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## A systematic review of reviews of neurocognitive functioning in eating disorders: The state of the literature and future directions

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### Abstract

**Objective:** In recent years there has been increasing clinical and empirical interest in neurocognitive functioning in eating disorders (EDs), which has resulted in numerous quantitative and qualitative reviews. However, there has yet to be a comprehensive synthesis or critical review of this literature to identify future directions to advance the field in this area. Therefore the aim of this systematic review of systematic reviews was to (1) characterize the existing literature on neurocognitive functioning in EDs based on recent reviews (i.e., published since 2010), (2) describe related limitations, and (3) suggest avenues for future research to address gaps in the current literature.

**Method:** Electronic databases were queried for reviews of neurocognitive domains (i.e., inhibitory control, decision making, central coherence, set-shifting, working memory, and attention bias) in EDs, which identified 28 systematic and meta-analytic reviews.

**Results:** Broadly, the literature indicates deficits across these neurocognitive domains in EDs, though heterogeneity was noted in the magnitude of these effects, which varied to some extent across ED subtypes, sample characteristics, and methodological approaches.

**Discussion:** While these reviews have generally suggested varying patterns of neurocognitive deficits across EDs, there remain critical limitations regarding the methodological quality of these studies (e.g., the lack of prospective designs, consideration of confounding influences, or examination of interrelationships between neurocognitive domains and relationships between neurocognition and other relevant behavioral constructs). Specifically, we outline ten key areas that are imperative to address in future research in this area in order to move our field forward.

### Keywords

anorexia nervosa; bulimia nervosa; binge eating disorder; neurocognition; executive functioning

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## 1. Introduction

Neurocognitive deficits have been broadly implicated as potential transdiagnostic mechanisms contributing to psychopathology (e.g., Goschke, 2014), and in recent years a wealth of research has emerged investigating underlying neurocognitive processes that may contribute to the etiology and/or maintenance of eating disorders (EDs). Executive functioning (also termed cognitive control) is a multidimensional construct referring to “top-down” processes that allow individuals to adapt information processing and behaviors according to their goals (Diamond, 2013). Moreover, cognitive control processes are inherent components of self-regulation and are essential for adaptive emotional, social, and physical functioning (Hofmann, Schmeichel, & Baddeley, 2012). Executive functioning can be further classified into several subdomains that are also broadly related to cognitive control, including inhibition and interference control (i.e., cognitive and behavioral inhibitory control, selective attention), working memory, and cognitive flexibility (Diamond, 2013).

While early ED studies focused on general cognitive deficits, a large body of subsequent research has examined specific facets of neurocognitive functioning hypothesized to contribute to ED psychopathology, specifically inhibitory control, decision making, central coherence, cognitive flexibility, attention bias, and working memory. A number of prior quantitative and qualitative reviews have synthesized functioning of these domains in EDs, though most recent reviews have focused on a single diagnostic category or neurocognitive domain, and thus far there has not been a comprehensive synthesis or critical review of this emergent literature. Systematic reviews of reviews offer a viable way of summarizing evidence and appraising the quality of reviews of primary studies that span multiple topics, methodologies, and samples (Smith, Deva, Begley, & Clarke, 2011). This methodology has been applied in several other fields and across healthcare interventions (e.g., de Vet, de Ridder, & de Wit, 2010; Greaves et al., 2011; Lamming et al., 2017; Lemmens, Oenema, Knut, & Brug, 2008; Maniglio, 2009) to synthesize evidence, resolve inconsistencies in findings, and evaluate methodological limitations. Systematic reviews of reviews therefore allow researchers and clinicians to form conclusions and develop new lines of investigation based on the most accurate and comprehensive depiction of a body of literature.

Given the plethora and diversity of reviews of neurocognitive functioning in EDs, such a review of this literature will not only provide a comprehensive assessment of the empirical evidence across various neurocognitive domains and ED diagnoses, but also help to identify the extent to which deficits are common to EDs or specific to a particular diagnosis, the limitations of the existing research, and future directions to advance our field in understanding potential neurocognitive mechanisms underlying ED psychopathology. Therefore the aim of this review of reviews was to (1) broadly characterize the literature to date on neurocognitive functioning (i.e., inhibitory control, decision making, central coherence, set-shifting, working memory, attention bias) in EDs by conducting a systematic review of recent systematic reviews (i.e., 2010 or later), (2) describe limitations of existing research, and (3) suggest avenues for future research to address gaps in the current literature.

## 2. Method

### Review Selection

Methodology for this review was informed by recommended guidelines for systematic reviews of systematic reviews (Smith et al., 2011). To identify relevant reviews, PsycInfo (“\*” allows for identification of terms with the same stem but have multiple endings), SCOPUS (limited to psychology and/or neuroscience subject areas), and PubMed electronic databases were queried using the following search terms: [“cognitive” or “inhibition” or “inhibitory” or “attention” or “working memory” or “central coherence” or “set shifting” or “set-shifting” or “flexibility” or “decision” or “decision making” or “executive” or “neurocognitive” or “neurocog\*” or “neuropsychology” or “neuropsych\*” or “risk taking”] in conjunction with [“eating disorder” or “disordered eating” or “anorexia” or “anorexic” or “bulimia” or “bulimic” or “binge”] in the title and/or abstract. Articles were included if a systematic or meta-analytic review was conducted that included a summary of studies examining one of the aforementioned neurocognitive domains in one or more ED diagnostic groups (i.e., anorexia nervosa [AN], bulimia nervosa [BN], and/or binge eating disorder [BED]). These diagnoses were selected given these are the ED groups in which neurocognitive functioning has been most commonly studied in recent years. Reviews were limited to those published in English between 2010 and March 2018 and which included a summary of primary studies using neurocognitive tasks to assess one or more of the domains of interest. The review selection process is summarized in Figure 1; authors K.S. and S.W. independently evaluated full-text articles for inclusion and resolved any discrepancies via discussion.

### Quality Assessment

Authors K.S. and S.W. independently evaluated the methodological quality of each review by assessing characteristics outlined in the Assessment of Multiple Systematic Reviews (AMSTAR) tool (Shea et al., 2009), which is a validated measure to assess the quality of systematic reviews. Authors agreed upon modified wording of some items on the AMSTAR items to improve clarity in completing ratings; a description of items is available in Supplementary Table 1. One point was assigned for each “yes” response to items on the AMSTAR measure, which were summed to create a composite score for each review. Total scores for meta-analyses and systematic reviews range from 0–11 and 0–9, respectively, with higher scores reflecting higher methodological quality. Inter-rater reliability for items was excellent ( $\kappa=.94$ ). Discrepancies were resolved between raters before calculating total scores.

### Data Extraction and Synthesis

A checklist was developed to systematically extract and summarize key characteristics and results from each review, including descriptive information (e.g., sample characteristics, study designs, and tasks), task-based results regarding neurocognitive functioning such as effect sizes for meta-analyses, and relevant covariates and/or moderators (e.g., ED severity, duration of illness, BMI, co-occurring psychopathology). After reviews were identified for inclusion, each of the five authors synthesized findings from one to two of the five neurocognitive domains according to the agreed upon guidelines.

### 3. Results

This search yielded a total of 28 review articles, including 13 meta-analyses. Of these, 12 reviewed set-shifting; 11 reviewed decision making; 9 reviewed inhibitory control; 9 reviewed central coherence; 8 reviewed attention bias; and 5 reviewed working memory. The mean quality score for meta-analyses was 6.54 ( $SD=1.98$ ; Range: 3–9) out of 11, and the mean score for systematic reviews was 3.47 ( $SD=1.19$ ; Range: 1–5) out of 9.

#### Inhibitory Control

Broadly, inhibitory control refers to a range of processes that reflect the ability to suppress or interrupt responses (Bari & Robbins, 2013), and previous research has suggested that EDs lie on an inhibition-disinhibition spectrum, with binge eating type EDs characterized by deficient inhibitory control, and restricting EDs (i.e., AN-restricting subtype [AN-R]) characterized by excessive inhibitory control (e.g., Wierenga et al., 2014a). Inhibitory control has been further delineated into subdomains of cognitive and behavioral (motor) response inhibition. *Cognitive* inhibition refers to the ability to filter out irrelevant stimuli from working memory and is often assessed in EDs by measures of interference control such as the Stroop task. *Behavioral* inhibition refers to the ability to withhold an inappropriate/unwanted motor response, which can be separated into proactive and reactive forms of inhibition. *Proactive* inhibition reflects inhibition of a response that has not been initiated (i.e., action restraint), and has generally been assessed in EDs using the Go/No-Go task. This task requires participants to respond to a frequently presented target and to inhibit responses to a less frequently presented non-target, and is typically indexed by commission errors (i.e., failures to inhibit). *Reactive* inhibition is the ability to stop an already initiated behavioral response (i.e., action cancellation), and has most commonly been assessed in EDs with the Stop Signal Task (SST). In the SST, participants are instructed to withhold a prepotent response when a “stop” signal is presented after the appearance of a target stimulus, with slower stop signal reaction time (SSRT) indexing poorer inhibitory control.

Nine systematic reviews including three meta-analyses were identified in this domain (see Table 1 for study characteristics and results). The majority of research focused on comparisons of adults with binge-type EDs with normal weight or obese control groups, and all were cross-sectional in design. Based on the largest review to date (Wu et al. 2013), converging evidence suggests that bulimic-spectrum EDs (i.e., AN binge-purge subtype [AN-BP], BN, BED) are associated with inhibitory control deficits across a range of measures (e.g., Go/No-Go, SST) compared to healthy controls (HC),  $g=-.32$ , with AN-BP associated with the greatest magnitude of deficits ( $g=-.91$ ). However, evidence appears more inconsistent when based *solely* on the SST, as five out of eight studies using the SST in a range of ED diagnoses found no differences in reaction time compared to HC, which may suggest that reactive behavioral inhibition is less strongly associated with ED psychopathology than proactive inhibition (Bartholdy et al., 2016). Although few studies have included individuals with AN-R or differentiated between AN subtypes, results thus far have not demonstrated consistent differences in inhibitory control functioning between AN subtypes (Bartholdy et al., 2016).

