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Eye-tracking research in eating disorders: A systematic review

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Abstract

Objective: Those with eating disorders (EDs) show attentional biases to disorder-relevant stimuli, such as food and body shape information. However, attentional bias research in EDs largely relies on reaction time based measures, which are limited in their ability to assess different components and the time course of attention. Eye-tracking paradigms have therefore been utilized to provide greater ecological validity, and directly capture the detailed sequence of processes in perception and attention. While numerous studies have examined eye movements in the mood, anxiety, and psychotic disorders, there has been a lack of studies in EDs. The purpose of this qualitative review is to provide a summary of eye-tracking studies in clinical ED populations. **Method:** The review was conducted using the PRISMA guidelines. Electronic databases were systematically searched to identify studies examining gaze parameters in ED compared to healthy controls (HCs). Thirty-one studies met inclusion criteria. **Results:** Across ED diagnoses, there was evidence of attentional biases towards food and body stimuli. In addition, differential patterns of attention to social information, and differences in smooth pursuit and saccadic eye movements were found in anorexia nervosa (AN). **Discussion:** Findings are discussed in relation to research in other psychiatric disorders, and recommendations for future studies using eye-tracking in EDs are given. The findings add to the wider literature on attentional biases in EDs, and provide potential avenues for treatment.

Key words: eating disorders, attentional biases, body image, eye gaze, eye movements, social perception

Introduction

Eating disorders (EDs) are characterized by dysfunctional cognitions related to food, weight, and body shape (Fairburn, Cooper, & Shafran, 2003). These cognitions may bias attention to ED-related stimuli, such that negative body schemas result in individuals attending to schema-consistent stimuli, in turn reinforcing negative self-image and leading to negative emotions (Williamson, White, York-Crowe, & Stewart, 2004). In healthy women, body dissatisfaction and dietary restriction can be increased by inducing an attentional bias towards unattractive body parts and negative food words respectively (Smith & Rieger, 2006; 2009). Furthermore, studies using attentional paradigms such as Stroop and dot-probe tasks have demonstrated that individuals with EDs show a bias towards negative food/eating stimuli compared to healthy and anxious controls (Renwick, Campbell, & Schmidt, 2013; Shafran, Lee, Cooper, Palmer, & Fairburn, 2007, 2008). Given that individuals with EDs also present with interpersonal difficulties (Treasure & Schmidt, 2013), attentional biases have also been studied in the context of social stimuli. In women with anorexia nervosa (AN) or bulimia nervosa (BN), an attentional bias towards angry and rejecting faces and away from neutral and compassionate expressions has been demonstrated (Cardi, Di Matteo, Gilbert, & Treasure, 2014; Cardi, Di Matteo, Corfield, & Treasure, 2012), and is associated with more emotion regulation difficulties (Harrison, Sullivan, Tchanturia, & Treasure, 2010). Further, these results have been replicated in individuals recovered from AN, suggesting that attentional biases towards threat may be a trait vulnerability factor (Harrison, Tchanturia, & Treasure, 2010).

Despite these findings, reaction time (RT) based measures (e.g. Stroop and dot-probe), are limited in their ability to assess different components of attention, such as differences in early automatic attention or attentional maintenance. Relatedly, it is difficult to distinguish the specific processes that are responsible for increased or decreased RTs. For example, in the emotional Stroop task, increased RTs for threatening stimuli are interpreted as hyper-vigilance (e.g., increased attention), as the emotional salience of the word interferes with the participants' ability to make a response. However, it is also the case that avoidance (decreased attention) might be responsible, such that participants divert their attention away from the emotional stimulus, thereby increasing RTs (Aspen, Darcy, & Lock, 2013). Finally, RT based measures are also limited in their ability to measure attention in real-life visual environments, thus lacking ecological validity. For example, while dot probe tasks have allowed us to determine whether a particular stimulus is attended to over another, findings lack generalizability. They cannot tell us where an individual will attend during a mealtime, while looking at their body in a mirror, or during a social interaction. Understanding attention in such contexts will be vital in identifying potential factors that may maintain ED behaviors and cognitions.

Studies have therefore utilized eye-tracking paradigms to capture selection of information in real time, and the underlying processing strategies, in both healthy and psychiatric populations. Generally, such research involves measurement of two fundamental gaze parameters: fixations and saccades. Fixations represent points of attention, where gaze is held within 1° of the visual field for a duration of at least 100-300ms (Toh, Rossell, & Castle, 2011). Saccades are rapid eye movements between fixations, shifting the focus from one point to another. A variety of processes can be inferred from these movements. For example, by measuring the latency of the first saccade towards a stimulus, or the relative proportion of trials in which the first saccade is made to a given stimulus, attentional engagement (early processing) can be measured. Similarly, attentional maintenance can be derived by calculating total duration or number of fixations to a stimulus, while saccade latency away from a stimulus can be taken as a measure of attentional disengagement (late processing).

Eye-tracking research can provide insights into cognitive, social, and emotional processes in psychiatric disorders. For example, in the social domain, both adults and children with autism spectrum disorder (ASD) spend less time looking at eye and face regions, and more time looking at non-social stimuli than healthy controls (HCs) (Frazier et al., 2017). These differences are associated with impairments in areas of social cognition, for example, less time spent looking at the eyes predicts impairments in recognizing fearful expressions in adults with Asperger's syndrome (Corden, Chilvers, & Skuse, 2008). Further, while viewing video clips, more time spent looking at objects predicts poorer social adjustment, while increased fixation on mouths predicts better social adjustment in young adults with ASD (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). These data suggest that by fixating on non-social stimuli, individuals with ASD may miss important social cues. Avoidance of the eyes has also been reported in social anxiety disorder (SAD) (Horley, Williams, Gonsalvez, & Gordon, 2003; Moukheiber et al., 2010; Weeks, Howell, & Goldin, 2013). For example, while a longer delay to orient to the eyes is associated with ASD, quicker attentional disengagement from the eyes is associated with higher levels of social anxiety, in line with the vigilance-avoidance theory of attention (Kleberg et al., 2017; Weierich, Treat, & Hollingworth, 2008).

Despite numerous reviews of eye-tracking literature in psychiatric disorders such as those discussed above (Black et al., 2017; Chen & Clarke, 2017; Chita-Tegmark, 2016; Frazier et al., 2017; O'Driscoll & Callahan, 2008; Toh et al., 2011), no review to date has provided a synthesis of eye-tracking studies in EDs. Such a review will be important in understanding the cognitive and social mechanisms underlying the attentional biases seen in EDs. Therefore, the aim of this systematic review is to provide a summary of eye-tracking studies in clinical ED populations.

Methods

This review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009).

Eligibility criteria

Studies were included if they used eye-tracking in a sample of individuals with a clinical ED, and included a HC group. Studies were also required to be published in a peer-reviewed journal and full text available. Studies investigating eye movement desensitization and reprocessing (EMDR) were not included.

Information sources and search

Studies were identified by searching the electronic databases PubMed, PsycInfo, SCOPUS, and Web of Science up to and including June 2018. Search terms included anorexia nervosa OR bulimia nervosa OR eating disorder AND eye-tracking OR eye gaze OR eye movements. No search limits were applied.

Study selection

Screening and selection of articles is displayed in Figure 1. Where titles of articles appeared relevant, abstracts were screened for eligibility, and full texts of potentially eligible studies were then retrieved. Any full texts that did not meet full eligibility criteria were excluded from the review.

Data collection

Independent study searches were carried out by authors JKG and AH. The following information was extracted from each paper: number of participants in each group, mean age and body mass index (BMI), percentage of female participants, group matching technique, stimuli and eye-tracking task used, outcome measures, and key findings.

Risk of bias in individual studies

Risk of bias in individual studies was assessed using the Kmet form for quantitative analysis (Kmet, Lee, & Cook, 2004). The Kmet form assesses quality of studies on 14 criteria relating to the study design, methods, samples, reporting of results, and conclusions. Three of the criteria did not apply to studies included in this review. The remaining 11 criteria are scored 0, 1, or 2, resulting in a maximum score of 22 (see Supporting Information 1).

