2), 424-427.

789

790 Hummel, G., Ehret, J., Zerweck, I., Winter, S. S., & Stroebele-Benschop, N. (2018). How eating
791 behavior, food stimuli and gender may affect visual attention–An eye tracking study. *Eating behaviors*,
792 *31*, 60-67.

793

Hummel, G., Zerweck, I., Ehret, J., Winter, S. S., & Stroebele-Benschop, N. (2017). The influence of the arrangement of different food images on participants' attention: An experimental eye-tracking study. *Food Quality and Preference*, *62*, 111-119.

Husted, M., Banks, A. P., & Seiss, E. (2016). Eating behaviour associated with differences in conflict adaptation for food pictures. *Appetite*, *105*, 630-637.

Jiang, W., Zhang, H., Yang, H., Zhang, Z., & Wang, A. (2024). The Absence of Attentional Bias to Low-Calorie Food Stimuli in Restrictive Dieters: Differences in the Allocation of Attentional Resources to High-Calorie Foods. *Brain Sciences*, *14*(6), 551.

Jin, L., Han, W., & Zheng, Z. (2023). Attentional vigilance of food information in disordered eating behaviors. *Frontiers in Psychiatry*, *14*, 1108995.

Johnson, F., Pratt, M., & Wardle, J. (2012). Dietary restraint and self-regulation in eating behavior. *International journal of obesity*, *36*(5), 665-674.

Jonker, N. C., Heitmann, J., Ostafin, B. D., MacLeod, C., Glashouwer, K. A., & de Jong, P. J. (2019). A new approach to facilitating attentional disengagement from food cues in unsuccessful dieters: the bouncing image training task. *Behaviour Research and Therapy*, *120*, 103445.

Kakoschke, N., Kemps, E., & Tiggemann, M. (2015). Combined effects of cognitive bias for food cues and poor inhibitory control on unhealthy food intake. *Appetite*, *87*, 358-364.

Kim, Y. R., Kim, C. H., Cardi, V., Eom, J. S., Seong, Y., & Treasure, J. (2014). Intranasal oxytocin attenuates attentional bias for eating and fat shape stimuli in patients with anorexia nervosa. *Psychoneuroendocrinology*, *44*, 133-142.

Kirsten, H., Seib-Pfeifer, L. E., Koppehele-Gossel, J., & Gibbons, H. (2019). Food has the right of way: Evidence for prioritised processing of visual food stimuli irrespective of eating style. *Appetite*, *142*, 104372.

Kochs, S., Pimpini, L., van Zoest, W., Jansen, A., & Roefs, A. (2022). Effects of mindset and dietary restraint on attention bias for food and food intake. *Journal of Cognition*, *5*(1), 43.

Kong, F., Zhang, Y., You, Z., Fan, C., Tian, Y., & Zhou, Z. (2013). Body dissatisfaction and restrained eating: Mediating effects of self-esteem. *Social Behavior and Personality: an international journal*, *41*(7), 1165-1170.

LaFata, E. M., Allison, K. C., Audrain-McGovern, J., & Forman, E. M. (2024). Ultra-processed food addiction: a research update. *Current Obesity Reports*, *13*(2), 214-223.

Landis, J.R. and Koch, G.G. (1977). An Application of Hierarchical Kappa-Type Statistics in the Assessment of Majority Agreement among Multiple Observers. *Biometrics, 33*, 363-374.

Leppanen, J., Cardi, V., Ng, K. W., Paloyelis, Y., Stein, D., Tchanturia, K., & Treasure, J. (2017). The effects of intranasal oxytocin on smoothie intake, cortisol and attentional bias in anorexia nervosa. *Psychoneuroendocrinology*, *79*, 167-174.

Linardon, J., Messer, M., Helms, E. R., McLean, C., Incerti, L., & Fuller-Tyszkiewicz, M. (2020). Interactions between different eating patterns on recurrent binge-eating behavior: A machine learning approach. *International Journal of Eating Disorders*, *53*(4), 533-540.

Liu, X., Pei, G., Zhao, J., Xu, M., Cao, L., Zhang, J., ... & Wang, L. (2025). Attention Affecting Response Inhibition in Overweight Adults with Food Addiction. *Biosensors*, *15*(3), 180.

Liu, Y., Roefs, A., & Nederkoorn, C. (2021). Food palatability directs our eyes across contexts. *Frontiers in psychology*, *12*, 664893.

Loeber, S., Grosshans, M., Herpertz, S., Kiefer, F., & Herpertz, S. C. (2013). Hunger modulates behavioral disinhibition and attention allocation to food-associated cues in normal-weight controls. *Appetite*, *71*, 32-39.