In addition, greater inhibitory control deficits have been observed with disorder-relevant (i.e., food or weight/shape-related) stimuli in BN (Wu et al., 2013) and BED (Giel et al., 2017; Kittel et al., 2015), and several studies found no difference between BED and obese or normal weight control groups using non-disorder relevant stimuli (Kittel et al., 2015). Thus, it is possible that BED is associated with ED-specific rather than general inhibitory control impairments. It is also not clear whether BED status is associated with additional inhibitory control deficits beyond what is seen in obesity, as suggested by one meta-analysis that found no additive influence of BED beyond obesity (Lavagnino et al., 2016). While most reviews focused on comparisons of task performance between ED and control groups, Bartholdy et al. (2016) also demonstrated positive associations between SSRT and ED symptom severity and BMI in BED, but not AN or BN groups; only one study was noted to have examined relationships between inhibitory control, age of onset, and illness duration. Lastly, no reviews reported assessment or analysis of the influence of co-occurring psychopathology.

### Set-shifting

Set-shifting, also termed cognitive flexibility, refers to the ability to shift thoughts or actions according to situational demands, which is integral to the self-regulation of behavior (Lezak, 1995). For instance, individuals may exhibit *perceptual* deficits in scanning or shifting perceptual sets, *conceptual* deficits that manifest in rigid approaches to understanding and problem-solving, and *response* deficits that are reflected by stereotyped, perseverative behaviors and difficulties switching behaviors to adapt to changing demands (Lezak, 1995). Poor set-shifting has been posited as a neurocognitive endophenotype of AN that may contribute to rigid and compulsive behaviors (Holliday, Tchanturia, Landau, Collier, & Treasure, 2005). A variety of measures have been used to assess set-shifting that require participants to switch from between previously learned strategies that are no longer effective to new rule sets. In EDs, set-shifting is most commonly assessed by the Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Curtiss, Kay, & Talley, 1993), as indexed by perseverative errors, and the Trail Making Task (TMT; Reitan, 1992), as indexed by task completion time.

There have been 12 systematic reviews including 6 meta-analyses that have focused on set-shifting (see Table 2). All reviews summarized cross-sectional studies of children and adults, which compared EDs to HC groups. In the most comprehensive meta-analysis of set-shifting to date, Wu et al. (2014) found evidence for poor set-shifting in all EDs compared to HC, with medium effect sizes ( $g=-.51-.53$ ) in AN-R, BN, and BED, but not in AN-BP ( $g=-.18$ ). Consistent with these findings, other reviews have found evidence for deficits in set-shifting in adults with AN (Westwood et al., 2016) and that set-shifting deficits in AN remain after controlling for depressive symptoms (Abbate-Daga et al., 2015). Notably, one meta-analytic review failed to find significant differences in set-shifting in children and adolescents with AN compared to age-matched controls using the TMT and WCST (Lang et al., 2014), and another meta-analysis did not find evidence of deficient set-shifting in BN (Zakzanis et al., 2010); however, these inconsistent findings may be related to the fact that Lang et al. and Zakzanis et al. included fewer studies compared to Wu et al. ( $k=64$ ).

Wu et al. (2014) compared set shifting abilities across the range of ED diagnoses and reported that AN, BN, and BED did not significantly differ from one another in set-shifting. However, in Voon's (2015) review, one study (i.e., Aloï et al., 2015) found that BED was associated with greater set-shifting impairments compared to AN. Research has yielded mixed findings regarding differences between AN subtypes. Wu et al. (2014) found evidence for deficits in set-shifting in AN-R compared to controls, but not AN-BP. However, in a systematic review of eight studies comparing AN-R and AN-BP in set-shifting, Van Autreve and Vervaeet (2015) noted that in two of the studies AN-BP performed worse than AN-R, while in the other six studies, there were no differences. In summary, current evidence tends to provide little support for set shifting differences among ED diagnostic groups.

The observed deficits may vary somewhat depending on the specific set-shifting task that is used, as well as participant age. The magnitude of effect sizes has varied across different set-shifting tasks among individuals with EDs (Wu et al., 2014). Effect sizes for the most frequently used tasks (i.e., TMT and WCST) were small to medium (TMT:  $g = -.41$ ; WCST:  $g = -.53$ ). However, the effect sizes for less frequently used tasks varied more, with a large effect size for the Uznadze task ( $g = -1.02$ ) and a smaller effect size for the Brixton task ( $g = -0.43$ ). While effect sizes were comparable across several tasks in both adolescent and adult samples with AN (Wu et al., 2014), a separate meta-analysis of studies by Westwood et al. (2016) focused on the WCST (2016) reported that effect sizes for deficits in set-shifting in AN were greater in adults compared to children and adolescents. Conclusions currently cannot be made regarding differences in set-shifting between adolescents and adults with EDs other than AN, as only one study investigated set-shifting in adolescents with BN (Darcy et al., 2012), and found no significant differences. To date, no study has evaluated adolescents with BED in terms of set shifting abilities (Wu et al., 2014).

### Central Coherence

Central coherence is characterized by the degree of focus on details in processing information and the global integration of such information (Frith, 1989). Several cognitive tasks are thought to assess central coherence, including the Group Embedded Figures Test (EFT/GEFT; Witkin et al., 2002), the Rey-Osterrieth Complex Figure Test (ROFT; Osterrieth et al., 1944), the Object Assembly task (OA; Wechsler et al., 1981), the Overlapping Figures Test (OFT; Della Salla et al., 1995), and the Fragmented Pictures Task (FPT; Snodgrass and Vanderwart, 1980). Each of these measures engages participants in a complex series of tasks regarding shape detection, drawing presented shapes, time to complete puzzles, or other components, which together reflect an emphasis on detail oriented information processing versus broad and global processing of information. In the case of the ROFT, an overall central coherence index (CCI) can be calculated in which higher scores represent a more global processing strategy.

Weak central coherence is considered a potential etiologic or maintenance factor for EDs due to the alleged propensity for persons with EDs to excessively focus on individual details (e.g. body weight) as opposed to broader concepts (e.g. broader sense of self), which in turn influence behavior. The fundamental idea that eating disordered individuals, particularly those with AN, display poor central coherence with over-attention to detail and reduced

global processing abilities was generally supported across the seven systematic reviews and three meta-analyses included in this review. As summarized in Table 3, the majority of the studies focused on between-group comparisons of adults with AN versus HC. The largest meta-analysis available (Lang et al., 2014) reveals that across several measures of central coherence (e.g., ROFT, GEFT, OA) individuals with AN displayed poorer central coherence than HC ( $d=-0.58$  to  $-0.63$ ). The effect sizes for comparisons of individuals with BN to HC were more variable across measures, but often significant ( $d=-0.28$  to  $-0.84$ ). There was no evidence of significant differences between AN-R and AN-BP subtypes in central coherence (VanAutre, and Vervaet, 2015). Furthermore, another systematic review found little evidence that differences between AN and HC could be accounted for by levels of depression (Abbate-Daga et al., 2015). Currently there are few studies of central coherence in BED.

### Attention Bias

Attention bias refers to a tendency to overfocus on environmental sources of information that are considered to be disorder relevant. The two most commonly employed behavioral methods of assessing attention bias in EDs are the modified Stroop task (Stroop, 1935) and variants of the dot-probe task (MacLeod, Mathews, & Tata, 1986). The modified Stroop interference task assesses the time taken to name the color of a written word when the word itself is either neutral (e.g. “hat”) or disorder salient (e.g., “fat”). An attention bias is inferred if the presence of a disorder-salient word increases the time taken to name the color of the word. In the dot-probe task, pairs of stimuli (e.g., a food- or body-related image and a neutral image) are presented, followed by a dot (the probe) at one of the two locations previously occupied by an image. Participants are then required to make a speeded response to the probe. An attention bias is demonstrated when response times (RTs) are reduced for trials in which the probe appears at the location of the disorder relevant stimulus, or, conversely, increased when the probe appears at a different location, suggesting that attention was automatically shifted to the location of the disorder-relevant stimulus (Posner, 1980).

Attention bias is relevant to EDs because these disorders are characterized by an overvaluation of and preoccupation with weight, shape, and food (American Psychiatric Association, 2013). In particular, it has been suggested that excessive concern with disorder-specific (i.e., body- and food-related) stimuli may maintain ED symptoms by directing limited cognitive resources towards disorder-salient stimuli, thereby interfering with tasks and distorting how the environment is perceived and interpreted (Blechert, Ansorge, & Tuschen-Caffier, 2010; Vitousek & Orimoto, 1993). Eight systematic reviews including two meta-analyses were identified in this domain (see Table 4). The majority of studies focused on comparisons of adults with AN, BN, and BED with normal weight or HC. One meta-analysis by Brooks and colleagues (2011) that examined attention bias in AN and BN versus HC, reported consistent evidence for an attention bias towards food words in the Stroop task ( $k=12$ ; for similar results, see also Jáuregui-Lobera, 2013 and Kittel et al., 2015), with overall effect sizes in the small to medium range (AN  $d=.38$ ; BN  $d=.43$ ). Similarly, a systematic review in binge-type EDs (BN, AN-B/P, BED; Stojek et al., 2018) found consistent evidence of biases towards food stimuli in binge-type EDs without compensatory

behaviors, though more inconsistent evidence in BN (Stojek et al., 2018; for similar mixed results, see Van den Eynde et al, 2011). However, a more consistent pattern in BN was found for Stroop studies using weight/shape and threat stimuli, which reported a larger attention bias in BN versus controls (Stojek et al., 2018). A meta-analysis of dot-probe task performance ( $k=4$ ) revealed a large attention bias towards negative shape-related stimuli ( $d=.80$ ) and away from positive eating and shape-related stimuli ( $d=-.83$ ) in AN and BN versus controls (Aspen et al., 2013; see also Brooks et al., 2011).

Finally, several systematic reviews included studies that measured attention bias in EDs by tracking eye movements during viewing of disorder-salient versus neutral stimuli (Giel et al., 2017; Kittel et al., 2015; Reville, O'Connor, & Frampton, 2016; Stojek et al., 2018). Although fairly heterogeneous overall, results suggest that women who binge eat may have difficulties disengaging from food cues, whereas women with BN exhibit both an attention bias towards and avoidance of food images versus neutral stimuli. Additionally, limited evidence suggests that women with BN may have difficulty disengaging from low-BMI images of other women and tend to avoid fixating on images of high-BMI people. Taken together, there is fairly reliable evidence for an attention bias in women with EDs compared to HC. However, research suggests that the presence of an attention bias, and whether this is primarily characterized by hyper-vigilance or avoidance tendencies, likely depends on a combination of stimulus timing, type of stimulus, and ED diagnosis (Aspen et al., 2013).