Synthesis of results

Studies were grouped by the type of stimulus used in the eye-tracking task: food, bodies, social, and smooth pursuit and saccades. The three former categories are commonly used in attention research, while smooth pursuit and saccades are unique to eye-tracking research. Findings are summarized with respect to differences between groups on specific outcome measures.

Results

Study selection

Thirty-one studies were included in the review (Table 1). Two studies also included another psychiatric group (anxiety disorders and body dysmorphic disorder). Eighteen studies included an AN group, two of which were weight restored (AN-WR), and one which compared recovered and acute groups. Five studies included a BN group, seven included a binge eating disorder (BED) group, one included a night eating syndrome (NES) group, and three studies included a mixed group of AN and BN. Two pairs of studies used the same sample for at least one group. Phillipou, Rossell, Gurvich, Castle et al. (2016) and Phillipou, Rossell, Gurvich, Hughes et al. (2016) used the same AN sample, while Bauer, Schneider, Waldorf, Braks et al. (2017) and Bauer, Schneider, Waldorf, Cordes et al. (2017) used the same HC sample. Due to the different processes and research questions being studied, the results from these studies are presented separately.

Study characteristics

Overall, reporting of study characteristics was good, with Kmet scores ranging from 13 to 21. All but one study (Watson, Werling, Zucker, & Platt, 2010) reported mean age of participants (range: 14.4 – 44.68 years), and only four studies did not report the mean BMI or % ideal body weight (IBW) of at least one participant group (Fujiwara, Kube, Rochman, Macrae-Korobkov, & Peynenburg, 2017; Stefano Pallanti, Quercioli, Zaccara, Ramacciotti, & Arnetoli, 1998; Pinhas et al., 2014; Watson et al., 2010). Most studies used exclusively female samples, however three studies examining either NES or BED included male participants (Baldofski, Lüthold, Sperling, & Hilbert, 2018; Schmidt, Lüthold, Kittel, Tetzlaff, & Hilbert, 2016; Sperling, Baldofski, Lüthold, & Hilbert, 2017). A wide variety of tasks were employed, the most common being free-viewing, where participants are asked to simply view stimuli as if they were watching television. Similarly, many different outcome measures were reported, often several within the same study (see Supporting Information 2 for descriptions of outcome measures). All but one study (Giel et al., 2013) fell into one of the four main categories used to group studies.

Synthesis of results

Food stimuli

Of the eight studies that used food stimuli, five included individuals with BED. Three studies used an antisaccade task, designed to measure the impulsivity component of inhibitory control (Leehr et al., 2016, 2018; Schag et al., 2013). In this task, a high caloric food picture or a non-food picture is presented on one side of the computer screen, and participants are instructed to look at the opposite side of the screen as quickly as possible after stimulus onset. In all three studies, individuals with BED made significantly more incorrect first saccades (looked to rather than away from the stimulus) than both weight-matched and normal weight HCs, who did not differ from one another. In Schag et al. (2013), all groups made more errors in food compared to non-food trials, however this was only true for the HC group in Leehr et al. (2018), and there was no effect of trial in Leehr et al. (2016). In addition, Schag et al. (2013) and Leehr et al. (2018) measured second saccade errors, where a similar pattern was observed. In the former study, participants with BED made more second saccade errors in food trials than both weight-matched and normal weight HC, whereas in the latter, BED only committed more second saccade errors when food and non-food trials were considered together. Thus, it seems that while those with BED have difficulties in inhibitory control, evidence is mixed as to whether these difficulties are general or specific to food stimuli.

Three studies examined attention to food versus non-food stimuli in adults (Schag et al., 2013; Sperling et al., 2017) and adolescents (Schmidt et al., 2016), during both free-viewing and visual search tasks. During free-viewing, pairs of food and non-food stimuli were presented for 3000ms. Across all three studies, there were no group differences in gaze direction bias. In both Schmidt et al. (2016) and Sperling et al. (2017), the groups did not show any bias towards either type of stimuli, however Schag et al. (2013) report that both participants with BED and HC tended to initially fixate on food stimuli. Regarding gaze duration bias, both participants with BED and HC tended to fixate on non-food stimuli longer than food stimuli. However, those with BED fixated on food stimuli longer than control groups in all three studies. Thus, while initial attention to food does not seem to differ in adults and adolescents with BED, there is increased attention when overall looking times are considered. In the visual search task, arrays of food and/or non-food images are presented, and participants are required to indicate whether all images are of the same category or whether one image is different. Adolescents with BED were faster to detect food targets, while HCs were faster to detect non-food targets (Schmidt et al., 2016). However, in adults, no significant group differences were found (Sperling et al., 2017). Using the same free-viewing and visual search tasks, Baldofski, Lüthold, Sperling, and Hilbert (2018) examined whether individuals with NES show similar patterns of attention to food as those with BED. No significant group differences were found in gaze direction or duration bias (free-viewing), or food detection bias (visual search). However, participants with NES did show an initial orienting bias to food stimuli in the free-viewing task (HC did not), and a marginally significant food detection bias in the visual search task when only those with full-syndrome NES were considered (HC did not).

Two studies examined attention to food stimuli in participants with AN. The first used a similar free-viewing paradigm to that used in BED and NES (Giel et al., 2011). Importantly, two control groups were included (a satiated group and an 8-hour fasted group), to control for fasting-related effects on attention. Similar to what was found in individuals with BED, there were no significant group differences in the proportion of initial fixations to food versus non-food pictures. However, despite all three groups showing a tendency to initially orient toward food pictures, this tendency was significant in participants with AN only. Again, there were no significant group differences regarding the duration of initial fixations, however fasted HCs showed a tendency to initially fixate longer on food pictures. Finally, regarding total gaze duration, significant differences were found across groups. HCs looked at food pictures longer than control pictures (fasted HC more so than satiated HC), whereas AN showed similar shorter gaze durations for the two categories of pictures.

The second study used eye-tracking, RTs, and magnetoencephalography (MEG) to investigate the temporal dynamics of food processing in participants with AN (acute and recovered) compared to HCs (Godier, Scaife, Braeutigam, & Park, 2016). Pictures of low or high calorie food were presented for 4000ms, during which time a small square would appear centrally between 500ms and 1500ms after stimulus onset. Participants were required to respond with a button press. While there were no group differences in RTs, the recovered AN group showed significantly more exploration (defined by deflection across the x and y axis from the central point) of the pictures, as well as increased pupil size compared to the other two groups. There was also a main effect of calorie, whereby high calorie foods were explored more than low calorie ones. Regarding neural responses, there were two time points where group differences reached significance – 150ms (posterior regions, AN > AN-REC, HC) and 320ms (occipital regions, AN-REC > AN, HC). The increase in neural activity in the recovered group may reflect an increase in the visual P300 component, modulation of which is related to emotional/motivational properties of visual stimuli (Hajcak, MacNamara, & Olvet, 2010).

Body stimuli

Self versus other bodies

Fourteen studies investigated attention to body stimuli, several of which examined attention towards photographs of one's own body compared to others' bodies. Using a modified dot-probe task, Blechert, Ansorge, and Tuschen-Caffier (2010) presented participants with AN, BN, and HCs with photographs of their own body alongside those of another body. Shortly after the picture pair was presented, colored frames would appear around the photographs, and participants had to indicate the photograph with the target color by making a saccade towards it. Saccade latency was therefore taken as a more ecological, covert measure of attention than the more frequently used button-press. Those with AN showed significantly shorter saccade latencies towards their own body than other bodies, whereas those with BN and HC did not show any attentional bias. In a similar paradigm, Svaldi, Caffier, and Tuschen-Caffier (2012) compared individuals with BED and overweight controls. Different from the previous study, trials were either cued, where participants were told which side their own body photo would appear on, or not cued, however they received no instruction of where they should look. The authors propose that the cued condition would prime participants to think of their own body, therefore activating body-related schema. Overall, first and second fixations were more often directed to and were longer for self pictures. However, those with BED directed both first and second fixations more often to self pictures than controls, and their second fixations towards other bodies were significantly shorter than those of controls. Importantly, these effects were only found in the cued condition, suggesting that the attentional bias found in BED may be a result of activation of body-related schemas, rather than automatic processes.

