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# Eating disorder-specific rumination moderates the association between attentional bias to high-calorie foods and eating disorder symptoms: Evidence from a reliable free-viewing eye-tracking task

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ABSTRACT

Cognitive theories of eating disorders implicate Attentional Bias (AB) towards food-related information in the development and maintenance of eating disorders. Empirical evidence for this proposal, however, has been inconsistent, and the measures used to examine AB to food-related stimuli typically showed poor reliability. The aim of the current study was twofold. Firstly, we aimed to examine the psychometric properties of a newly devised eye-tracking task for the assessment of AB in the context of eating disorders. Secondly, we examined the role of Eating Disorder-specific (ED-specific) rumination as a potential moderator of the association between attentional bias to food images and eating disorder symptoms. One hundred and three female students were recruited and completed an eye-tracking task comprising 21 matrices that each contained 8 low-calorie and 8 high-calorie food images. Each matrix was presented for 6 s. First fixation location, first fixation latency, and total dwell time were assessed for low and high-calorie food images and the dwell-time based AB measure showed good reliability based on Cronbach's alpha, McDonald's Omega, and split-half method. In addition, the results revealed that the ED-specific rumination plays the hypothesized moderating role. Specifically, while participants with high levels of ED-specific rumination exhibited a positive association between AB to high-calorie foods and eating disorder symptoms, this association was not present among participants with lower levels of ED-specific rumination. The employed free-viewing task seems a reliable measure of AB to food-related stimuli, and the moderation analysis emphasizes the critical role of ED-specific rumination for eating disorder symptoms. Implications, limitations, and directions for future research are discussed.

## 1. Introduction

Attentional bias (AB) is a tendency to preferentially attend to emotionally and motivationally relevant information (Cisler & Koster, 2010). Cognitive theories of eating disorders propose that attentional bias to food-related information plays a critical role in weight-related behaviors and eating disorders (Field et al., 2016; Higgs, 2016; Werthmann, Jansen, & Roefs, 2015). However, not all studies have observed an association between this attentional bias and eating disorder symptoms. While some have found eating disorder symptoms to be positively associated with attentional biases towards food-related information (Blechert, Feige, Joos, Zeeck, & Tuschen-Caffier, 2011; Giel et al., 2011), others have not found this link between attentional bias and eating disorder symptomatology (see Aspen, Darcy, & Lock, 2013). This inconsistency suggests the importance of identifying potential moderators of the association between attentional bias to food-related information and eating disorder symptoms. The present study was therefore designed to examine the potential role of Eating Disorder-specific (ED-specific) rumination as a candidate moderator.

ED-specific rumination is characterized by preoccupation with food, eating, weight, and their control (Dondzilo, Rieger, Palermo, Byrne, & Bell, 2016). Several previous studies have shown the association between elevated ED-specific rumination and heightened eating disorder symptoms (Grafton, Southworth, Watkins, & MacLeod, 2016; Joormann, Dkane, & Gotlib, 2006; Morrison & O'Connor, 2008). There is also evidence about the role of ED-specific rumination in AB to thin body

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images (Dondzilo, Rieger, Palermo, Byrne, & Bell, 2017), but to the best of our knowledge, no research to date has investigated the potential moderating role of ED-specific rumination in the association between the attentional bias to food-related stimuli and eating disorder symptoms. However, hypothesizing this association is plausible considering the theoretical and experimental evidence for an association between general ruminative thinking and AB to negative self-referent information, which suggests the existence of a potential association between ED-specific rumination and AB to food-related information. For example, Donaldson, Lam, and Mathews (2007) showed that AB toward negative information is more pronounced among individuals with higher ruminative thinking. Therefore, as a preoccupation with one's emotional concerns increases AB toward related emotional information, it can be hypothesized that the relationship between AB to high-calorie foods and eating disorder symptoms might be especially pronounced or restricted to individuals with higher levels of ED-specific rumination. It must be recognized that ED-specific rumination is correlated with the general form of ruminative thinking (Smith, Mason, & Lavender, 2018). Therefore, we also examined the specificity of ED-specific rumination as a moderator of the relationship between AB and eating disorder symptoms.