### Working Memory

Working memory functioning refers to the ability to hold and work with information in mind and use such information to guide behavior (Lezak, 1995). Working memory, which can be subtyped into verbal and non-verbal (visual-spatial) components, is centrally important in a range of cognitive processes, including incorporating new information into plans and actions (updating), considering alternatives, seeing connections between separate elements, and integrating perceptual input (Diamond, 2013). While a variety of tasks may be used to assess working memory, commonly noted measures in EDs included the spatial and digit span tasks and the N-back task.

Four systematic reviews and one meta-analysis were located that included working memory task results in EDs, with the majority of studies comparing AN to HC (see Table 5). Limited data were available regarding study characteristics, and some reviewers did not include details regarding tasks or stimuli. An earlier review by Zakzanis and colleagues (2010) found that AN groups evidenced deficits in working memory functioning compared to HC ( $d=-.35$ ), though a more recent review of 16 studies found inconsistent results across studies comparing working memory functioning in AN to HC (Brooks, 2017). There were fewer studies assessing BN and BED groups, though evidence suggested small or non-significant differences in visual and verbal working memory between BN and HC (Van den Eynde et al., 2011; Zakzanis et al., 2010:  $d=-.12$ ). Results were inconsistent with respect to visual and verbal working memory in BED compared to obese controls in the presence of neutral stimuli (Kittel et al., 2015; Van den Eynde et al., 2011), though it was noted that more interference on the N-back was seen in BED compared to overweight controls in the context of food-related stimuli relative to neutral stimuli (Kittel et al., 2015).



The majority of studies discussed were cross-sectional group comparisons of currently ill patients with EDs, though three studies examined (1) individuals with AN before and after treatment and (2) individuals recovered from AN compared to controls, with findings indicating improvements in working memory after treatment and in recovered states (Brooks et al., 2017). In AN, working memory functioning was noted to be related to duration of illness, but was not consistently correlated with other measures of ED symptoms (Brooks et al., 2017). Taken together, thus far there is some evidence suggesting working memory deficits across EDs, yet there is substantial heterogeneity across studies with respect to the magnitude of deficits, types of measures, and stimuli, and few studies have examined the potential influence of other relevant factors such as illness duration, symptom severity, or co-occurring psychopathology.

### Decision Making

Decision making is a construct involving multiple processes including stimulus appraisal, action selection and execution, outcome evaluation, and preference formation (Ernst & Paulus, 2005). Two tasks that have been most commonly employed to examine decision making in EDs are the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994) and the Game of Dice Task (GDT; Brand et al., 2007). In the IGT, participants complete a series of trials involving selection of a card from one of four decks, two of which are disadvantageous (i.e., result in higher levels of net loss) and two of which are advantageous (i.e., result in lower levels of net loss). The IGT net score, calculated as the number of advantageous choices minus the number of disadvantageous choices, represents the index of decision making. In the GDT, decision making is indexed by the number of safe choices minus the number of risky choices.

Another common approach to investigating decision making in EDs has been the use of temporal or delay discounting tasks (see Odum, 2011), which are thought to assesses the capacity to delay gratification/receipt of reward. The general procedure involves participants completing a series of trials involving a selection between a larger reward provided following a variable delay versus a smaller reward provided immediately. Choosing the larger reward with a delay is considered reduced delay discounting, while picking the smaller reward with no delay is considered increased delay discounting. Monetary stimuli are most commonly employed in the task, although ED-related stimuli have been used as well. Performance on the task is most commonly reported as the discounting parameter  $k$  (see Odum, 2011).

Given that EDs are characterized by inconsistencies in goals and actions (e.g., engaging in binge eating despite a desire to lose or maintain weight) or persistence of actions despite evidence supporting the need for a modification (e.g., continued caloric restriction in the context of seriously low weight), decision making has been investigated across the range of ED psychopathology. Eleven systematic review and meta-analyses were identified in this domain, with the majority focused on comparisons of adults currently ill with an ED versus controls (see Table 6). All but two of these studies addressed AN, with BN and BED represented similarly across a smaller number of studies compared to AN. Comparison

groups varied depending on the ED diagnosis of primary interest, with overweight or obese controls often included in comparisons focused on BED.

Based on the reviews that focused primarily on studies using the IGT and GDT, converging evidence suggests that individuals ill with AN or BN demonstrate impairments compared to HC. In particular, meta-analyses evidenced significant effects that were medium to large (AN:  $g_s=.62-.74$ ,  $d_s=.57-.85$ ). Evidence for BED was more mixed, and dependent on the comparison group. Although a significant large effect ( $g=1.26$ ) was found for BED in one meta-analysis (Guillaume et al., 2015), the comparison condition was HC, while other reviews included overweight or obese control conditions and reported inconsistent findings. Notably, there were fewer reviews that focused on temporal/delay discounting, and the pattern of findings for these studies was more heterogeneous. Despite some evidence of potentially reduced discounting in AN (i.e., greater ability to delay reward), the reviews noted inconsistencies in the findings and the small existing literature. Similarly, while there was some evidence of greater discounting in BED (i.e., reduced ability to delay reward), the results were inconsistent depending on the weight-status of the comparison group (i.e., significant differences were less common with overweight or obese comparison groups). In the largest review to date (including studies utilizing the IGT, GDT, DDT, and other relevant tasks), Wu et al. (2016) reported a significant medium effect size for studies using non-food reward stimuli in tasks in comparing individuals with an ED versus controls ( $g=.49$ ); in contrast, the corresponding comparison for studies using food-related stimuli in tasks (although based on a much smaller number of studies) was not significant. With regard to specific ED diagnoses, Wu et al. reported significant medium effects for AN ( $g=.61$ ) and BN ( $g=.44$ ) for studies using non-food reward stimuli in tasks, but the corresponding effect was nonsignificant for BED ( $g=.17$ ).

Finally, a number of reviews addressed possible heterogeneity in effects. For instance, Wu et al., (2016) found significant effects for studies with adults, but not adolescents, although only three studies had adolescent ED samples. Wu et al. also reported significant variability of effect sizes across tasks. Notably, effect sizes for the two mostly commonly applied tasks (i.e., IGT and GDT) were significant, with a medium effect size found for studies using the IGT ( $g=-.51$ ) and a small effect size ( $g=-.26$ ) found for studies using the GDT. With regard to possible AN subtype differences, inconsistent findings were reported across reviews, although findings were generally consistent in suggesting non-significant differences across AN and BN. Further, although addressed in only a few reviews, evidence suggests that the impairments in those currently ill with an ED are either reduced or absent in samples that are recovered from an ED, suggesting that the deficits are related to aspects of the illness state (e.g., malnutrition).

#### 4. Discussion

Despite the expanding number of studies on neurocognitive functioning in EDs, significant methodological issues have emerged across this literature. In this section, we will address a number of these issues, which together limit the conclusions that can be drawn from this body of research, as well as highlight important areas to address in future research. It is also important to consider that the quality ratings applied in the present review of reviews reflect

additional methodological limitations in the way data were extracted and synthesized, which highlights areas to address in future systematic reviews of these domains. Specifically, reviews did not consistently employ duplicate study selection and data extraction procedures, consider unpublished “grey” literature, provide adequate information regarding excluded studies, or systematically assess and consider methodological quality of primary studies to inform conclusions, which together may introduce bias and contribute to discrepancies across this literature.

### Ten Key Areas to Address in Future Research

**Characterizing neurocognitive functioning across ED diagnoses.**—A limited number of studies have examined neurocognitive functioning across the full spectrum of ED psychopathology. While existing research on inhibitory control has primarily focused on EDs characterized by binge eating, the literature on set-shifting and central coherence research has generally focused on AN samples, and attention bias and decision making studies have been more equally distributed across ED diagnoses. Furthermore, findings thus far have not demonstrated consistent differences between ED diagnoses in the extent of these deficits. While some researchers have suggested neurocognitive endophenotypes may exist across disease states in AN based on set-shifting and central coherence (e.g., Holliday et al., 2005; Lopez et al., 2009; Kanakam & Treasure, 2013), recent research has challenged such conclusions (Talbot, Hay, Buckett, & Touyz, 2015), and evidence remains inconclusive regarding the presence of such endophenotypes in BN or BED. It also has yet to be determined whether neurocognitive task performance can accurately characterize symptom heterogeneity across EDs during acute illness, such as whether restricting-type and bulimic-spectrum EDs lie on an inhibition-disinhibition spectrum. Thus, future research in larger, heterogenous ED samples across illness stages is needed to address these issues.

**Possible confounding influences in research design.**—The majority of research has not taken into account possible confounds that may influence neurocognitive functioning. Most notably, studies have not utilized psychiatric controls, and few have covaried for non-ED psychopathology (e.g., depression, anxiety), which precludes examination of the specificity of observed deficits. Given the well-documented finding that altered functioning in many of these neurocognitive domains are associated with psychopathology (e.g., Snyder, Miyake, & Hankin, 2015), it is not clear whether the observed deficits are specific to EDs versus broader transdiagnostic factors. In addition, few data exist regarding the degree to which malnutrition and weight status influence neurocognitive functioning in EDs. Relatedly, extant evidence is inconclusive as to whether BED status exacerbates inhibitory control and decision making deficits in the context of overweight or obesity, and studies of BED have not consistently accounted for weight status. Furthermore, many studies do not report whether or not participants were receiving psychotropic medications during the study, which could influence performance on neurocognitive tasks.

It is also possible that deficits (e.g., set-shifting, decision making) are associated with duration of illness and/or age, though little research has addressed these issues or their relevance to risk and maintenance models. For instance, age is particularly important to consider given that EDs typically onset during adolescence and young adulthood (Schmidt et

al., 2016). Adolescence is an especially important period for neurodevelopment, particularly in terms of frontal regions involved in executive functions and frontolimbic connectivity underlying evaluation of, and responses to, risk and reward, as well as emotion regulation (Steinberg, 2005). Furthermore, while the course of adolescence is generally characterized by improvements in executive functions (Crone, 2009), their development continues into late adolescence and occurs alongside physical, social, and emotional changes, which in turn modulate cognitive processes (Crone, 2009; Steinberg, 2005). Consequently, during adolescence there are potential risks for imbalances between motivational drives and cognitive control, which may promote self-regulation difficulties and various forms of psychopathology (Steinberg, 2005). Therefore, executive functioning deficits will be imperative to consider in ED risk models. For instance, Kaye and colleagues' (2009) previously outlined a developmental model of AN describing the multiple influences of temperament, neurobiological factors, and psychosocial processes that potentiate AN onset. In sum, additional work is needed that assesses relevant covariates, examines neurocognitive processes as risk factors across the spectrum of ED psychopathology, and the extent to which such deficits *interact* with other relevant developmental factors during adolescence (e.g., sociocultural influences, emotional functioning) to potentiate the development of EDs versus other forms of psychopathology.