In contrast to the above findings, two studies did not find group differences in attention to self versus other bodies. Bauer, Schneider, Waldorf, Braks, et al. (2017) presented photographs of participants' own bodies and other bodies one at a time during free-viewing. Participants were adolescents with AN, BN, clinical controls with anxiety disorders, and HCs. All groups fixated longer on their own body compared to other body pictures. Finally, a study by Blechert, Nickert, Caffier, and Tuschen-Caffier (2009) examined social comparison strategies in participants with BN and HC. Trials consisted of a photograph of the participants' own body, with three lower and three higher BMI bodies alongside. Similar to previous findings in BN, there were no group differences in attention to self bodies. While no direct comparison of attention towards self versus other bodies was carried out, it was found that attention to other bodies differed as a function of that body's BMI in those with BN. Participants with BN looked significantly longer at low BMI bodies, and significantly less at high BMI bodies than HCs. Although participants were not explicitly instructed to compare the bodies shown, the authors suggest that individuals with BN engage in more downward social comparisons. Further, there was a significant decline in body satisfaction scores from pre- to post-testing in the BN group (while it increased in HC), lending support for social comparison theory.

Attractive versus unattractive body parts

Several studies examined attention to body parts participants deemed attractive or unattractive. Importantly, attractiveness ratings are made after the eye-tracking task, to ensure that attention is not biased by the judgements. These studies consistently show that when looking at their own bodies, participants with AN and BN pay more attention to parts of their body they rate as most unattractive, compared to HC. For example, during free-viewing, those with AN and BN spend significantly more time looking at parts of their body they are dissatisfied with, while HC spend a similar proportion of time looking at satisfactory and unsatisfactory body parts (Freeman et al., 1991; Tuschen-Caffier et al., 2015). Interestingly, in participants with AN, there is evidence that this bias appears only in the early stage of processing. To investigate whether those with AN show threat-related patterns of attention (early vigilance and later avoidance), Bauer, Schneider, Waldorf, Cordes, et al. (2017) measured the time course of attention while participants viewed pictures of their own body. Twelve body areas of interest (AOIs) were drawn individually for each body picture, following a standardized procedure in terms of area definition. Pictures were presented for 6000ms, and fixation times to unattractive areas (relative to overall fixation times) were measured across six 1000ms intervals. It was found that attention to unattractive areas was significantly higher in AN than HC in the first 3000ms only. Further, attention to unattractive body parts significantly decreased over time in those with AN, while in HC, there was no change over time. These findings indicate an automatic, pre-intentional pattern of attention to unattractive areas of one’s own body in AN.

In another study comparing participants with AN and HC, the effects of mood on attention to attractive and unattractive body parts was examined (Svaldi et al., 2016).

Participants received a positive or negative mood induction (recalling an event from the past few weeks), then eye movements were tracked while viewing their bodies in a mirror for three minutes. In the positive mood condition, both groups looked longer and more frequently at their most unattractive body parts than attractive parts. However in the negative condition, only individuals with AN looked significantly longer at their most unattractive part compared to their most attractive part, while attention was balanced in HCs. It is suggested that HC may engage in some form of “mood-repair” in response to the negative mood induction, perhaps by paying more attention to neutral or positive body information. However in those with AN, attention to negative information is increased by negative mood, thus reinforcing negative body schemas.

Bauer, Schneider, Waldorf, Braks, et al. (2017) examined whether a bias for unattractive body parts was also present when looking at other’s bodies. The procedure used in Bauer, Schneider, Waldorf, Cordes, et al. (2017) was used to map AOIs. Across groups (adolescents with AN, BN, anxiety disorders, or HC), participants attended to unattractive body areas longer than attractive areas for both self and other bodies, however this preference was stronger for one’s own body. Further, those with AN-R looked at unattractive parts significantly longer, and attractive parts less than controls, however this effect was for bodies overall rather than their own body specifically. These results are in contrast with those of the aforementioned studies, who generally found weaker or no attentional biases in HC (Bauer, Schneider, Waldorf, Cordes, et al., 2017; Freeman et al., 1991; Svaldi et al., 2016; Tuschen-Caffier et al., 2015). Instead, they suggest that adolescents, with or without EDs show a general bias for unattractive body areas, especially for their own bodies. This question has also been investigated in those with BED. Svaldi, Caffier, and Tuschen-Caffier (2011) presented women with BED and HCs with photos of their own body alongside a BMI matched control photo. Both groups looked at the most unattractive body part longer and more frequently than the most attractive body part of both self and control bodies, however, this tendency was stronger in those with BED compared to HC. Thus, like other EDs, a stronger attentional bias towards unattractive body parts is apparent in individuals with BED.

Making judgements on attractiveness and body size

In contrast to the above studies, a few studies aimed to examine which parts of the body those with AN and HC looked at when making attractiveness and body size judgements. Importantly, these studies used a novel approach to mapping AOIs to increase spatial resolution. All body images were morphed together to produce a reference image, and fixations can then be transformed into a heat map displaying fixation densities across the body. George, Cornelissen, Hancock, Kiviniemi, and Tovée (2011) found that when judging the attractiveness of photographs of other bodies, those with AN made significantly more fixations to the lower stomach, groin, upper chest, and collar bone, while HC fixated more on the center of the rib cage. When estimating body size, participants with AN made significantly more fixations to the lower stomach and groin, whereas HCs fixated more on the upper stomach and lower region of the rib cage. Cornelissen, Cornelissen, Hancock, and Tovée (2016) examined whether the pattern of eye movements displayed in those with AN is specific to those with the disorder, or whether it is also present in healthy individuals who overestimate body size. It was found that while all groups (AN-WR, over-estimating HC, and accurate HC) spent most time looking at the abdominal region of others' bodies, AN-WR looked at this area significantly less than accurate HCs, but significantly more than over-estimating HCs. Further, AN-WR looked significantly longer at the face than both HC groups. Thus, in agreement with George et al. (2011), accurate body size estimation is associated with more time spent looking at the abdominal region, whereas a more dispersed pattern of fixations up along the torso and onto the face may be specific to those with AN.

The final study to examine eye movements during body size estimation took a different approach, using point-light walkers (Phillipou, Rossell, Gurvich, Castle et al., 2016). These stimuli represent biological motion through the movements of a few points representing the major joints of the body. Walkers were either male or female, and varied in body size. To investigate whether the explicit instruction to estimate body size would influence eye movements, both an explicit task (body size estimation) and an implicit task (gender discrimination) were included. In contrast to the results of George et al. (2011) and Cornelissen et al. (2016), individuals with AN and HC did not differ in the parts of the body fixated on during either task. There were also no group differences in accuracy of body size judgments or gender discrimination. The lack of overestimation of body size in the AN group may be a result of them looking at the same parts of the body as HCs when making their judgements, different from the previous studies. Although groups did not differ in where they looked, there were differences in how they looked – those with AN showed an increased number of fixations of shorter duration during both tasks. This may be evidence of "hyper-scanning"; a type of scanning behavior associated with anxiety disorders (Horley, Williams, Gonsalvez, & Gordon, 2004).

Social stimuli

Five studies examined attention while viewing social stimuli. Similar to several of the body-related attention studies, Kollei, Horndasch, Erim, and Martin (2017) examined attention to attractive versus unattractive parts of one's own and other's faces in participants with BN, body dysmorphic disorder (BDD), and HC. Participants viewed photographs of their own and other female faces, and afterwards rated the attractiveness of parts of the faces. While HC spent similar amounts of time looking at attractive and unattractive features of both their own and other faces, participants with BN or BDD spent less time looking at attractive features of their own face than HC. Further, BDD and BN spent more time looking at attractive features compared to unattractive features of other faces. The findings indicate a possible neglect of positive aspects of one's own face in BDD and BN, and/or an upward social comparison strategy. Such a strategy may be responsible for the increase in negative emotions seen in BN and BDD (but not HC) after image viewing.