To date, most of the studies that examined AB to food have used RT-based tasks such as the Emotional Stroop task and the Dot-Probe paradigm (Kerr-Gaffney, Harrison, & Tchanturia, 2018; Ralph-Nearman, Achee, Lapidus, Stewart, & Filik, 2019). These tasks rely on RT to infer the allocation of attention to different stimuli. The RT-based tasks have been criticized for their limitations such as poor reliability, non-continuous measurement of attention, and ecological validity of the stimulus display (Hagan, Alasmar, Exum, Chinn, & Forbush, 2020).

The available RT-based tasks have shown very poor reliability scores (Mazidi, Vig, Ranjbar, Ebrahimi, & Khatibi, 2019; Rodebaugh et al., 2016; Staugaard, 2009). Poor reliability has statistical and conceptual implications such as decreasing statistical power and reproducibility of findings (Loken & Gelman, 2017; MacLeod, Grafton, & Notebaert, 2019). In addition to reliability problems, the RT-based tasks give only a snapshot of where attention is oriented, and they cannot measure attentional bias in a direct and continuous way, which has significant implications for its theoretical understanding (see Cisler & Koster, 2010). There are also serious concerns about confounding elements of motor preparation and response execution in RT-based paradigms (Armstrong & Olatunji, 2012). Finally, the very limited number of stimuli that RT-based tasks can present in each trial – typically just a pair of images or words – has raised the concern about their task representativeness of the complexity and richness of the real-life food relevant situations (Hertel & Mathews, 2011; Richards, Benson, Donnelly, & Hadwin, 2014). A way to overcome this limitation is by employing tasks with a more complex stimulus configuration and various competing stimuli to reflect the complexity of the world in a more ecologically valid approach (Lazarov, Abend, & Bar-Haim, 2016; Richards et al., 2014; Soleymani, Ivanov, Mathot, & de Jong, 2020).

To address the above-mentioned shortcomings, eye-tracking has been increasingly used as a method that does not suffer from the limitations caused by the indirect AB assessment tasks. The eye-tracking method applies a continuous assessment of attention as a dynamic phenomenon (Armstrong & Olatunji, 2012). The reliability of eye-tracking indices has been shown to be greater than RT-based measures (Christiansen, Mansfield, Duckworth, Field, & Jones, 2015; Skinner et al., 2018). Other studies also recorded participants' eye movements while completing a dot-probe task, but they did not report reliability indices (Doolan, Breslin, Hanna, Murphy, & Gallagher, 2014; Monem & Fillmore, 2019; Werthmann et al., 2019). Virtually all of these studies used a relatively simple visual display with presenting only two stimuli in each trial, which does not address the criticism about the low ecological validity of attentional bias tasks. But in an interesting study, Popien, Frayn, von Ranson, and Sears (2015), used complex real-world images (one image in each trial) to explore attention bias to high and low-calorie foods. The results of their study showed that participants with binge-eating symptoms attended to food earlier and for longer duration in comparison with the comparison group without binge eating symptoms.

A free-viewing approach combined with eye-tracking provides the potential to tackle the drawback of presenting a limited number of stimuli. In such a paradigm, stimuli are presented on a screen with no instruction for participants to attend to a particular type of stimulus or perform any task other than simply looking at the images in a way they prefer. Previous studies applied the free-viewing paradigm for measuring AB towards various food-related stimuli (Baldofski, Lüthold, Sperling, & Hilbert, 2018; Giel et al., 2011; Graham, Hoover, Ceballos, & Komogortsev, 2011; Horndasch et al., 2020; Hummel, Ehret; Zerweck, Winter, & Stroebele-Benschop, 2018; Nijs, Muris, Euser, & Franken, 2010; Potthoff & Schienle, 2020; Schäfer, Schmidt, Müller, Dietrich, & Hilbert, 2020; Schag et al., 2013; Sperling, Baldofski, Lüthold, & Hilbert, 2017). These studies were however compromised by presenting only a pair of images in each trial and not reporting the reliability of AB indices.