**Tasks and procedural stimuli.**—Another methodological limitation of this literature pertains to task purity and variability, as well as the nature of stimuli. While the domains discussed in this review are multi-dimensional constructs, studies have typically only used one task to assess a given neurocognitive domain. Furthermore, some tasks are more complex than others and tap multiple cognitive capabilities (e.g., Stroop, WCST), and the nature of certain tasks complicates the determination of which processes underlie the observed effects. There is also wide variability in the type of tasks used across studies, as well as inconsistent reporting of task indices.

With respect to stimuli, increasing evidence suggests that some deficits are particularly salient in the context of disorder-specific stimuli, which also may differ according to ED diagnosis. For example, based on existing data from BN and BED samples, it appears inhibitory control deficits are most pronounced, or only observed, in the presence of disorder-specific stimuli (i.e., food/shape/weight-related), and it is unclear whether AB are specific to ED-relevant stimulus categories (e.g., body images), or, alternately, whether they reflect more general processing differences. Thus it remains to be determined whether impairments in such domains are context-specific or more extensive in nature. Taken together, careful consideration of task specificity, standardized approaches to reporting results, and systematic comparisons of stimuli categories are needed.

**Neurocognitive functioning: a stable trait or variable state?**—To date, most studies have utilized cross-sectional designs and have conceptualized these areas of neurocognitive functioning as trait-like constructs. Emerging ecological momentary assessment (EMA) research suggests some domains such as inhibitory control vary within persons without EDs (e.g., Powell, McMinn, & Allan, 2017), and thus could be state-dependent, and recent progress has been made in adapting cognitive tasks for mobile

assessment (e.g., Moore, Swendsen, & Depp, 2017; Sliwinski et al., 2018). In EDs, it is yet unclear to what extent these neurocognitive abilities fluctuate within persons and how state neurocognitive deficits may maintain ED behaviors. Incorporating neurocognitive assessments in EMA protocols could provide insights into whether deficits reflect state or trait phenomena, identify momentary antecedents and consequences (e.g., affect, restraint, ED behaviors) of fluctuations in cognitive functioning, as well as explore between-person differences in cognitive functioning.

In addition to the need for *intensive* longitudinal designs (i.e., EMA) to examine momentary processes, the lack of longitudinal studies precludes inferences regarding directionality as to whether neurocognitive deficits are a risk factor for, or consequence of EDs. Extant evidence regarding the persistence of neurocognitive deficits into recovery remains inconsistent and inconclusive. Thus, longitudinal research is needed to clarify whether specific neurocognitive deficits reflect endophenotypes that begin prior to the illness and persist after recovery, start with the onset of the illness and improve with symptom reduction, or might be best viewed as scars of the illness that begin with the onset of the illness, but persist after recovery. Given the methodological difficulties associated with longitudinal studies, one promising option to address such obstacles going forward is by harnessing the advantages of ambulatory and web-based neurocognitive assessment methods that are more easily accessible to participants (e.g., Hansen, Haferstrom, Brunner, Lehn, & Håberg, 2015; Morrison, Simone, Ng, & Hardy, 2015; Sliwinski et al., 2018).

**Neurocognitive interventions.**—A substantial body of research in other areas of psychopathology has demonstrated potential for cognitive training approaches (e.g., Koster, Hoorelbeke, Onraedt, Owens, & Derakshan, 2017; Linetzký, Pergamin-Hight, Pine, & Bar-Haim, 2015; Wykes, Huddy, Cellard, McGurk, & Czobor, 2011). Despite the broad pattern of deficits noted in this review there is comparatively limited research in EDs focused on cognitive training and examining the effectiveness of such treatments. While emerging theory and empirical evidence suggests various neurocognitive processes may be modifiable through interventions (e.g., Boutelle, Monreal, Strong, & Amir, 2016; Eichen, Matheson, Appleton-Knapp, & Boutelle, 2017; Jones et al., 2016; Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013; Tchanturia et al., 2014), much of this research in EDs is preliminary and has been limited to small samples. For example, initial findings suggest that attention bias modification (ABM) may lead to improvements in binge eating and other ED symptoms (Boutelle et al., 2016), and a recent meta-analysis demonstrated that single-session inhibitory control training (ICT) led to significant decreases in food and alcohol choices or consumption in a laboratory study (Jones et al., 2016). With respect to interventions targeting cognitive flexibility, one systematic review of cognitive remediation therapy for AN (CRT-AN) concluded that CRT-AN led to improvements in set-shifting, though some studies found that neurocognitive improvements were not significantly greater than those observed in other treatment groups (Tchanturia et al., 2014), which suggests that additional work is needed to clarify the specificity of effects observed in CRT-AN. Investigations should also examine whether such interventions are best applied as a stand-alone intervention or an augment to existing treatments, and evaluate possible mechanisms of change. Thus far, studies also have yet to determine whether improving specific

neurocognitive abilities translates into behavioral changes in daily life, which would be well-suited to address with EMA. In sum, while initial cognitive training interventions have shown promise in targeting and improving functioning in some domains, there is a need for larger samples and longer follow-up periods to assess the durability and generalizability of effects, as well as the optimal therapeutic doses of training.

**Relationships between neurocognitive domains.**—Notably, studies have typically evaluated specific neurocognitive domains in isolation from others and have not considered how associations or interactions *between* neurocognitive processes may relate to ED symptomatology. All of the domains discussed in the present review fall under a larger “umbrella” of executive functioning, which are multifaceted and interrelated domains that together influence goal-directed behavior and self-regulation (Diamond, 2013). For example, evidence from basic vision science research has shown that holding a particular object or feature in working memory biases attention towards matching objects in the environment (e.g., Soto, Heinke, Humphreys, & Blanco, 2005). This raises the possibility that attention bias towards disorder salient information in EDs may be mediated by the storage of ED-relevant (e.g., shape or food-related) information in working memory; in turn, preoccupation with food, shape- or weight-related cognitions could increase attention towards similar cues in the environment in a self-perpetuating cycle (Higgs, 2016). Thus, in the context of EDs, deficient cognitive inhibition may serve to increase processing of salient emotional or ED-related information in working memory and lead to subsequent negative affect. Similarly, weak central coherence and difficulties with set-shifting (i.e., cognitive inflexibility) may be related to and/or exacerbate attention bias, such that individuals with high levels of attention bias may have difficulties shifting attention away from ED-related stimuli. With respect to behavioral inhibition, difficulties holding task-relevant information in working memory may also interfere with one’s ability to inhibit impulsive or prepotent responses. Taken together, further study is needed to elucidate how neurocognitive domains may interact with each other, as deficits in different domains may have interactive or synergistic effects that potentiate ED symptoms.

**Relationships between neurocognitive domains and other relevant constructs.**—Limited data exists regarding how these neurocognitive domains may interact with other factors known to influence eating behaviors (e.g., reward sensitivity, dietary restraint, affect). As one example, negative affectivity and emotion dysregulation have been implicated in the onset and maintenance of ED behaviors across diagnoses (e.g., Lavender et al., 2015; Stice, 2001), and outside of EDs, substantial research has demonstrated that neurocognitive processes are related to emotion in a variety of ways (Okon-Singer et al., 2015). However, these relationships have yet to be elucidated in EDs. As outlined in a well-supported model of cognitive control of emotion, neurocognitive processes play a role in each stage of emotion generation and regulation via the processes of perception, attention deployment, stimulus appraisal, and response modulation (Ochsner et al., 2012). In addition, the multidimensional model of emotion regulation (Gratz & Roemer, 2004) outlines several dimensions of emotion regulation that are implicitly related to neurocognitive processes (e.g., inhibitory control). Within these frameworks, attention and

cognitive control functions are particularly relevant constructs, all of which exhibit altered functioning in EDs based on the aforementioned evidence.

For example, regarding attention bias, the ability to effectively modulate attention is closely tied to emotion regulation and cognitive control processes, specifically the ability to filter or gate information in working memory. Attentional focus is determined by a combination of automatic, bottom-up, stimulus-driven (i.e., exogenous) and deliberate (i.e., endogenous) attention processes (Egeth & Yantis, 1997). Emotionally salient cues and information are thought to “grab” exogenous attention and are thus more likely to enter working memory; conversely, emotional states guide attention towards mood-congruent cues. Once in working memory, emotional information “hijacks” endogenous attention and interferes with cognitive control processes. In turn, difficulties with working memory filtering result in increased processing of emotionally salient information, and subsequent elevation or maintenance of negative affect (Okon-Singer et al., 2015). Additionally, while attentional processes may be involved in the generation and intensification of emotion, deliberate attention deployment or redirection also has a regulating effect on emotion, in that shifting attention away from emotional cues can alter one’s emotional response by reducing processing of such information (Okon-Singer et al., 2015).

In addition to attention bias, the ability to maintain regulatory goals and inhibit irrelevant stimuli (i.e., cognitive inhibition) in working memory is also related to the ability to modulate input from emotional systems and engage in emotion regulation strategies (e.g., cognitive re-appraisal; Rolls, 2013). Further, response inhibition is a salient component of the emotion regulation dimensions involving behavioral control in the context of negative emotion (Gratz & Roemer, 2004), whereas cognitive flexibility (related to set shifting) is important to the flexible and situationally appropriate application of emotion regulation strategies (Gratz & Roemer, 2004). While we highlighted the need for assessment and analysis of emotion-cognition relationships to provide an example for future research directions, we also believe that it will be important for future studies to consider interactions between cognitive control and other domains that are relevant to EDs, particularly habit and reward processes, in light of growing neurobiological evidence implicating these processes (Frank, 2015; Steinglass & Walsh, 2016; Wierenga et al., 2014a).

**Integrative assessment and analytic approaches.**—In light of the aforementioned issues, future research must adopt innovative, multimethod assessment approaches to clarify findings, lend insights into mechanisms underlying neurocognitive deficits in EDs, and elucidate the functional significance of these deficits. For example, intensive longitudinal designs that integrate *momentary* assessments of cognition, affect, and behavior would be ideally suited to elucidate within-person mechanisms that potentiate ED behaviors. With respect to neuroimaging research, promising directions for future research may include examining neural activation during neurocognitive tasks across distinct conditions (e.g., neutral versus negative affect induction), as well as the adoption of network perspectives and analytic approaches that can evaluate temporally related activations both within and between functionally related brain regions (e.g., dynamic functional connectivity). It will also be necessary to assess whether neurocognitive deficits and functional brain abnormalities

assessed in laboratory settings predict behavioral phenomena in daily life, as recently demonstrated by integrated EMA-fMRI research by Fischer and colleagues (2017).