Extending previous work demonstrating an attentional bias to bodies in those with AN (Dobson & Dozois, 2004; Shafran et al., 2007), Pinhas et al. (2014) aimed to examine whether this bias would persist when bodies were presented alongside pictures of social interactions, a class of stimuli that is typically rewarding. When presented together, participants with AN showed a hierarchy of attention allocation, looking more at thin body shapes, followed by fat body shapes, and finally social interactions. In contrast, HC spent similar amounts of time on all three types of image, and significantly less time on body shape images than those with AN. Thus, when social and body images are competing for attention, individuals with AN show an attentional bias towards bodies, especially thin ones. However, a question remains over whether there is abnormal processing of social stimuli in the absence of such disorder-related stimuli. Watson et al. (2010) presented AN-WR and HCs with images of faces, or whole body images including faces. Those with AN-WR looked less at faces when the body was also present within the image compared to controls, thus showing an attentional bias towards body stimuli. Importantly, when faces were presented alone, AN-WR looked significantly less at the eyes than HC, providing the first eye-tracking evidence for abnormal processing of social stimuli in AN (without the influence of body/shape stimuli). These results were further clarified in a monetary choice task. In each trial, participants were given a choice between a constant cash payout, or a variable payout which would also show the face or body stimulus. It was found that AN-WR assigned higher monetary values to thin bodies, while reward value of body pictures was uninfluenced by weight in HC. In addition, HC consistently sacrificed money to see face stimuli, while AN-

WR did not. Taken together, these results suggest that while HC show approach behavior to social stimuli, AN-WR tend to be indifferent or avoid viewing the faces or eyes of others.

Two studies examined eye movements during facial emotion recognition. The first (Phillipou et al., 2015) used Ekman faces displaying the seven basic emotions (anger, disgust, fear, happiness, sadness, surprise, and neutral), as well as photographs of participants' own faces while they were asked to hold a neutral expression. Adults with AN were just as accurate as HCs in recognizing the facial expressions of others, but were more likely to misidentify their own face as showing sadness. Regarding eye movements, those with AN showed an increased number of fixations of shorter duration to faces in general compared to HC, similar to the hyper-scanning behavior found by Phillipou, Rossell, Gurvich, Castle et al. (2016). Thus, it is possible that faces may also be anxiety-provoking to individuals with AN. Lending some support for this possibility, participants with AN avoided salient features (eyes, nose, and mouth) of their own face compared to HC, however this effect was not found for other's faces. Building on this study, Fujiwara, Kube, Rochman, Macrae-Korobkov, and Peynenburg (2017) investigated whether differences in eye movements might drive potential difficulties in facial emotion recognition commonly found in those with EDs (Caglar-Nazali et al., 2014). To control for the role of alexithymia in emotion recognition, both a high- and a low-alexithymia HC group, as well as a mixed group of participants with AN or BN were included. In each trial, participants were asked to estimate the mixture ratio of two emotional expressions blended into one face on a visual analogue scale. In contrast to Phillipou et al. (2015), those with EDs were less accurate at judging ambiguous angry and disgust expressions compared to HCs (particularly those with low alexithymia). Importantly, difficulty in judging anger and disgust in participants with ED was predicted by avoidance of these faces, in particular the eye region. When ED differed from HC, group differences tended to be significant only compared with HC-LA, with performance of HC-HA lying between the two. This, along with the finding that visual attention was linked to performance in the ED group only, suggests that alexithymia is not solely responsible for difficulties in emotion recognition.

Smooth pursuit and saccades

Three studies have measured smooth pursuit parameters and/or saccadic eye movements in individuals with AN. In contrast to saccades, smooth pursuit is the process by which a moving stimulus is followed by the eyes in a slow, smooth eye movement. These eye movements have been useful in understanding the neurobiology of a variety of psychiatric disorders, as they are governed by known brain regions. For example, the superior colliculus (SC) is involved in the initiation and inhibition of saccades. Activity here is negatively related to saccade latency, such that the higher the activity of the SC, the faster the saccade to a target (Bittencourt et al., 2013). Smooth pursuit involves integration of activity from the frontal eye fields (FEF), visual and vestibular circuitry, cerebellum, thalamus, and the muscles and neural circuitry directly responsible for eye-movement (Gottesman & Gould, 2003).

Pallanti et al. (1998) aimed to examine links between eye movement parameters during smooth pursuit and clinical features. In each trial, a target moves in a horizontal arc at a constant speed, which the participant follows while their eye movements are recorded. Target speed differs across trials. AN-WR displayed a larger drop-off in performance as target speed increased compared to HC, and a greater number and total amplitude of anticipatory saccades (anticipatory jumps ahead of the target). While eye movements were not related to BMI, weight lost, length of illness, global psychopathology, or depression, poorer smooth pursuit performance was associated with OCD symptoms and ED psychopathology (perfectionism, drive for thinness, and interoceptive awareness).

Saccadic eye movements can also be studied during fixation on a stationary target. While some saccadic intrusions occur during fixation in the healthy population, increased rates have been found in both neurodegenerative and psychiatric disorders (Bittencourt et al., 2013; Terao, Fukuda, & Hikosaka, 2017). Phillipou, Rossell, Castle, Gurvich, and Abel (2014) examined the incidence of square wave jerks (SWJs), the most widely studied saccadic intrusion, in participants with AN and HC. While fixating on a central cross, those with AN made significantly more SWJs than HC. In addition, more SWJs were associated with lower anxiety scores in the AN group only. It is suggested that γ-aminobutyric acid (GABA) has a role in lowering anxiety, as shown by anxiolytic treatments such as benzodiazepines being used to enhance GABA activity in anxious individuals (Tallman, Paul, Skolnick, & Gallager, 1980). Higher GABA activity in areas containing fixation neurons such as the SC and FEF may result in increased SJWs and difficulty maintaining fixation, providing a potential explanation for the association with anxiety in this group.

A final study used a battery of saccadic eye movement tasks, including self-paced saccades, memory guided saccades, and a prosaccade/antisaccade/no-go (PAN) task (Phillipou, Rossell, Gurvich, Hughes et al., 2016). In the memory-guided saccade task, inhibitory error rates were higher in those with AN than HC, indicating a failure to inhibit reflexive responses. Further, in the PAN task, latency of correct prosaccades (saccades towards the stimulus) was significantly shorter in the AN group. Taken together, the results indicate potential functional alterations in the neuronal circuits that control eye movements in those with AN, however replications are required.

Discussion

The aim of this review was to provide a qualitative synthesis of studies that have utilized eye tracking in ED samples. Studies mostly examined attention to disorder-related stimuli; namely food and bodies, and found a variety of differences between ED and HC on specific outcome measures. A small number of studies also examined eye-movements while viewing social stimuli, while a few others examined smooth pursuit performance and saccadic eye-movements. Some key findings will be discussed here.

Several studies provided evidence for differential attention to images of food in individuals with ED compared to HC. Firstly, those with BED showed more difficulty in inhibiting their automatic attention to both food and non-food stimuli compared to HC (Leehr et al., 2016, 2018; Schag et al., 2013), as well as delayed disengagement to food stimuli, indicating increased food-related reward sensitivity (Schag et al., 2013; Schmidt et al., 2016; Sperling et al., 2017). Given that weight-matched controls without BED did not show these difficulties, it is unlikely that increased inhibition errors are merely a consequence of overweight/obesity. Difficulties in inhibitory control, a component of impulsivity, are likely to facilitate binge eating behavior, therefore maintaining core psychopathology of the disorder (Balodis, Grilo, & Potenza, 2015). The lack of group differences between those with NES and HCs suggests different attentional processes area associated with NES and BED (Baldofski et al., 2018). However, it is possible that the small sample size in the NES group (n=19), especially when only full-syndrome cases were considered (n=12), resulted in insufficient power to detect group differences. Larger studies in both BED and NES are required.

There was evidence that individuals with AN or BED process images of their own body differently from the bodies of others, as opposed to having a general bias towards body related stimuli (Svaldi et al., 2012). However, due to the diverse range of methodologies used in these studies, findings were mixed. For example, Blechert et al. (2010) used a dot-probe paradigm, finding that participants with AN showed an attentional bias towards photographs of their own bodies, whereas those with BN and HC did not. However, another study reported no differences in viewing times between those with AN, BN, clinical controls, or HCs – all groups looked at their own bodies for more time than other bodies (Bauer, Schneider, Waldorf, Braks, et al., 2017). The dot-probe paradigm taps into covert attention when self and other bodies are competing, and may reflect an automatic, pre-intentional bias. These subtle differences may have been missed in the latter study, which measured looking times when photographs were presented alone.