Loeber, S., Grosshans, M., Korucuoglu, O., Vollmert, C., Vollstädt-Klein, S., Schneider, S., ... & Kiefer, F. (2012). Impairment of inhibitory control in response to food-associated cues and attentional bias of obese participants and normal-weight controls. *International journal of obesity*, *36*(10), 1334-1339.

Mercado, D., Schmidt, U., O'Daly, O. G., Campbell, I. C., & Werthmann, J. (2020). Food related attention bias modification training for anorexia nervosa and its potential underpinning mechanisms. *Journal of Eating Disorders*, *8*(1), 1.

Meregalli, V., Tenconi, E., Cardi, V., Bonifanti, A., Meneguzzo, P., Favaro, A., & Collantoni, E. (2023). Strategic avoidance of food stimuli in patients with restrictive anorexia nervosa: An eye-tracking evaluation. *European Eating Disorders Review*, *31*(6), 813-821.

Meule, A., Papies, E. K., & Kübler, A. (2012). Differentiating between successful and unsuccessful dieters. Validity and reliability of the Perceived Self-Regulatory Success in Dieting Scale. *Appetite*, *58*(3), 822-826.

Meule, A., Vögele, C., & Kübler, A. (2012). Restrained eating is related to accelerated reaction to high caloric foods and cardiac autonomic dysregulation. *Appetite*, *58*(2), 638-644.

Moore, K., Walker, D., & Laczniak, R. (2022). Attention mediates restrained eaters' food consumption intentions. *Food Quality and Preference*, *96*, 104382.

Nannt, J., van den Hoek Ostende, M. M., Tuschen-Caffier, B., Heinrichs, M., Sippel, D., Hallschmid, M., & Svaldi, J. (2025). Oxytocin Effects on Food Stimulus Processing and Food Intake in Females With or Without Binge Eating Disorder. *International Journal of Eating Disorders*, *59*(2), 249-259.

Neimeijer, R. A., de Jong, P. J., & Roefs, A. (2013). Temporal attention for visual food stimuli in restrained eaters. *Appetite*, *64*, 5-11.

Neimeijer, R. A., Roefs, A., & de Jong, P. J. (2017). Heightened attentional capture by visual food stimuli in anorexia nervosa. *Journal of abnormal psychology*, *126*(6), 805.

Olea López, A. L., & Johnson, L. (2016). Associations between restrained eating and the size and frequency of overall intake, meal, snack and drink occasions in the UK adult national diet and nutrition survey. *PLoS One*, *11*(5), e0156320.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj*, *372.*

Page, M. J., Sterne, J. A., Higgins, J. P., & Egger, M. (2021). Investigating and dealing with publication bias and other reporting biases in meta-analyses of health research: A review. *Research synthesis methods*, *12*(2), 248-259.

Papies, E. K., & Hamstra, P. (2010). Goal priming and eating behavior: enhancing self-regulation by environmental cues. *Health Psychology*, *29*(4), 384.

Pasqualette, L., & Kulke, L. (2024). Differences between overt, covert and natural attention shifts to emotional faces. *Neuroscience*, *559*, 283-292.

Polivy, J., & Herman, C. P. (2020). Overeating in restrained and unrestrained eaters. *Frontiers in Nutrition*, *7*, 513340.

Price, M. J., Blake, H. A., Kenyon, S., White, I. R., Jackson, D., Kirkham, J. J., Neilson, J. P., Deeks, J. J., & Riley, R. D. (2019). Empirical comparison of univariate and multivariate meta-analyses in Cochrane Pregnancy and Childbirth reviews with multiple binary outcomes. *Research synthesis methods*, *10*(3), 440–451. https://doi.org/10.1002/jrsm.1353

Price, R. B., Kuckertz, J. M., Siegle, G. J., Ladouceur, C. D., Silk, J. S., Ryan, N. D., ... & Amir, N. (2015). Empirical recommendations for improving the stability of the dot-probe task in clinical research. *Psychological assessment*, *27*(2), 365.

Puttevils, L., De Bruecker, M., Allaert, J., Sanchez-Lopez, A., De Schryver, N., Vervaet, M., ... & Vanderhasselt, M. A. (2023). Attentional bias to food during free and instructed viewing in anorexia nervosa: An eye tracking study. *Journal of Psychiatric Research*, *164*, 468-476.

Racine, S. E., Burt, S. A., Iacono, W. G., McGue, M., & Klump, K. L. (2011). Dietary restraint moderates genetic risk for binge eating. *Journal of Abnormal Psychology*, *120*(1), 119.