Notably, task performance may not always serve as accurate indicators of aberrant neural functioning, as some research has reported differences in brain activation despite a lack of behavioral differences in task performance (e.g., Oberndorfer et al., 2011; Wierenga et al., 2014b), which may contribute to divergent findings in the literature. In addition, some have suggested that while deficits in some domains (e.g., decision making) may be observed across EDs, the specific neural mechanisms underlying altered task performance may differ across diagnoses (e.g., Guillame et al., 2015). Thus, further functional neuroimaging studies domains may provide meaningful information that is not possible to obtain from behavioral data alone, and may elucidate the extent to which neural circuitry underlying various tasks and domains converge.

**Transdiagnostic and dimensional perspectives.**—The majority of existing relevant research has assessed neurocognitive functioning between categories based on ED diagnosis or weight status. Consistent with the objectives of the National Institute of Mental Health Research Domain Criteria (RDoC) initiative, assessing ED psychopathology in dimensional terms (e.g., bulimic-spectrum) could help clarify whether deficits are specific to *diagnostic categories*, or rather correspond to *types and levels* of particular symptoms. Within EDs, studying mixed ED samples and employing empirical classification approaches (e.g., latent profile analysis) could also elucidate possible distinct neurocognitive subtypes across EDs and/or patterns of neurocognitive deficits that may differentiate broad symptom patterns, such as bulimic-spectrum and restricting-type EDs.

Notably, an extensive body of research has documented executive functioning problems across psychopathology (Goschke, 2014; McTeague, Goodkind, & Etkin, 2016; Snyder et al., 2015), yet this body of research has not received sufficient consideration in studies of neurocognition in EDs. As previously described, emotional processes are known to influence neurocognitive functioning, and notably, EDs commonly co-occur with mood and anxiety disorders (Hudson, Hiripi, Pope, & Kessler, 2007). Given that few studies in the existing neurocognitive task literature have controlled for other psychiatric symptoms, it is unclear to what degree the observed neurocognitive deficits are related to common impairments across psychopathology or specific to EDs. Thus, transdiagnostic studies that include samples of both ED groups and psychiatric controls could begin to address this question and help to understand common and specific neurocognitive impairments across psychopathology.

**Integrative theory.**—Despite a large body of research indicating neurocognitive deficits in EDs and across psychopathology, there are relatively few well-articulated and integrative models of how neurocognitive processes interact with other processes to influence EDs, and none have considered the role of co-occurring psychopathology. Aspen et al. (2013) proposed a model in which cognitive vulnerabilities (i.e., genetic predispositions, executive functioning deficits, and cognitive inefficiencies) predispose individuals to exhibit attention bias in the context of ED-relevant stimuli, which in turn leads to negative affect and ED behaviors. Another recent review synthesized literature across neuroimaging, neurocognitive, and animal studies in BED to provide a cohesive account of the possible



neuropathophysiology of this disorder (Kessler, Hutson, Herman, & Potenza, 2016). In brief, this model suggested that BED is characterized by alterations in circuits implicated in inhibitory control, reward and motivation, and habitual behavior; however, the authors also note several other domains to examine in future studies, including neurobiological investigations of the role of stress and emotion regulation in BED (Kessler et al., 2016). Taken together, both developing and empirically testing such integrative theories would be important directions for future research in EDs, as doing so could lead to more parsimonious models and mechanism-focused treatments.

## Conclusions

In summary, there is an extensive and ever-growing body of literature examining neurocognitive functioning in EDs, as reflected by the publication of 28 identified *review* articles since 2010 alone. While these reviews have broadly suggested EDs are associated with a range of neurocognitive deficits, there remain critical limitations regarding the methodological quality and design of these studies and reviews, most of which have relied on cross-sectional comparisons of ED samples to HC. Although several of these limitations and methodological issues have been noted in prior work (e.g., ecological validity, prospective assessment, influence of emotion), these issues remain unaddressed in the majority of studies conducted. Together these limitations preclude our ability to make definitive conclusions regarding the role of neurocognitive deficits in the etiology and maintenance of EDs, or to move our field forward in the development of integrative models and more effective interventions. In the present review, we have identified and described ten areas that we believe are imperative to address in future research, which will serve to provide a more nuanced understanding of the nature and specificity of neurocognitive deficits in EDs.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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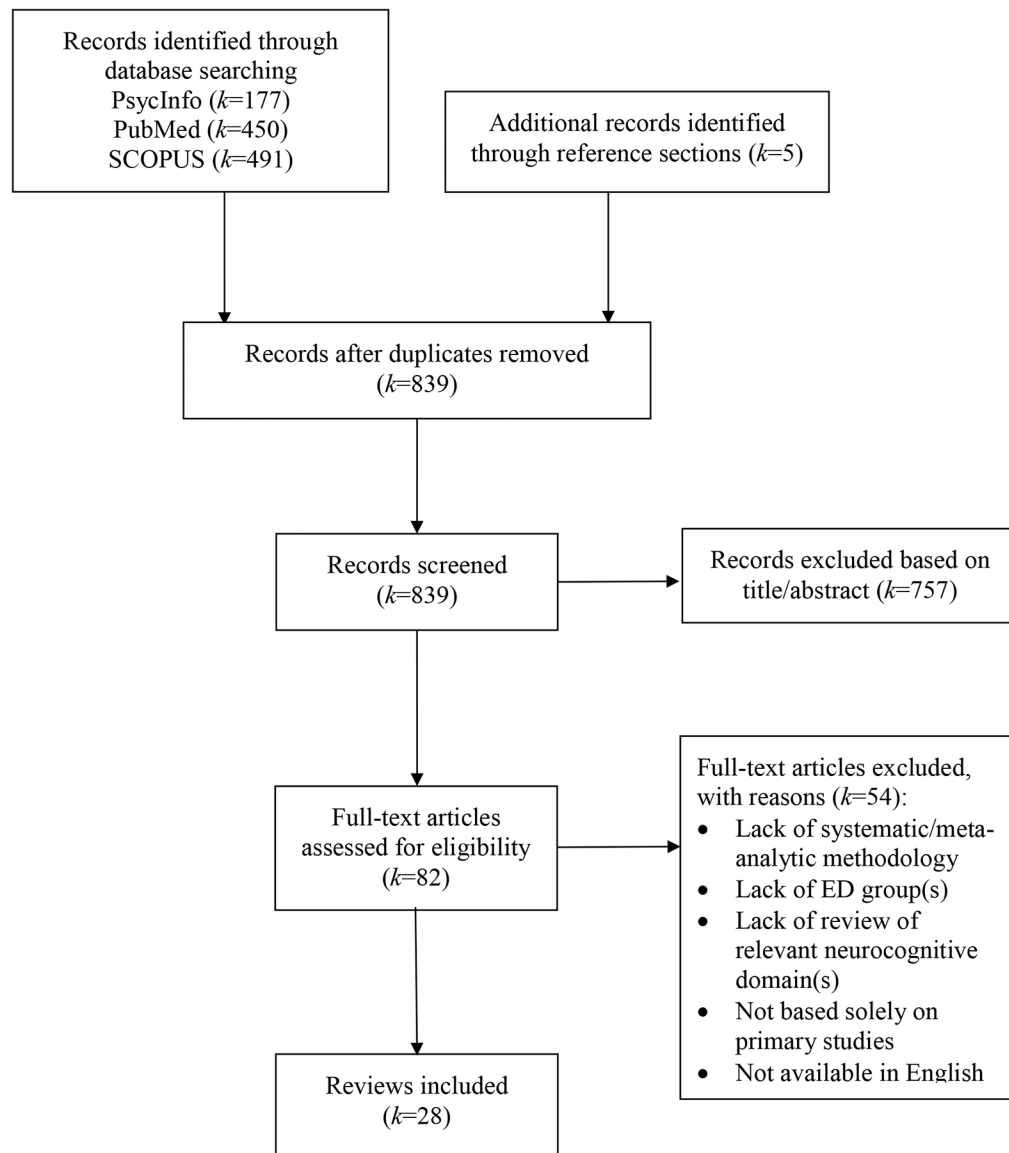
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**Figure 1.**  
PRISMA flow diagram of study selection.



Table 1

## Summary of reviews of inhibitory control in EDs (2010–2018)

Review	Method	No. of included studies ( <i>k</i> )	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <sup>1</sup>	Key findings and effect sizes
Bartholdy et al. (2016)	Systematic review	8	Adults ( <i>k</i> =7) and adolescents ( <i>k</i> =1)	AN-R, AN-BP, AN-rec, BN, BED, EDNOS	HC	SST	N.S.	5/9	<ul style="list-style-type: none"> <li>5/8 studies found no differences in SSRT, MRT, and/or accuracy.</li> <li>3 studies reported higher SSRT in ED groups (AN, BN, BED).</li> <li>No differences were found in MRT.</li> <li>SSRT positively correlated with ED severity and BMI in BED but not AN or BN groups.</li> </ul>
Giel et al. (2017)	Systematic review	7	Adults ( <i>k</i> =6) and adolescents ( <i>k</i> =1)	BED, OB/BED	OBC, NWC	Go/No-go, SST, anti-saccade tasks	Food-specific and neutral	4/9	<ul style="list-style-type: none"> <li>4/5 studies found adult BED groups showed lower IC in the context of food stimuli compared to OBC and NWC.</li> <li>Food-specific IC deficits were found in 1 study of OB/BED children.</li> <li>1 study of mixed OB/BED adults found no differences compared to NWC.</li> </ul>
Jáuregui-Lobera (2013)	Systematic review	N.S.	Adults	BN, EDNOS-BN	HC	Go/No-go	Food-specific and neutral	4/9	<ul style="list-style-type: none"> <li>1 of 2 studies found a BN group demonstrated poorer IC than HC especially in the context of food stimuli.</li> </ul>
Kittel et al. (2015)	Systematic review	8	N.S.	BED	OBC and NWC	Go/No-go, SST, Stroop, R5CSRT, CCPT	Food/body-related and neutral	3/9	<ul style="list-style-type: none"> <li>6 studies found no differences between BED and OBC/NWC for neutral stimuli.</li> </ul>