Generally, AN, BN, and BED displayed an attentional bias for parts of their body they deemed unattractive, a pattern which was weaker or not present in HC (Freeman et al., 1991; Tuschen-Caffier et al., 2015; Svaldi et al., 2016; Svaldi et al., 2011). Again, in those with AN, this bias seems to be automatic (Bauer, Schneider, Waldorf, Cordes, et al., 2017). Cognitive theories of body dissatisfaction propose that schemas related to body image give rise to a number of cognitive biases affecting attention, memory, interpretation, and judgement. These selective cognitive processes lead to negative emotions regarding body image, and further reinforce negative schemas (Rodgers & DuBois, 2016). Indeed, several studies included here reported that the more dissatisfied participants were with their body, the stronger their attentional bias was (Bauer, Schneider, Waldorf, Braks, et al., 2017; Blechert et al., 2010; Svaldi et al., 2012; Svaldi et al., 2016; Tuschen-Caffier et al., 2015). This effect has been reported in non-clinical populations (Rodgers & DuBois, 2016), and generally was not specific to those with EDs in the studies included here.

These findings regarding body-related attention may have implications for treatment. Attentional bias modification treatment (ABMT) aims to implicitly retrain early attentional processes away from threatening/emotional stimuli, and has been used successfully in anxiety disorders (Hakamata et al., 2010; Heeren, Reese, McNally, & Philippot, 2012). ABMT has also shown promise in reducing negative interpretation biases for social stimuli in individuals with AN (Cardi et al., 2015; Turton, Cardi, Treasure, & Hirsch, 2017), and reducing ED symptoms in those with BED (Boutelle, Monreal, Strong, & Amir, 2016; Schmitz & Svaldi, 2017). While mirror exposure is often used in enhanced cognitive behavioral therapy (CBT-E) for EDs, such techniques involve conscious reappraisal and gradual extinction of the negative affective response towards one's body (Fairburn et al., 2008), rather than directly manipulating subcortical attentional processes (Renwick, Campbell, & Schmidt, 2013). ABMT for body image bias has yet to be explored in clinical ED samples.

Individuals with AN and AN-WR looked at different areas of the body when making judgments about attractiveness and body size, compared to HCs (Cornelissen et al., 2016; George et al., 2011). The pattern of fixations displayed by HCs (concentrated on the waist and stomach area) was consistent with an efficient sampling strategy, given these areas are a good index of overall BMI (Cornelissen, Toveé, & Bateson, 2009). However, when stimuli were point-light walkers, fixation patterns and body size judgements did not differ between those with AN and HC (Phillipou, Rossell, Gurvich, Castle et al., 2016). The differing results are likely due to the use of biological motion stimuli, which are devoid of information about the surface level shape of the body. Thus, it seems that overestimation of body size, a key characteristic of AN, is based on different sampling of the body size information available. Techniques that reveal this discrepancy may be helpful as part of an intervention to improve body image disturbance in AN. Although body image disturbance is considered a particularly difficult symptom to treat, new experimental methods such as virtual reality have provided promising results, demonstrating that body size judgments can be changed (Keizer, van Elburg, Helms, & Dijkerman, 2016).

Eye-movement patterns in participants with AN showed some similarities to those found in anxiety disorders. For example, individuals with AN had a stronger initial tendency to orient to food stimuli, but looked at food for less time overall than HC (Giel et al., 2011). This is consistent with vigilance-avoidance theory; a pattern of attention characterized by early attention to, and subsequent avoidance of a fear-relevant stimulus. Such patterns of attention have been demonstrated in those with social anxiety (Garner, Mogg, & Bradley, 2006; Vassilopoulos, 2005) and spider phobia (Pflugshaupt et al., 2005; Rinck & Becker, 2006). Early vigilance towards one's own body compared to other body stimuli was also demonstrated, and towards unattractive areas of one's own body (Bauer, Schneider, Waldorf, Cordes, et al., 2017; Blechert et al., 2010). These findings suggest an automatic, pre-cognitive bias for food and body stimuli in those with AN, possibly reflecting the aversive nature of these stimuli. There was also evidence for "hyper-scanning" of biological motion stimuli and faces in AN, a behavior thought to reflect increased vigilance due to anxiety (Phillipou et al., 2015; Phillipou, Rossell, Gurvich, Castle et al., 2016). However, only one study included a measure of anxiety (Blechert et al., 2010), but did not examine its association with eye-movements. Including measures of comorbid traits such as anxiety may be important in determining factors that contribute to attentional biases in EDs.

Relatedly, similarities between AN and other psychiatric disorders were found in smooth pursuit and saccadic eye-movement parameters. Lower pursuit gain reported in those with AN-WR (Pallanti et al., 1998) has been found in those with schizophrenia, depression (Kathmann, Hochrein, Uwer, & Bondy, 2003; O'Driscoll & Callahan, 2008; Tien, Ross, Pearlson, & Strauss, 1996), and OCD (Pallanti et al., 1996). Commenting on the similarities with OCD, Pallanti et al. (1998) suggest that the obsessional and perfectionistic traits in AN may reflect a behavioral expression of a shared underlying biological vulnerability. Increased rates of inhibitory errors on a memory guided saccade task were also reported in those with

AN (Phillipou, Rossell, Gurvich, Hughes, et al., 2016), a finding that has again been reported in OCD (Rosenberg, Dick, O'Hearn, & Sweeney, 1997). To explore whether eye movement abnormalities are state or trait markers in AN and other EDs, it would be of interest to examine whether performance on smooth pursuit and saccade measures are related to clinical improvements. In schizophrenia, eye-movement abnormalities improve alongside improvements in delusional symptoms, however they do not reach the level of HCs even in the remitted state (Beedie, Benson, & St Clair, 2011).

There is emerging evidence for avoidance of eyes and faces in those with AN, a finding that has also been demonstrated in non-clinical samples with high ED psychopathology (Sharpe, Wallis, & Ridout, 2016). Eye avoidance was also found in AN-WR, suggesting independence from clinical improvements (Watson et al., 2010). Avoidance of the eyes and social stimuli has been reported in ASD, and is considered a key characteristic of the disorder (Black et al., 2017). Interestingly, AN and ASD show a range of similarities in symptoms, including difficulties in theory of mind (Leppanen, Sedgewick, Treasure, & Tchanturia, 2018), emotion recognition (Bal et al., 2010; Kucharska-Pietura, Nikolaou, Masiak, & Treasure, 2004; Kuusikko et al., 2009) and production (Davies et al., 2016; McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006), high levels of alexithymia (Bird & Cook, 2013; Westwood, Kerr-Gaffney, Stahl, & Tchanturia, 2017) and social anxiety (Kerr-Gaffney, Harrison, & Tchanturia, 2018; Simonoff et al., 2008). Around 10% of those with AN meet diagnostic criteria for ASD, while a further 40% show high levels of ASD symptoms (Westwood, Mandy, Simic, & Tchanturia, 2018). To understand possible mechanisms behind the eye movement patterns associated with AN, it may be useful to investigate their associations with comorbid psychopathology, such as ASD or social anxiety. For example, the eye avoidance hypothesis proposes that there is hyper-arousal of the amygdala in response to social stimuli in ASD. As a result, individuals direct their attention away from the eyes to regulate their arousal and perceived threat (Corden et al., 2008; Tanaka & Sung, 2016).

Several methodological limitations are apparent across studies. For example, only three studies controlled for the effects of psychotropic medication on eye-movements (Fujiwara et al., 2017; Giel et al., 2011; 2013), while a further three only included participants who were medication free (Baldofski et al., 2018; Pallanti et al., 1998; Sperling et al., 2017). Atypical antipsychotics and benzodiazepines have been found to reduce saccadic velocity and increase latency in healthy individuals, due to their sedative effect on the central nervous system (Reilly, Lencer, Bishop, Keedy, & Sweeney, 2008). Although the results of the studies included in this review did not generally differ when medication was controlled for, most did not report on medication status. Given that atypical antipsychotics are increasingly being used to treat those with AN (McKnight & Park, 2010), this is an important methodological consideration for future eye-tracking research.