The current study applied the free-viewing paradigm to present a complex set of stimulus configurations of high and low-calorie foods. Previous studies in the area of alcohol and affective disorders have successfully employed this paradigm with more complex stimuli displays and found promising results in terms of reliability. For example, Soleymani et al. (2020) recorded participants' eye movements while they were freely looking at an array of 16 images consisting of eight alcoholic and eight non-alcoholic beverages that were presented for 6 s during each trial. First fixation location, first fixation latency, and dwell time on alcoholic and non-alcoholic images were computed to index AB to alcoholic drinks. The Cronbach's alpha score of attentional bias indices extracted from dwell time was excellent (Cronbach's alpha = .90). Significant positive correlations were also found between attentional bias and craving, and problematic behaviors related to alcohol use. In other words, longer dwell time and more fixations on alcoholic drinks were associated with greater craving and alcohol problems. The same paradigm was employed in the context of social anxiety and major depression with matrices of 16 threatening and neutral faces and satisfactory internal consistency was reported for the attentional bias index based on the total dwell time (Lazarov et al., 2016; Lazarov, Ben-Zion, Shamai, Pine, & Bar-Haim, 2018). Also, Sears, Quigley, Fernandez, Newman, and Dobson (2018) used a free-viewing eye tracking task to measure attention bias to explore the reliability of this task for emotional images. They also reported a moderate to excellent reliability as indexed by Cronbach's alpha and low to moderate test-retest reliability for emotional images.

The aim of the current study was twofold. Firstly, we examined the reliability of a modified version of the free-viewing task originally designed by Lazarov et al. (2016) as a measure of attentional bias to food pictures. Consistent with previous studies (Lazarov et al., 2016, 2018; Soleymani et al., 2020), we computed eye-tracking measures of both early (first fixation location and latency) and later attention (total dwell time) and examined their relationships with measures of several relevant constructs such as hunger, dietary restraint, general and eating-related rumination, eating disorder symptoms, and subjective attitudes towards food images. Secondly, we examined the hypothesis that ED-specific rumination moderates the association between AB to high-calorie food images and eating disorder symptoms. To ensure that we examined the role of ED-specific rumination rather than ruminative thinking in general, we also assessed general rumination, in order to examine the specificity of ED-specific rumination as a moderator of the relationship between AB and eating disorder symptoms.

## 2. Methods

### 2.1. Participants

To reach a statistical power of at least 0.80 to reliably detect a correlation of medium effect size ($r \geq 0.30$), we intended to recruit at least 64 participants (Cohen, 1992). Because gender might play a key role in the relationship between attention to food cues and eating behavior (Hummel, Ehret, Zerweck, Winter, & Stroebele-Benschop, 2018), and dieting behavior is more common in women (de Ridder, Adriaanse, Evers, & Verhoeven, 2014; Wardle, Haase, & Steptoe, 2006) we preferred a homogeneous sample of female participants. Eventually, 103 first-year psychology female students took part in the study. The only condition for enrollment in the study was uncorrected eyesight to prevent eye-tracking calibration difficulties. The study was approved by the ethical committee of the psychology department of the University of Groningen (ECP approval code = 18820-S).

### 2.2. Materials

#### 2.2.1. Questionnaires

*2.2.1.1. Eating Disorder Examination Questionnaire (EDE-Q; Fairburn & Beglin, 2008).* The Eating Disorder Examination Questionnaire (EDE-Q; Fairburn & Beglin, 2008) consists of 22 items assessing eating disorder pathology in the past 28 days. It contains questions regarding restraint, shape concerns, weight concerns, and eating concerns. For example, one of the questions is "Have you had a definite desire to have a totally flat stomach?". Items indexed the frequency or severity of symptoms and were answered on a scale ranging from 0 ("*never/not at all*") to 6 ("*every day/markedly*"). In their psychometric study, Aardoom, Dingemans, SlofOp't Landt, and Van Futh (2012) found no support for the theorized four subscales. They found that the theorized four subscales tap one general underlying dimension, rather than separable sub dimensions. Therefore, the average of the 22 items was used as a measure of global eating pathology severity (Aardoom et al., 2012). Internal consistency of this global score in the current sample was excellent (Cronbach's alpha = .94, and Omega = .94).