Ramírez-Contreras, C., Farrán-Codina, A., Izquierdo-Pulido, M., & Zerón-Rugerio, M. F. (2021). A higher dietary restraint is associated with higher BMI: a cross-sectional study in college students. *Physiology & Behavior*, *240*, 113536.

Radix, A. K., Sfärlea, A., Rinck, M., Becker, E. S., Platt, B., Schulte-Körne, G., & Legenbauer, T. (2023). Watch out! A path from anxiety to anorexia nervosa through biased attention?. *European Eating Disorders Review*, *31*(5), 670-684.

Sablottny, L., Werle, D., Svaldi, J., Thörel, N., Caffier, D., & Tuschen-Caffier, B. (2025). Attentional bias toward food in binge eating disorder: baseline differences and the limits of attention modification training. *Journal of Eating Disorders*, *13*(1), 1-17.

Sambal, H., Bohon, C., & Weinbach, N. (2021). The effect of mood on food versus non-food interference among females who are high and low on emotional eating. *Journal of Eating Disorders*, *9*(1), 140.

Schag, K., Teufel, M., Junne, F., Preissl, H., Hautzinger, M., Zipfel, S., & Giel, K. E. (2013). Impulsivity in binge eating disorder: food cues elicit increased reward responses and disinhibition. *PloS one*, *8*(10), e76542.

Schmid, C.H., Stijnen, T., & White, I. (Eds.). (2020). Handbook of Meta-Analysis (1st ed.). Chapman and Hall/CRC. https://doi.org/10.1201/9781315119403

Schmidt, R., Lüthold, P., Kittel, R., Tetzlaff, A., & Hilbert, A. (2016). Visual attentional bias for food in adolescents with binge-eating disorder. *Journal of Psychiatric Research*, *80*, 22-29.

Schmitz, F., Naumann, E., Trentowska, M., & Svaldi, J. (2014). Attentional bias for food cues in binge eating disorder. *Appetite*, *80*, 70-80.

Seage, C. H., & Lee, M. (2017). Do disinhibited eaters pay increased attention to food cues?. *Appetite*, *108*, 151-155.

Seo, C. L., & Lee, J. H. (2021). Attentional bias to high-calorie food in binge eaters with high shape/weight concern. *Frontiers in psychiatry*, *12*, 606296.

Skinner, I. W., Hübscher, M., Moseley, G. L., Lee, H., Wand, B. M., Traeger, A. C., ... & McAuley, J. H. (2018). The reliability of eye-tracking to assess attentional bias to threatening words in healthy individuals. *Behavior research methods*, *50*(5), 1778-1792.

Smeets, E., Roefs, A., & Jansen, A. (2009). Experimentally induced chocolate craving leads to an attentional bias in increased distraction but not in speeded detection. *Appetite*, *53*(3), 370-375.

Soetens, B., Braet, C., & Bosmans, G. (2008). No evidence for a food-related attention bias after thought suppression. *Psychologica Belgica*, *48*(1).

Soleymani, A., Mazidi, M., Neimeijer, R., & de Jong, P. J. (2022). Eating disorder-specific rumination moderates the association between attentional bias to high-calorie foods and eating disorder symptoms: Evidence from a reliable free-viewing eye-tracking task. *Appetite*, *171*, 105934.

Sperling, I., Baldofski, S., Lüthold, P., & Hilbert, A. (2017). Cognitive food processing in binge-eating disorder: an eye-tracking study. *Nutrients*, *9*(8), 903.

Stamataki, N. S., Scott, C., Elliott, R., McKie, S., Bosscher, D., & McLaughlin, J. T. (2020). Stevia beverage consumption prior to lunch reduces appetite and total energy intake without affecting glycemia or attentional bias to food cues: A double-blind randomized controlled trial in healthy adults. *The Journal of nutrition*, *150*(5), 1126-1134.

Stormark, K. M., & Torkildsen, Ø. (2004). Selective processing of linguistic and pictorial food stimuli in females with anorexia and bulimia nervosa. *Eating behaviors*, *5*(1), 27-33.

Stott, N., Fox, J. R., & Williams, M. O. (2021). Attentional bias in eating disorders: A meta-review. *International Journal of Eating Disorders*, *54*(8), 1377-1399.

Taylor, J. M., & Alanazi, S. (2023). Cohen's and Hedges'g. *Journal of Nursing Education*, *62*(5), 316-317.