Relatedly, few studies reported on associations between eye movements and clinical variables such as BMI, illness duration, or ED psychopathology. Such factors may be important given the neural, cognitive, and low-level motor impairments that occur with malnutrition in AN (Joos et al., 2010; King et al., 2015; Titova et al., 2013; Zakzanis et al., 2010). Indeed, in the few studies that did report associations with clinical variables, higher BMI and ED psychopathology in those with BED or NES was found to be associated with shorter gaze duration to food stimuli (Baldovski et al., 2018; Schmidt et al., 2016). This pattern may reflect attentional avoidance or disengagement strategies being employed by those with more severe ED psychopathology. Such strategies may be dysfunctional, as they may interfere with habituation to food stimuli, thus resulting in more binge eating episodes and associated weight gain (Epstein, Leddy, Temple, & Faith, 2007; Epstein, Robinson, Roemmich, & Marusewski, 2011). Interestingly, shorter gaze duration to food was associated with higher ED psychopathology and lower BMI in participants with AN (Giel et al., 2011), perhaps illustrating a cycle observed clinically, whereby avoidance of food and further restriction increases ED cognitions. Given these findings, future eye-tracking research in EDs should consider the effect of state variables on eye movement patterns and attentional biases.

Another limitation is that many different outcome measures were used across studies, however the rationale for using one over the other was not always clear. The lack of standardization of outcome measures may have influenced the way in which the results were reported. Similarly, variations in stimuli and presentation times make comparisons across studies difficult. For example, when examining attention to body parts, a few studies did not exclude the head/face from the body stimuli (Cornelissen, Cornelissen, Hancock, & Tov, 2016; Freeman et al., 1991; Svaldi et al., 2016; Tuschen-Caffier et al., 2015; Von Wietersheim et al., 2012). Since faces are highly salient to humans (Bindemann, Burton, Hooge, Jenkins, & de Haan, 2005; Theeuwes & Van der Stigchel, 2006), their inclusion is likely to affect attention considerably, thus introducing a potential confound and making comparisons across studies difficult. On the other hand, body stimuli that include faces are likely to better represent visual stimuli encountered in everyday life.

In addition, different types of eye trackers, with different spatial and temporal resolutions will affect the accuracy of the results. Most studies used a tracker that required the head to be held stable using a chin rest, which, while perhaps providing better spatial accuracy, suffers from a lack of ecological validity (Niehorster, Cornelissen, Holmqvist, Hooge, & Hessels, 2018). Remote view eye-trackers, which do not restrict head movements, were also used in several studies. It is proposed that such techniques provide a more natural assessment of eye gaze, however they have been found to suffer from considerable data loss and reduced sampling rates when participants' heads are in non-optimal orientations (Niehorster et al., 2018). Despite these limitations, some innovative techniques were demonstrated, for example using head mounted eye-tracking devices to measure gaze towards participants' own image in a mirror (Svaldi et al., 2016; Tuschen-Caffier et al., 2015). This technique is particularly fitted to ED populations, given the body checking behaviors often seen in this group. Nonetheless, there is a need for studies to follow a standardized methodological approach for investigating eye movements to substantiate some of the findings included in this review. For example, protocols have been developed for studying saccadic eye-movements in order to improve reproducibility (Nij Bijvank et al., 2018). This would also be helpful in making comparisons across psychiatric disorders (Bittencourt et al., 2013; Rommelse, Van der Stigchel, & Sergeant, 2008).

To conclude, a variety of interesting paradigms have been used in eye-tracking research in EDs, however replications and more consistent use of specific outcome measures and tasks are required. Attentional biases towards food and body stimuli in those with EDs may represent an important target for treatment, for example using ABMT. Emerging evidence suggests there are also differences in the way those with AN attend to social information, and future studies should utilize the paradigms that have been established in disorders such as ASD. If social information is not attended to, social cues that are key to successful interactions are likely to be missed, making it difficult to build relationships. This is important, given that interpersonal difficulties are associated with poorer treatment outcomes in EDs (Jones, Lindekilde, Lübeck, & Clausen, 2015; Vall & Wade, 2015). Further, the saccadic abnormalities found in those with AN should be investigated in other EDs, in order to examine possible alterations in neuronal circuits responsible for ocular motor control.

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Table 1. *Characteristics of studies*

Study	***N* and group**	**Mean age (SD)**	**Mean BMI (SD)**	**% female**	**Groups matched by**	**Stimuli**	**Eye-tracking task**	**Outcome measures**	**Main findings**
Food stimuli									
Baldofski et al. (2018)	19 NES (12 full-syndrome, 7 subsyndromal)	44.42 (13.15)	35.12 (9.28)	57.89	Age, sex, BMI	Food vs non-food	1. Free viewing	1. Gaze direction bias	Group difference = ns. NES showed an initial orienting bias towards food stimuli, whereas HC did not.
	19 HC	44.68 (14.01)	35.54 (10.33)	57.89				2. Gaze duration bias	Group difference = ns. NES and HC fixated longer on non-food than food stimuli.
							2. Visual search task	1. Food detection bias score	Groups difference = ns.
Giel et al. (2011)	19 AN	24.4 (4.1)	15.8 (1.8)	NR	NR	Food vs non-food	1. Free viewing	1. Gaze direction bias	Group differences = ns. All groups showed an initial tendency for food pictures, and this was strongest and significant in AN.
	18 HC (fasted)	24.4 (2.6)	21.6 (1.5)	100				2. Initial fixation duration bias	Group differences = ns. HC (fasted) showed a significant tendency to fixate on food pictures.
	20 HC (non-fasted)	24.2 (2.9)	21.3 (1.7)	100				3. Gaze duration bias	AN < HC (non-fasted) < HC (fasted). Both HC groups showed a significant tendency to continuously attend to food over non-food images.
Godier et al. (2016)	13 AN-R	31.2 (5.3)	15.7 (1.9)	100	Sex	Food, low vs high calorie	1. Responding to stimulus (black square)	1. X-span and Y-span	AN-REC > AN-R, HC. All groups explored high-calorie pictures more than low calorie pictures.

	14 AN-REC	27.1 (6.5)	20.9 (1.6)	100				2. P-span	AN-REC > AN-R, HC. All groups had larger pupil dilation in response to high calorie pictures compared to low calorie pictures.
	15 HC	23.7 (5.4)	21.4 (1.9)	100					
Leehr et al. (2016)	21 BED	31.0 (12.3)	34.4 (5.5)	100	Age, sex	High calorie food vs non-food	1. Antisaccade task (inhibitory control)	1. Number of 1st saccade errors	BED > obese controls, HC (food and non-food trials)
	23 Obese controls	31.7 (11.2)	33.2 (4.2)	100					
	25 HC	31.4 (10.9)	22.3 (1.7)	100					
Leehr et al. (2018)	24 BED	31.46 (12.03)	34.93 (5.24)	100	Age, sex	High calorie food vs non-food	1. Antisaccade task (inhibitory control) after negative mood induction	1. Number of 1st saccade errors	BED > overweight controls, HC (food and non-food trials).
	23 Obese controls	28.39 (7.55)	32.99 (3.81)	100				2. Number of 2nd saccade errors	BED > HC (food and non-food trials considered together)
	26 HC	33.15 (12.63)	22.22 (1.77)	100					
Schag et al. (2013)	25 BED (22 full-syndrome, 3 subsyndromal)	39.7 (11.7)	35.4 (5.6)	100	Age, sex, BMI	Food vs non food	1. Free viewing	1. Initial fixation position	Group differences = ns. All groups tended to initially fixate on food stimuli.
	26 overweight controls	39.9 (12.6)	35.4 (5.4)	100				2. Gaze duration bias	BED > overweight controls, HC. All groups tended to fixate longer on non-food than food stimuli.
	25 HC	39.4 (11.8)	22.5 (1.6)	100			2. Antisaccade task	1. First saccade errors	BED > overweight controls, HC (food and non-food trials). All groups made more errors in food trials than non-food trials.
								2. Second saccade errors	BED > overweight controls, HC (food trials only).
								3. Sequential errors	BED > overweight controls, HC (food and non-food trials).