Review	Method	No. of included studies (k)	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <i>I</i>	Key findings and effect sizes
Lavagnino et al. (2016)	Systematic review & meta-analysis	7	Adults	OB/BED	OBC and NWC	SST, Stroop, Go/No-Go <sup>2</sup>	Food-specific and neutral	7/11	<ul style="list-style-type: none"> <li>2 studies found lower IC in BED compared to OBC/NWC groups for food/body stimuli compared to neutral stimuli.</li> <li>3/7 studies found lower IC in OB/BED compared to OBC groups.</li> <li>A meta-analysis of 3 studies indicated OB/BED and OBC groups did not differ on SSRT (Standardized Mean Difference= .05).</li> </ul>
Schag et al. (2013)	Systematic review	2	Adults	OB/BED	OBC and NWC	Go/No-go	Food/body-related and neutral	3/9	<ul style="list-style-type: none"> <li>1 study found no differences between OB/BED and NWC groups, but more commission errors and lower RT for food stimuli in both groups.</li> <li>1 study found more errors in inhibiting food/body stimuli on Go/No-go task in BED compared to OBC and NWC groups.</li> </ul>
Van den Eynde et al. (2011)	Systematic review	16	Adults and adolescents	BN, BED	HC	Stroop, Go/No-Go, MFFT, HSCT, modified ELF	Neutral	5/9	<ul style="list-style-type: none"> <li>7/12 studies found no Stroop interference effect in BN/BED compared to HC.</li> <li>1 of 2 studies found more commission errors on Go/No-Go in BN than HC.</li> <li>BN showed more impairment than HC on HSCT and modified ELF (<i>k</i>=1).</li> </ul>

Review	Method	No. of included studies (k)	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <sup>1</sup>	Key findings and effect sizes
Wu et al. (2013)	Systematic review and meta-analysis	36	Adult (k=34) and adolescent (k=2); Neutral stimuli: M=26.4 yrs, 16–40; ED stimuli: M=25.5 yrs; 19–27)	AN-BP, BN, BED, HC	HC	SST, Go/No-Go, Stroop, MFFT, HSCT, SST, ELF	Food/body-related and neutral	9/11	<ul style="list-style-type: none"> <li>Inconsistent results on MFFT (k=2).</li> <li>Decreased IC was found in bulimic-type ED compared to HC groups (<math>g=-.32</math>).</li> <li>AN-BP groups evidenced the largest magnitude of deficits (<math>g=-.91</math>), followed by BN (<math>g=-.26</math>); no significant difference was found between BED and HC groups (<math>g=-.16</math>).</li> <li>Greater deficits were observed for food/body-related stimuli in BN compared to HC groups (<math>g=-.61-.67</math>).</li> </ul>
Zakzanis et al. (2010)	Meta-analysis	AN: 6 BN: 5	AN: 23.60±3.68 yrs (14–29) BN: 23.74±2.70 yrs (19–28)	AN, BN, HC	HC	SST, Go/No-Go, Stroop	N.S.	4/11	<ul style="list-style-type: none"> <li>AN and BN groups evidenced lower IC compared to HC (AN: <math>d=.34</math>; BN: <math>d=.43</math>).</li> </ul>

Note. ED=eating disorder; IC=inhibitory control; AN=anorexia nervosa; ANrec=Recovered anorexia nervosa; AN-R=AN-restricting subtype; AN-BP=AN binge-purge subtype; AN-P=AN purging subtype; BN=bulimia nervosa; BED=binge eating disorder; EDNOS=eating disorder not otherwise specified; HC=healthy control; OBC=obese control; OWC=overweight control; NWC=normal weight control; N.S.=not specified; SST=stop signal task; SSRT=stop signal task; SSRT=stop signal task; MRT=mean reaction time; HSCT=Hayling Sentence Completion Test; MFFT=Matching Familiar Figure Test; SSIT=Simon Spatial Incompatibility Task; ELF=Excluded Letter Frequency test.

<sup>1</sup> Quality scores for systematic reviews are based on a total possible score of 9; scores for meta-analyses are based on a total possible score of 11.

<sup>2</sup> Studies assessing inhibitory control using the delay discounting task were excluded from the summary.

Table 2

## Summary of reviews of set-shifting in EDs (2010–2018)

Review	Method	No. of included studies ( <i>k</i> )	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <sup>1</sup>	Key findings and effect sizes
Abbate-Daga et al. (2015)	Systematic review	16	Adolescents and adults	AN	HC	WCST, TMT A and B, Brixton Test	Neutral	4/9	<ul style="list-style-type: none"> <li>67% (<i>k</i> = 29) of studies found differences between AN and controls.</li> <li>In 4 of 5 studies, differences in set-shifting between individuals with AN and controls remained after co-varying for depressive symptoms.</li> <li>2 of 16 studies found a significant positive correlation between depressive symptoms and poor set-shifting.</li> </ul>
Hirst et al. (2017)	Meta-analysis	28	Adults and adolescents	AN; BN	HC	WCST, TMT, Brixton	Neutral	7/11	<ul style="list-style-type: none"> <li>No differences between AN and HC on the WCST Correct Responses (<math>z=1.60</math>) or the Brixton Spatial Anticipation Task (<math>z=-0.88</math>); both tasks demonstrated significant heterogeneity.</li> <li>AN performed worse on WCST Failure to Maintain Set (<math>g=-.28</math>).</li> <li>BN performed worse than HC on the TMT B (<math>g=-.57</math>), WCST non-perseverative errors (<math>g=-.61</math>), and WCST perseverative errors (<math>g=-.80</math>).</li> </ul>
Jáuregui-Lobera (2013)	Systematic review	57	Adults and adolescents	AN; BN	HC	TMT	Neutral	4/9	<ul style="list-style-type: none"> <li>Some studies reviewed showed deficits in set-shifting among women with AN and BN.</li> <li>Evidence suggests that set shifting impairment in AN is unrelated to polymorphisms of the SNAP-25 gene.</li> <li>Set shifting impairments have not been found in adolescent patients with AN.</li> <li>Research shows that both AN patients and recovered AN patients demonstrate deficits in set shifting.</li> </ul>
Kittel, Brauhardt, & Hilbert (2015)	Systematic review	4	Adults	BED	OBC; OWC; NWC	TMT, Rule Shift Cards Test, WCST	Neutral	3/9	<ul style="list-style-type: none"> <li>In one of three studies using the TMT, set-shifting was impaired in BED compared to OW/OB controls.</li> </ul>

Review	Method	No. of included studies ( <i>k</i> )	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <sup>1</sup>	Key findings and effect sizes
Lang, Stahl, Espie, Treasure, Tchanturia (2014)	Systematic review and meta-analysis	9	Children and adolescents	AN	HC	WCST, TMT, Brixton Task, IED, Color-Word Interference Test, Verbal Fluency Test, Groton-Maze Learning Task, Switching of Attention Test, The Category Learning Task, Visual Set-Shifting Task	Neutral	5/11	<ul style="list-style-type: none"> <li>Individuals with co-occurring obesity and BED did not differ from OB controls on the Rule Shift-Cards Test, but they did differ on the WCST.</li> <li>Another study found no difference on the WCST between individuals with BED and normal weight controls.</li> <li>Meta-analytic effect sizes comparing AN vs. controls on WCST (<math>d=-.20</math>) and TMT (<math>d=-.005</math>) were non-significant.</li> <li>In the systematic review, one study found a significant difference on the Groton-Maze Learning Task and one study found a significant difference on the Brixton Task.</li> <li>Impaired set-shifting in AN independent of disease stage</li> <li>Impairments exist in sisters who are discordant for an eating disorder.</li> <li>Decreased activation of frontostriatal circuits (e.g., ventral striatum, anterior cingulate cortex, and supplementary motor area) may underlie deficits in set-shifting</li> </ul>
Reville, O'Connor, & Frampton (2016)	Systematic review	9	Adults and adolescents	AN	HC	WCST	Neutral	5/9	<ul style="list-style-type: none"> <li>Studies suggest that current and recovered patients with AN perform worse than HC.</li> <li>Duration of illness is related to deficits in set-shifting.</li> <li>Set-shifting is worse in AN-R compared to AN-BP.</li> </ul>
Stedal, Frampton, Landro, & Lask (2015)	Meta-analysis	11	Adults and adolescents	AN	HC	TMT	Neutral	5/11	<ul style="list-style-type: none"> <li>AN performed worse on the TMT switching task compared to HC (<math>d=-.49</math>).</li> </ul>
Van Aultreue & Vervaeke (2015)	Systematic review	8	Adults and adolescents	AN	HC	WCST, TMT, Brixton Task, Intra/Extra Dimensional Set Shift Subtest, Verbal Fluency Test, Haptic Illusion, Picture Set Test, Cat Bat Test,	Neutral	3/9	<ul style="list-style-type: none"> <li>6 of 8 studies found no differences between AN-BP and AN-R on set-shifting.</li> </ul>

Review	Method	No. of included studies ( <i>k</i> )	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <sup>1</sup>	Key findings and effect sizes
Van den Eynde et al. (2011)	Systematic review	6 (card sorting paradigm); 6 (TMT); 2 (Haptic Illusion); 1 (CATBAT; Picture Set Test)	Adults and adolescents	BN; BED	HC	Adapted Task Switching Paradigm WCST, TMT Brixton, Haptic Illusion task, Cat Bat, Picture Set Test	Neutral	5/9	<ul style="list-style-type: none"> <li>2 of 8 studies found poorer set-shifting in AN-BP compared to AN-R.</li> <li>In studies using the WCST, two studies found that set-shifting was impaired in BN/BED compared to HC and two found no differences</li> <li>No differences between BN/BED and HC on Brixton.</li> <li>There are mixed findings regarding whether individuals with BN/NED perform worse on the TMT.</li> <li>Those with BN performed worse than HC on the Haptic Illusion task, CATBAT, and Picture Set Test.</li> </ul>
Westwood, Stahl, Mandy, & Tchanturia (2016)	Meta-analysis	22	Adults, children, and adolescents	AN	HC, ASD	WCST	Neutral	8/11	<ul style="list-style-type: none"> <li>Significant difference between AN and HC on WCST (<math>d=-.43</math>); only significant for adult samples when adults (<math>d=-.49</math>) and children (<math>d=-.25</math>) were analyzed separately.</li> <li>No significant differences between AN and ASD on WCST (<math>p=.27</math>); marginally significant effect (<math>p=.053</math>) for children samples when adults and children were analyzed separately (ASD worse than AN).</li> </ul>
Wu et al. (2014)	Meta-analysis	64	Adults and adolescents	AN; BN; BED	HC	Probabilistic Object Reversal Task, Rule Shift Cards Test, Berg's Card Sorting Test, Brixton Task, Cognitive-behavioural flexibility task, Category Learning Test, Uznadze haptic illusion test, Intra-Dimensional/Extra-Dimensional, Nelson's Card Sorting Test, Picture Set Test, Set-Shifting Test, TMT, Verbal Fluency Test, WCST, Weigl's Sorting Test.	Neutral	9/11	<ul style="list-style-type: none"> <li>Poor set-shifting across the full spectrum of EDs, compared to controls, with small to medium effect sizes (<math>g_s=-0.44</math> for AN, <math>-0.53</math> for BED, <math>-0.50</math> for BN), except in individuals with AN-BP (<math>g_s=-.18</math>).</li> <li>Effect sizes were comparable for adolescent and adult samples with AN; conclusions cannot be made regarding differences in set-shifting between adolescents and adults with other EDs as only one study investigated adolescents with BN (no significant differences) and no study has looked at adolescents with BED.</li> </ul>