Valenzuela, A. U. Z. (2019). *Attentional Bias for Food Cues After Sleeve Gastrectomy: A Behavioral and Electrophysiological Study*. Pontificia Universidad Catolica de Chile (Chile).

van Ens, W., Schmidt, U., Campbell, I. C., Roefs, A., & Werthmann, J. (2019). Test-retest reliability of attention bias for food: Robust eye-tracking and reaction time indices. *Appetite*, *136*, 86-92.

van Strien, T., & Bazelier, F. G. (2007). Perceived parental control of food intake is related to external, restrained and emotional eating in 7–12-year-old boys and girls. *Appetite*, *49*(3), 618-625.

Veenstra, E. M., de Jong, P. J., Koster, E. H., & Roefs, A. (2010). Attentional avoidance of high-fat food in unsuccessful dieters. *Journal of Behavior Therapy and Experimental Psychiatry*, *41*(3), 282-288.

Waliłko, J., Bronowicka, P., He, J., & Brytek-Matera, A. (2021). Dieting and disinhibited eating patterns in adult women with normal body weight: Does rumination matter?. *Nutrients*, *13*(7), 2475.

Wang, Y., Dong, D., Todd, J., Du, J., Yang, Z., Lu, H., & Chen, H. (2016). Neural correlates of restrained eaters' high susceptibility to food cues: An fMRI study. *Neuroscience letters*, *631*, 56-62.

Watson, P., & Le Pelley, M. E. (2021). A meta-analysis of the relationship between eating restraint, impaired cognitive control and cognitive bias to food in non-clinical samples. *Clinical psychology review*, *89*, 102082.

Waechter, S., Nelson, A. L., Wright, C., Hyatt, A., & Oakman, J. (2014). Measuring attentional bias to threat: Reliability of dot probe and eye movement indices. *Cognitive therapy and research*, *38*(3), 313-333.

Weng, C. Y., Chen, H., & Zhu, L. (2012). Attentional biases toward food-related information among restrained eaters based on the goal conflict model of eating. *Acta Psychologica Sinica*, *44*(5), 680.

Wells, G. A., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M., & Tugwell, P. (2000). The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. URL: https://web.archive.org/web/20210716121605id_/www3.med.unipmn.it/dispense_ebm/2009-2010/Corso%20Perfezionamento%20EBM_Faggiano/NOS_oxford.pdf

Werle, D., Sablottny, L., Tuschen-Caffier, B., & Svaldi, J. (2024). Modifying biased attention towards food stimuli in binge eating disorder: A multi-session training study. *Appetite,* 107284.

Werthmann, J., Field, M., Roefs, A., Nederkoorn, C., & Jansen, A. (2014). Attention bias for chocolate increases chocolate consumption–an attention bias modification study. *Journal of Behavior Therapy and Experimental Psychiatry*, *45*(1), 136-143.

Werthmann, J., Roefs, A., Nederkoorn, C., & Jansen, A. (2013). Desire lies in the eyes: attention bias for chocolate is related to craving and self-endorsed eating permission. *Appetite*, *70*, 81-89.

Werthmann, J., Roefs, A., Nederkoorn, C., Mogg, K., Bradley, B. P., & Jansen, A. (2013). Attention bias for food is independent of restraint in healthy weight individuals—An eye tracking study. *Eating behaviors*, *14*(3), 397-400.

Wilson, C., & Wallis, D. J. (2013). Can the dot probe task detect food-related attentional biases in restrained eaters?. *Appetite*, *71*, 490.

Xie, X., & Chen, H. (2025). Dissociation between wanting and liking for high-calorie foods across physiological states in restrained eating subgroups. *Eating Behaviors*, 102048.

Xu, I., Passell, E., Strong, R. W., Grinspoon, E., Jung, L., Wilmer, J. B., & Germine, L. T. (2025). No evidence of reliability across 36 variations of the emotional dot-probe task in 9,600 participants. *Clinical Psychological Science*, *13*(2), 261-277.

Xu, M., Rowe, K., & Purdon, C. (2023). To Approach or to Avoid: The Role of Ambivalent Motivation Towards High Calorie Food Images in Restrained Eaters. *Cognitive Therapy and Research*, *47*(4), 669-680.

Yamamiya, Y., & Stice, E. (2024). Risk factors that predict future onset of anorexia nervosa, bulimia nervosa, binge eating disorder, and purging disorder in adolescent girls. *Behavior Therapy*, *55*(4), 712-723.

Yong, C., Liu, H., Yang, Q., Luo, J., Ouyang, Y., Sun, M., ... & Lin, Q. (2021). The relationship between restrained eating, body image, and dietary intake among university students in China: a cross-sectional study. *Nutrients*, *13*(3), 990.

Zhou, S., & Shen, C. (2022). Avoiding definitive conclusions in meta-analysis of heterogeneous studies with small sample sizes. *JAMA Otolaryngology–Head & Neck Surgery*, *148*(11), 1003-1004.