Schmidt et al. (2016)	25 BED	14.68 (2.85)	BMI-SDS 1.77 (0.95)	88	Age, sex, BMI, SES	Food vs non-food	1. Free viewing	1. Gaze direction bias	Group differences = ns. Neither group showed a bias for food.
	25 HC	15.28 (2.39)	BMI-SDS 1.77 (0.82)	NR				2. Gaze duration bias	BED > HC (attractive food only).
							2. Visual search task	1. Detection bias score	BED > HC. BED were faster to detect food targets, while HC were faster to detect non-food targets.
Sperling et al. (2017)	23 BED (17 full-syndrome, 6 subsyndromal)	35.30 (11.39)	32.40 (9.24)	65.2	Age, sex, BMI	Food vs non-food	1. Free viewing	1. Gaze direction bias	Group differences = ns. Neither group showed a bias for food.
	23 HC	35.96 (12.20)	32.79 (9.01)	65.2				2. Gaze duration bias	BED > HC. Both groups showed a bias for non-food stimuli, however BED looked at food stimuli longer than HC.
							2. Visual search task	1. Detection bias score	Group differences = ns. In comparisons with full-syndrome BED only, there was a marginally significant tendency for BED > HC (faster detection of unattractive food stimuli), whereas HC did not show any bias.
Body stimuli									
Bauer, Schneider, Waldorf, Braks, et al. (2017)	30 AN-R	15.80 (1.09)	16.38 (1.36)	100	Sex	Body, self vs other	1. Free viewing	1. Fixation times	AN-R < HC = AN-BP, BN, anxiety (attractive areas); AN-R > HC, anxiety = AN-BP, BN (unattractive areas). All groups looked longer at unattractive areas compared to attractive areas, and their own compared to other's bodies.
	26 AN-BP	16.42 (0.85)	16.73 (1.37)	100					
	22 BN	16.72 (0.76)	20.91 (2.21)	100				2. Gaze duration bias	Bias for unattractive parts of one's own body were associated with

	20 anxiety	15.94 (1.64)	19.98 (2.57)	100				for unattractive body parts	subsequent lower body satisfaction in all groups. The same pattern for other's bodies was seen in HC and anxious controls only.
	43 HC	15.85 (1.77)	19.97 (2.44)	100					
Bauer, Schneider, Waldorf, Cordes, et al. (2017)	56 AN	16.09 (1.03)	16.54 (1.36)	100	Sex	Body, self	1. Free viewing	1. Gaze duration bias for unattractive body parts	AN > HC in the first half (0-3000ms) of stimulus presentation time only
	43 HC	15.85 (1.77)	19.97 (2.44)	100					
Blechert et al. (2009)	20 BN	26.6 (7.68)	22.6 (3.40)	100	Sex	Body, self vs other (lower vs higher BMI)	1. Free viewing	1. Fixation times (% of total presentation time)	BN > HC (lower BMI bodies), BN < HC (high BMI bodies). Group differences for own bodies = ns.
	22 HC	26.5 (4.65)	20.3 (2.24)	100					
Blechert et al. (2010)	19 AN	23.5 (4.66)	16.5 (1.35)	100	Sex	Body, self vs other	1. Dot-probe task	1. First saccade latency	Group differences = ns. AN had significantly shorter saccade latencies for self trials compared to other trials (no difference in BN and HC).
	18 BN	26.9 (8.35)	22.9 (3.39)	100				2. Saccade difference score	In AN, faster saccades for self-photos were associated with lower satisfaction to the self-photo.
	21 HC	27.1 (4.77)	20.3 (2.12)	100					
Cornelissen et al. (2016)	20 AN-WR	23.70 (4.43)	21.71 (3.95)	100	Sex, BMI	Body, other	1. Body size estimation in comparison to self	1. Fixation count (per cell)	Face: AN-WR > HC (acc), HC (over); Central abdominal region: HC (acc) > AN-WR > HC (over). All groups spend longer looking at the abominal region than anywhere else.
	20 HC (accurate estimators)	23.25 (7.93)	23.01 (4.11)	100					
	20 HC (over-estimators)	20.60 (2.89)	23.19 (5.10)	100					

Freeman et al. (1991)	15 AN or BN	21.9 (7.2)	16.5 (2.8)	100		Sex, age	Body, self	1. Free viewing	1. Fixation times (%)	Group differences not reported. In HC, there was a similar proportion of time spent looking at and satisfaction with each body region. In ED, patients spent more time looking at parts of their body they were dissatisfied with.
	10 HC	25.7 (8.1)	19.8 (3.1)	100					2. Evaluative gaze index	HC > ED
George et al. (2011)	16 AN	26.2 (7.9)	16.8 (2.1)	100		Age, sex	Body, other	1. Attractiveness rating	1. Fixation count (per cell)	Centre rib cage: HC > AN; lower stomach and groin, upper chest and collar bone: AN > HC
	16 HC	26.1 (7.7)	22.8 (3.0)	100				2. Body size estimation		Upper stomach and lower rib cage: HC > AN; lower stomach and groin: AN > HC.
Horndasch et al. (2012)	17 AN or BN	16.0 (1.9)	18.6 (2.2)		100	Sex	Body, other	1. Free viewing	1. Fixation time	ED > HC (unclothed body parts). Both groups looked longer at "index areas" (hip, abdomen, buttocks, upper legs) than at the rest of the body.
	25 HC	15.3 (1.9)	21.3 (1.6)		100					
Phillipou, Rossell, Gurvich, Castle et al. (2016)	24 AN	23.07 (6.88)	16.52 (1.14)	100		Age, sex, premorbid IQ	Point light walkers	1. Implicit task - gender identification	1. Fixation count	AN > HC. In AN, fixation count increased for mid-heavy size male stimuli relative to female stimuli. Fixation count to male and female stimuli did not differ in HC.
	24 HC	22.72 (3.25)	22.26 (3.59)	100				2. Explicit body size estimation	2. Fixation duration	AN < HC. Longer fixations were made to both thin and heavy stimuli than other sizes, and during the implicit task compared to the explicit task.
									3. Saccade amplitude	AN < HC (implicit task). Larger amplitudes were found for found for thin and thin-mid body sizes, and male stimuli.

Svaldi et al. (2011)	26 BED	44.2 (9.56)†	38.7 (8.22)	100	Sex	Body, self vs other	1. Free viewing	1. Fixation count	BED > overweight controls (ugliest self body part); BED > overweight controls (ugliest other body part). Both groups looked at ugly body parts more frequently than beautiful parts (self and other stimuli).
	18 overweight controls		30.0 (3.80)	100				2. Fixation times	BED > overweight controls (ugliest self body part); BED > overweight controls (ugliest other body part). Both groups looked at ugly body parts for longer than beautiful parts (self and other stimuli).
Svaldi et al. (2012)	23 BED	40.33 (11.6)†	37.7 (6.85)	100	Sex	Body, self vs other	1. Cued for self stimuli vs no cue (instruction/task not reported)	1. 1st fixation direction (frequency)	Cued condition: BED > overweight controls (self stimuli); BED < overweight controls (other body).
	23 overweight controls		29.8 (3.94)	100				2. 1st fixation duration	Group differences = ns.
								3. 2nd fixation direction (frequency)	Cued condition: BED > overweight controls (self stimuli); BED < overweight controls (other body).
								4. 2nd fixation duration	Cued condition: BED < overweight controls (other body). Overall, fixations were longer for self stimuli than other bodies.