Review	Method	No. of included studies ( <i>k</i> )	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <sup>1</sup>	Key findings and effect sizes
Zakzanis et al (2010)	Meta-analysis	15 (AN); 6 (BN)	Adults	AN; BN	HC	Brixton Task; Controlled Oral Word Association Test, TMT-B; WCST; Weigl's sorting	Neutral	4/11	<ul style="list-style-type: none"> <li>Deficits in the psychomotor facet of set-shifting had the greatest effect size (<math>g=-1.02</math>)</li> <li>ED subtypes (i.e., AN, BN, and BED) did not significantly differ from one another in set-shifting.</li> <li>Poorer set-shifting was found in AN compared to HC (<math>d=.35</math>), but not BN compared to HC (<math>d=.16</math>).</li> </ul>

Note. ED=eating disorder; AN=anorexia nervosa; AN-R=AN-restricting subtype; AN-BP=AN binge-purge subtype; AN-P=AN purging subtype; BN=bulimia nervosa; BED=binge eating disorder; EDNOS=eating disorder not otherwise specified; HC=healthy control; OBC=obese control; OWC=overweight control; NWC=normal weight control; ASD=Autism Spectrum Disorder group; WCST=Wisconsin Card Sorting Test; Trail Making Task; IED= Intra/Extra Dimensional Set Shift test.

<sup>1</sup>Quality scores for systematic reviews are based on a total possible score of 9; scores for meta-analyses are based on a total possible score of 11.

**Table 3**

Summary of reviews of central coherence in EDs (2010–2018)

Review	Method	No. of included studies (k)	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score /	Key findings and effect sizes
Abbate-Daga et al. (2015)	Systematic review	20	Adults	AN	HC	ROFT	N.S.	4/9	<ul style="list-style-type: none"> <li>15/20 studies found AN differed from HC.</li> <li>Depression did not account for these group differences.</li> </ul>
Hirst et al. (2017)	Meta-analysis	3	Adults and adolescents	AN	HC	ROFT	N.S.	7/11	<ul style="list-style-type: none"> <li>Meta analytic results comparing AN and healthy controls reveal significant differences with AN participants displaying poorer central coherence on the central coherence index of the ROFT (<math>d = -.49</math>).</li> </ul>
Lang & Tchanturia (2014)	Systematic review	7	Adults and adolescents	AN	HC	ROFT, OA, OFT	N.S.	4/9	<ul style="list-style-type: none"> <li>4/4 studies using Booth's central coherence index found AN to have weaker central coherence with a less globally oriented processing style, but no differences in accuracy.</li> <li>The remaining 3 studies also revealed less</li> </ul>



Review	Method	No. of included studies ( <i>k</i> )	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score	Key findings and effect sizes
Lang et al. (2014)	Systematic review and meta-analysis	19	Adults	AN, BN, ED-rec, AN-rec	HC	ROFT, OA, OFT, FPT, GEFT	N.S.	5/11	Evidence of poor central coherence, across several measures, in individuals with AN compared to healthy controls ( $d = -.58$ to $d = -.65$ ).  • Smaller effect sizes for comparisons of individuals with BN to healthy controls ( $d = -.028$ to $d = -.084$ ).
Madsen et al. (2013)	Systematic review	26	Adults and adolescents	AN	HC	ROFT, GEFT, MFFT	N.S.	2/9	• AN characterized by weaker central coherence, over-attention to detail and reduced processing of global features.
Reville et al. (2016)	Systematic review	1	N.S.	AN	HC, non-affected Sisters	N.S.	N.S.	5/9	• AN characterized by reduced central coherence and greater attention to detail. This trait appears related to

Review	Method	No. of included studies (k)	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score	Key findings and effect sizes
Stedal et al. (2012)	Meta-analysis	9	N.S.	AN	HC	ROFT	N.S.	5/11	Recall condition of ROFT revealed poorer performance in patients than controls, suggesting evidence of a detail focused style ( $d=-.68$ ).  • One study with a central coherence index reported similar findings.
Van Aultreuve & Vervaeke (2015)	Systematic review	4	Adults	AN-R AN-BP	HC	MFFT, FPT, OA, ROFT, GEFT, BDT	N.S.	3/9	• AN participants display poor central coherence, but subtype differences in AN not clearly identified.
Van den Eynde et al. (2011)	Systematic review	1	Adults	BN	HC	ROFT, GEFT, BDT	N.S.	5/9	• Only one study rigorously examined central coherence with evidence suggesting BN < HC on central coherence.

Note. ED=eating disorder; AN= Anorexia Nervosa; BN= Bulimia Nervosa; AN-R= Anorexia Nervosa-Restricting Type; AN-BP= Anorexia Nervosa-Binge Purge Type; ED-rec=recovered from ED; AN-rec=recovered from AN; HC= Healthy Controls; ROFT= Rey Osterreith Complex Figures Test; OA= Object Assembly; OFT= Overlapping Figures Test; PPT= Fragmented Pictures Test; GEFT= Group Embedded Figures Test; MFFT= Matching Familiar Figure Test; BDT= Block Design Test.

<sup>1</sup> Quality scores for systematic reviews are based on a total possible score of 9; scores for meta-analyses are based on a total possible score of 11.

Table 4

## Summary of reviews of attention bias in EDs (2010–2018)

Review	Method	No. of included studies ( <i>k</i> )	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score /	Key findings and effect sizes
Aspen (2013)	Systematic review and meta-analysis	4	Adults	AN, BN, BED, EDNOS	HC	DP	Body/eating, positive/negative	3/11	<ul style="list-style-type: none"> <li>1/4 studies found AB away from positive body shape stimuli (<math>d=-.83</math>), and 2/4 found AB towards negative shape stimuli (<math>d=-.80</math>).</li> <li>2/3 studies found AB away from positive and towards negative eating stimuli.</li> <li>Results most robust in BN, with more heterogeneity found for AN.</li> </ul>
Brooks et al. (2011)	Meta-analysis	17	Adults	AN, BN	HC	Stroop, DP, DT	Food words, high/low calorie food images	7/11	<ul style="list-style-type: none"> <li>9/9 Stroop studies found AB towards food stimuli in AN (<math>d=.38</math>), 8/10 found AB towards food stimuli in BN (<math>d=.43</math>)</li> <li>2/2 DP studies found AB away from high-calorie food images (<math>d=-.93</math>) in AN and BN, and AB towards low-calorie stimuli (<math>d=-.72</math>).</li> <li>For distractor tasks, 1/2 studies found large distracting effect of high-calorie food images in AN and BN (<math>d=1.86</math>) and faster RTs to detect high and low calorie food images (<math>d=-.27</math>).</li> </ul>
Giel et al. (2017)	Systematic review	4	Adults ( $k=3$ ) and adolescents ( $k=1$ )	BED, OB/BED	OBC, NWC	RSVP, spatial cuing, free viewing	Food-specific and neutral	4/9	<ul style="list-style-type: none"> <li>4/4 studies found early AB to food pictures in Adult BED compared to OBC and NWC. No early AB was observed for adolescent BED samples.</li> </ul>

Review	Method	No. of included studies ( <i>k</i> )	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <i>I</i>	Key findings and effect sizes
Jáuregui-Lobera (2013)	Systematic review	8	Adults	AN, BN, BED	HC	Stroop, Flankers task	Words-“fat” and “thin” vs. neutral. Food-specific and neutral	4/9	<ul style="list-style-type: none"> <li>• Late attention bias to food pictures was observed in 1/1 studies in adolescent BED and 2/3 studies of adult BED.</li> <li>• One study found no difference in sustained attention between AN and HC groups.</li> <li>• 7/8 studies found AB to “fat” and “thin” words in AN.</li> <li>• One study showed increased attentional disengagement to food vs. non-food pictures during free viewing, with degree of Attentional Disengagement related to BMI.</li> <li>• One study found AB away from thin physique words in AN and BN; for large physique words, AN showed AB towards whereas BN show AB away.</li> </ul>
Kittel et al. (2015)	Systematic review	4	Adults	BED	OBC and NWC	Stroop, free viewing	Food/body-related and neutral	3/9	<ul style="list-style-type: none"> <li>• 3 studies showed greater AB towards food vs. non-food stimuli in OB vs BED and NWC controls.</li> <li>• 1 study found larger AB to food stimuli for OB individuals with BED, versus OB and NWC.</li> <li>• 1 study found AB towards self-rated ugly body parts in both BED and OWC.</li> </ul>

Review	Method	No. of included studies (k)	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <sup>I</sup>	Key findings and effect sizes
Reville et al (2016)	Systematic review	5	Adults	AN	HC	Free viewing (eye tracking)	Body, eating stimuli, faces-angry and neutral	5/9	<ul style="list-style-type: none"> <li>3 studies found AB in AN</li> <li>1 study found that oxytocin increased vigilance to angry faces in AN but decreased vigilance in HC.</li> <li>1 study found no AB to threat-related stimuli in AN.</li> </ul>
Stojek et al (2018)	Systematic review	50	Adults and adolescents	BED, BN (clinical and sub-clinical), AN-B/P	HC, sub-clinical/recovered BN	Stroop, DP, Visual cuing, Visual Search, free viewing	Weight/shape, food, threat words/images	3/9	<ul style="list-style-type: none"> <li>11/15 Stroop studies showed greater AB to weight/shape in BN vs. HC, and greater AB for women with BN vs. recovered/sub-clinical binge eating.</li> <li>7/8 studies showed greater AB to threat stimuli in women with binge eating or BN behaviors.</li> <li>10/16 studies showed no difference in AB for food cues in BN vs. HC, though more consistent biases were found in binge-type EDs without compensatory behaviors.</li> <li>DP, visual search and cuing studies show consistent AB for food.</li> </ul>
Van den Eynde et al. (2011)	Systematic review	16	Adults and adolescents	BN, BED	HC	Stroop	Neutral	5/9	<ul style="list-style-type: none"> <li>7/12 studies found no Stroop interference effect in BN/BED compared to HC.</li> </ul>

Note. ED=eating disorder; AN=anorexia nervosa; ANrec=Recovered anorexia nervosa; AN-R=AN-restricting subtype; AN-BP=AN binge-purge subtype; AN-P=AN purging subtype; BN=bulimia nervosa; BED=binge eating disorder; EDNOS=eating disorder not otherwise specified; HC=healthy control; OBC=obese control; OWC=overweight control; NWC=normal weight control; N.S.=not specified; AB=attention bias; ES=emotional Stroop; DP=dot-probe; AB=attention bias; ES=emotional Stroop; DP=dot-probe; DT=distracter tasks; RSV=rapid serial visual presentation task.

<sup>I</sup>Quality scores for systematic reviews are based on a total possible score of 9; scores for meta-analyses are based on a total possible score of 11.

Table 5

## Summary of reviews of working memory functioning in EDs (2010–2018)

Review	Method	No. of included studies (k)	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score /	Key findings and effect sizes
Brooks et al. (2017)	Systematic review	16	N.S.	AN, ANrec	HC	N.S.	N.S.	2/9	<ul style="list-style-type: none"> <li>AN vs. HC results have been inconsistent.</li> <li>WM improved after treatment (<math>k=2</math>).</li> <li>ANrec&lt;HC (<math>k=1</math>).</li> <li>Longer duration of illness related to worse WM functioning.</li> <li>WM functioning has not consistently correlated with ED symptom measures.</li> </ul>
Kittel et al. (2015)	Systematic review	3	N.S.	BED	OBC	Digit span test, spatial span test, N-back with lures	Food-specific and neutral	3/9	<ul style="list-style-type: none"> <li>Neutral stimuli: 1 study found no difference between BED and OBC in visual WM; 1 of 2 studies found BED&lt;OBC in verbal WM.</li> <li>1 study found BED&lt;OBC and showed more WM interference in the context of food and neutral stimuli.</li> </ul>
Reville et al. (2016)	Systematic review	1	N.S.	AN	HC	N.S.	N.S.	5/9	<ul style="list-style-type: none"> <li>AN did not differ significantly from HC groups.</li> </ul>
Van den Eynde et al. (2011)	Systematic review	3	N.S.	BN, BED	HC	Digit-span and block-span tests	Neutral	5/9	<ul style="list-style-type: none"> <li>BN did not differ from HC in verbal or visual WM (<math>k=2</math>).</li> </ul>

Review	Method	No. of included studies (k)	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score	Key findings and effect sizes
Zakzanis et al. (2010)	Meta-analysis	12	AN: 23.60±3.68 yrs (14-29) BN: 23.74±2.70 yrs (19-28)	AN, BN	HC	Block span, CANTAB-spatial-span, CDR-quality-of-working-memory, CFT-20-number-sequencing, Digit span, Supraspan	Neutral	4/11	• BED>OBC on backwards digit-span ( $k=1$ ). • AN was associated with somewhat greater deficits ( $d=-.35$ ; $k=9$ ) than BN ( $d=-.12$ ; $k=3$ ) compared to HC groups.

Note. ED=eating disorder; WM=working memory; AN=anorexia nervosa; ANrec=Recovered anorexia nervosa; BN=bulimia nervosa; BED=binge eating disorder; EDNOS=eating disorder not otherwise specified; HC=healthy control; OBC=obese control; N.S.=not specified; CANTAB=Computer Automated Neuropsychological Test Battery; CDR=Computerized Drug Research Battery; CFT=Culture Fair Test.

<sup>1</sup>Quality scores for systematic reviews are based on a total possible score of 9, scores for meta-analyses are based on a total possible score of 11.

Table 6

## Summary of reviews of decision making in EDs (2010–2018)

Review	Method	No. of included studies ( <i>k</i> )	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <sup>1</sup>	Key findings and effect sizes
Abbate-Daga et al. (2015)	Systematic Review	15	Adults	AN	HC	IGT	Neutral	4/9	<ul style="list-style-type: none"> <li>12 of 15 studies reported differences between AN and HC.</li> <li>8 studies examined AN vs. HC controlling for depression; only 1 found differences were no longer significant.</li> </ul>
Guillaume et al. (2015)	Meta-analysis	23	AN: 25.9±6.5 BN: 25.49±5.2 BED: 38.3±10.8	AN (ill, recovered, subtypes) BN, BED	HC	IGT (primary)	Neutral	7/11	<ul style="list-style-type: none"> <li>Significant group differences (vs HC) on IGT net scores: Ill AN (<math>g=-.72</math>), restrictive AN (<math>g=-.63</math>), BN (<math>g=-.62</math>), BED (<math>g=-1.26</math>).</li> <li>Non-significant group differences (vs HC) on IGT net scores: Recovered AN (<math>g=-.29</math>), purging AN (<math>g=-0.33</math>).</li> <li>IGT net scores significantly differed across restrictive AN and purging AN (<math>g=-.43</math>), but not across AN and BN (<math>g=-.06</math>).</li> </ul>
Hirst et al. (2017)	Meta-analysis	3	Adults and adolescents	AN, BN	HC	IGT	Neutral	7/11	<ul style="list-style-type: none"> <li>Impairment in IGT performance in AN (<math>g=-.74</math>).</li> </ul>
Jáuregui-Lobera (2015)	Systematic review	N.S.	N.S.	AN	HC	IGT	Neutral	4/9	<ul style="list-style-type: none"> <li>Inconsistent findings for AN</li> <li>Impairments may be similar across EDs and in extreme weight conditions.</li> </ul>
Kittel et al. (2015)	Systematic review	5	Adults	BED	OBC and NWC	IGT; GDT, DDT	Food/ body-related and neutral	3/9	<ul style="list-style-type: none"> <li>Inconsistent IGT results for neutral stimuli; varying</li> </ul>



Review	Method	No. of included studies (k)	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score /	Key findings and effect sizes
McClelland et al. (2016)	Systematic review	10	Adults and adolescents	AN, BN, BED/LOC	HC	TD Tasks	Disorder-related and neutral	4/9	<p>methodologies and covariates across studies.</p> <ul style="list-style-type: none"> <li>In 1 study of delay discounting with neutral stimuli, BED did not differ from OBC and NWC controlling for education level.</li> <li>In 1 study of delay discounting with neutral and disorder-related stimuli, OB with BED exhibited greater discounting than OBC and NWC for all stimuli.</li> </ul> <p>4 studies in AN with mixed findings; reduced TD (vs HC) may be present only in those currently ill with AN.</p> <ul style="list-style-type: none"> <li>1 study in BN found increased TD vs HC.</li> <li>5 studies in BED/LOC; some evidence of increased TD in BED vs HC; mixed findings based on BMI of comparison group (i.e., OBC vs NWC).</li> </ul>
Reville et al. (2016)	Systematic review	9	Adults and adolescents	AN	HC	IGT (primary)	Neutral	5/9	<ul style="list-style-type: none"> <li>AN tend to perform more poorly on IGT vs HC.</li> <li>Greater-brain activation related to successful decision making in AN suggests lower neuropsychological efficiency.</li> </ul>
Stojek & MacKillop (2017)	Systematic Review	8	Youth and Adults	BED, AN	OBC and NWC	DDT	Disorder-related and neutral	1/9	<ul style="list-style-type: none"> <li>Generally increased delay discounting in BED versus HC; mixed findings based on BMI of comparison group (i.e., OBC vs NWC).</li> </ul>

Review	Method	No. of included studies (k)	Age	ED diagnoses included	Non-ED comparison group(s)	Method(s) of assessment	Stimuli	Quality score <sup>1</sup>	Key findings and effect sizes
Van den Eynde et al. (2011)	Systematic review	7	Adults and adolescents	BN, BED	HC	IGT; GDT; DDT	Neutral	5/9	<ul style="list-style-type: none"> <li>Some evidence for reduced delay discounting in AN, but results were mixed.</li> <li>2 studies with IGT and 1 with GDT showed impairment in BN vs HC; 1 of the IGT studies found no difference between BN (mean BMI in obese range) vs OBC.</li> <li>2 studies with IGT found similar performance in BN vs HC.</li> <li>1 study with IGT showed impairment in BED vs NWC, but not vs OBC; 1 study with GDT showed impairment in BED vs HC.</li> <li>1 study with DDT found impairments in BED vs NWC, but not OBC.</li> </ul>
Wu et al. (2016)	Systematic review and meta-analysis	50	Adults and adolescents	AN, BN, BED (k=44); recovered AN (k=6)	NWC, HC	IGT; GDT; DDT; BART; CARROT; MGT; IWT; PMRT; PRT	Non-food reward (k=46); food reward (k=4)	9/11	<ul style="list-style-type: none"> <li>Non-food reward, currently ill ED vs controls: <math>g=-.49</math>; across ED diagnoses, significant effect for AN and BN, but not BED.</li> <li>Food reward, currently ill ED vs controls: <math>g=-.47</math>, Non-food reward, recovered AN vs controls: <math>g=-.30</math>.</li> </ul>
Zakzanis et al. (2010)	Meta-Analysis	4	Adults and adolescents	AN, BN	HC	IGT, GDT	Neutral	4/11	<ul style="list-style-type: none"> <li>Impairments in AN (<math>d=-.57</math>) and BN (<math>d=-.85</math>) vs HC.</li> </ul>

Note. ED=eating disorder; AN=anorexia nervosa; BN=bulimia nervosa; BED=binge eating disorder; EDNOS=eating disorder not otherwise specified; HC=healthy control; OBC=obese control; NWC=normal weight control; N.S.=not specified; IGT=Iowa Gambling Task; GDT=Game of Dice Task; DDT=Delay Discounting Task; BART=Balloon Analogue Risk Task; CARROT=Card Arranging Reward Responsiveness Objective Test; MGT=Monetary Guessing Task; IWT=Implicit Wanting Task; PMRT=Premature Responding Task; PRT=Progressive Ratio Task.

<sup>1</sup>Quality scores for systematic reviews are based on a total possible score of 9; scores for meta-analyses are based on a total possible score of 11.