Svali et al. (2016)	12 AN	15.14 (1.55)	18.13 (1.46)	100	Age, sex	Body, self (mirror)	1. Free viewing (2 conditions: postive and negative mood induction)	1. Fixation times	AN > HC (most ugly body part, negative mood condition). AN looked longer at the most ugly than the most beautiful body part in both positive and negative mood inductions, while HC looked longer at the most ugly part in the positive mood induction only.
	12 HC	15.15 (1.57)	20.56 (2.29)	100				2. Gaze frequency	AN > HC (most ugly body part, negative mood condition). AN looked more frequently at the most ugly than the most beautiful body part in both mood inductions. HC showed a trend to look more frequently at the most ugly part in the positive mood induction only.
Tuschen-Caffier et al. (2015)	16 AN	22.09 (3.29)	14.55 (1.15)	100	Sex	Body, self (mirror)	1. Free viewing	1. Fixation times	Group differences not reported. AN and BN spent more time looking at their most dissatisfying and ugly body parts than satisfying and beautiful parts. In HC, there were no differences.
	16 BN	22.31 (6.00)	21.10 (2.92)	100				2. Gaze frequency	Group differences not reported. AN and BN looked more frequently at their most dissatisfying and ugly body parts than satisfying and beautiful parts. In HC, there were no differences.
	16 HC	23.65 (1.34)	21.41 (2.80)	100					
Von Wietersheim et al. (2012)	35 AN	22.9	16.4	100	Sex	Body, self vs other	1. Free-viewing	1. Fixation times (as a proportion of a total)	AN < HC (breasts of other body stimuli); AN > HC (thighs of own body). In AN, those who rated their abdomen as less attractive fixated on it longer. In HC, those who rated their thighs as less attractive fixated on them longer.

	32 HC	22.2	21.5	100				2. Fixation count	AN < HC (breasts of own body)
Social stimuli									
Fujiwara et al. (2017)	24 AN or BN	23.33 (7.12)	19.3	100	Sex	Faces, blended emotions	1. Emotion discrimination	1. Dwell time	Angry and disgust faces: ED < HC-LA, HC-HA. In ED shorter dwell time predicted more difficulty judging ambiguous anger and disgust faces.
	25 HC (high alexithymia)	18.60 (2.04)	NR	100				2. Eye-preference	Group differences = ns. In ED less attention to the eyes predicted more difficulty judging ambiguous anger and disgust faces.
	25 HC (low alexithymia)	19.92 (3.8)	NR	100				3. Saccades	Group differences = ns.
Kollei et al. (2017)	21 BN	23.67 (4.31)	20.91 (2.15)	100	Sex	Face, self vs other	1. Free viewing	1. Dwell time	HC > BDD, BN (most attractive facial feature, self); BDD ≥ BN ≥ HC (least attractive facial feature, self). Group differences for other faces = ns.
	19 BDD	23.79 (4.25)	21.84 (2.93)	100				2. Fixation count	Main effect of group for least attractive facial part (self), but group differences = ns. Group differences for other faces = ns.
	21 HC	23.52 (2.84)	22.25 (2.93)	100					
Phillipou et al. (2015)	23 AN	22.18 (5.45)	16.47 (1.13)	100	Sex	Faces, self vs other	1. Implicit task - gender identification	1. Fixation count	AN > HC. Both groups made a greater number of fixations to their own faces and faces depicting anger and fear.
	24 HC	22.64 (3.25)	22.36 (3.66)	100			2. Explicit emotion identification task	2. Fixation duration	AN < HC.
								3. Saccade amplitude	Group differences = ns.

								4. Feature Fixation Index (FFI) and Feature Duration Index (FDI)	HC > AN. FFI and FDI were higher for participants own faces, and faces depicting anger, disgust, fear, and sadness. Salient features were also attended to more during the implicit task compared to the explicit task.
Pinhas et al. (2014)	13 AN	14.5 (1.61)	90.1% IBW	100	Age, sex	Thin body shapes (TBS) vs fat body shapes (FBS) vs social interactions	1. Free viewing	1. Relative fixation times (%)	AN > HC (TBS & FBS); AN < HC (social images). AN spent more time looking at both thin and fat body shapes than social images, and more time looking at thin compared to fat body shapes. HC spent similar amounts of time on all 3 types of image.
	20 HC	14.4 (1.82)	NR	100				2. Fixation count	AN: TBS > social images; FBS > social images. HC: TBS = social images; FBS = social images.
								3. Fixation duration	AN: TBS > social images; FBS > social images. HC: TBS = social images; FBS = social images.
Watson et al. (2010)	11 AN-WR	NR	NR	100	Sex	Faces vs bodies, other	1. Free viewing	1. Dwell time	Faces: AN-WR < HC (when bodies were also present). Eyes: AN-WR < HC (when faces presented alone). Participants looked at faces of extremely thin females less than faces of other weight classes.
	11 HC	NR	NR	100					
Smooth pursuit and saccades									
Pallanti et al. (1998)	28 AN-WR	23.9 (3.4)	NR	100	Age, sex, education	Horizontal arcs	1. Smooth pursuit	1. Typical target velocity	AN < HC
	28 HC	24.4 (3.8)	NR	100				2. Typical matching target velocity	AN < HC

								3. Anticipatory saccades (total number)	AN > HC
								4. Anticipatory saccades (total amplitude)	AN > HC
								5. SWJ rate	Group differences not reported. SWJ were present in 10.7% of AN and 0% of HC.
Phillipou et al. (2014)	23 AN	23.14 (7.03)	16.54 (1.16)	100	Age, sex, premorbid IQ	Fixation cross	1. Fixation task	1. SWJ rate	AN > HC
	22 HC	22.94 (3.23)	22.70 (3.63)	100					
Phillipou, Rossell, Gurvich, Hughes et al. (2016)	24 AN	23.07 (6.88)	16.52 (1.14)	100	Age, sex, premorbid IQ	Dots	1. Self-paced saccades	1. Saccade rate	Group differences = ns.
	24 HC	22.67 (3.19)	22.4 (3.59)	100				2. Gain	Group differences = ns.
								3. Intersaccadic interval	Group differences = ns.
								4. Peak velocity	Group differences = ns.
							2. Memory-guided saccades	1. Gain	Group differences = ns.
								2. Latency	Group differences = ns.
								3. Peak velocity (5°, 10° targets)	Group differences = ns.
								4. Inhibitory error rate (5°, 10° targets)	AN > HC (10° targets)

								5. Directional error rate	Group differences = ns.
							3. Pro-saccade /antisaccade/no-go task	1. PAN error rate	Group differences = ns.
								2. Prosaccade gain	Group differences = ns.
								3. Prosaccade latency	AN < HC
								4. Prosaccade peak velocity (5°, 10° targets)	Group differences = ns.
								5. Antisaccade gain	Group differences = ns.
								6. Antisaccade latency	Group differences = ns.
								7. Antisaccade peak velocity (5°, 10° targets)	Group differences = ns.
Other									
Giel et al. (2013)	15 AN	23.9 (4.9)	15.4 (1.7)	100	Age, sex	Pictures depicting physical activity vs inactivity	1. Free viewing	1. Gaze direction bias	Group differences = ns. All group showed a tendency to first attend to active stimuli.
	15 athletes	24.5 (3.0)	21.8 (1.8)	100				2. Gaze latency bias	Group differences = ns. All groups showed a tendency to orient their attention quicker to active than inactive stimuli.

	15 HC	24.7 (2.8)	21.3 (1.5)	100		3. Gaze duration bias	HC < AN, athletes. AN and athletes looked longer at active stimuli, whereas HC looked at active and inactive stimuli for similar lengths of time.

AN = anorexia nervosa; AN-BP = anorexia nervosa binge purge sub-type; AN-R = anorexia nervosa restricting sub-type; AN-REC = recovered AN; AN-WR = weight-restored anorexia nervosa; BDD = body dysmorphic disorder; BED = binge eating disorder; BMI = body mass index; BMI-SDS = body mass index standard deviation score; BN = bulimia nervosa; ED = eating disorder; HC = healthy control; IBW = ideal body weight; IQ = intelligence quotient; NES = night eating syndrome; NR = not reported; ns = not significant; PAN = pro-saccade /antisaccade/no-go; RT = reaction time; SD = standard deviation; SES = socioeconomic status; SWJ = square wave jerk

†Only reported for groups combined

Figure legends:

Figure 1. Systematic review search process.