*2.2.1.2. Ruminative Response Scale for Eating Disorders (RRS-ES; Cowdrey & Park, 2011).* The RRS-ES consists of 9 items, measuring brooding and reflection tendencies regarding undesired eating behavior and concerns with food consumption. The items were scored on a four-point Likert scale ranging from 0 (almost never) to 3 (almost always). As an example, "Think 'why do I always react this way around food?". The total score ranges from 0 to 27, with a higher score corresponding with a higher level of ruminative disposition. Past findings have found the scale to be sufficiently reliable (Cowdrey & Park, 2011). In the current sample, the scale demonstrated exceptional reliability, with $\alpha = .91$, and Omega = .92.

*2.2.1.3. Ruminative Response Scale-short form (RRS; Treynor, Gonzalez, & Nolen-Hoeksema, 2003).* The RRS consists of 10 items from the original 22-item form (Nolen-Hoeksema & Morrow, 1991) and measures brooding and reflection tendencies (Treynor et al., 2003). Each item is scored on a 4-point Likert scale, ranging from 1 (almost never) to 4 (almost always). Previous research incorporating the scale reported good reliability ($\alpha = .84$; Parola et al., 2017). Also in the present sample, the scale demonstrated good reliability ($\alpha = .82$, and Omega = .81).

*2.2.1.4. Hunger Scale (Grand, 1968).* The item "please indicate the number of hours since your last meal (to the nearest 15 min)" from the Hunger Scale (Grand, 1968) was used to measure participants' satiation (cf. Jonker, Bennik, de Lang, & de Jong, 2020). The more time has elapsed since the last meal, the lower the level of satiation was assumed to be.

*2.2.1.5. The restraint scale (Herman & Polivy, 1980).* The restraint scale (RS) is a 10-item assessment tool to evaluate concern for dieting and weight fluctuations. The RS is often used to identify individuals who have troubles dieting effectively and tend to overeat. For example, one of the questions is "How often are you dieting?". The RS has been validated for the female population of both normal and excessive weight (van Strien, Herman, Engels, Larsen, & van Leeuwe, 2007). Estimated reliability as indexed by Cronbach's alpha ($\alpha = .82$) and test re-test reliability ($r = 0.95$) evaluated by Herman and Polivy (1980) showed the suitable psychometric quality of this tool to measure dietary restraint. In the current investigation, Cronbach's alpha for the RS was 0.79, and Omega = .78.

*2.2.1.6. Items for rating image stimuli.* Each stimulus picture was rated by each participant after the eye-tracking task on the dimensions of appeal ("How favorable do you find this picture"), salience ("How much does this picture grab your attention?"), and distress ("How distressing do you find this picture?"). Each question was rated on a five-point scale from 0 (not at all) to 4 (very strongly). There were 56 unique images in each image category, i.e., high, and low-calorie images. The reliability score (Cronbach's alpha and Omega) of each dimension was computed for high and low-calorie food images separately. The Cronbach's alpha and Omega scores were as follows: salience high-calorie: alpha = .91, and Omega = .90, salience low-calorie: alpha = .90, and Omega = .89, distress high-calorie: alpha = .98, and Omega = .97, distress low-calorie: alpha = .97, and Omega = .97, appeal high-calorie: alpha = .86, appeal low-calorie: alpha = .86.

#### 2.2.2. The free viewing eye-tracking task

The free viewing AB assessment task was designed in OpenSesame (Mathôt, Schreij, & Theeuwes, 2012). Eye-gaze data was collected with an Eyetribe ET1000 eye-tracker. Areas of Interest (AOI) were defined as the area in pixels of each of the displayed images. Thus, in our task, we had 16 AOIs per trial. The eye-tracking plugin collected eye-gaze position (i.e., x, y coordinates) at 30 Hz, and determined whether the current eye-gaze position falls within an AOI, or not. Before the start of each session, a 9-point eye-gaze calibration was performed. During each trial, a randomized 4 x 4 matrix was presented for 6 s (see Fig. 1). Each matrix consisted of 8 low-calorie food pictures and 8 high-calorie pictures. These pictures were taken from the Image database for experimental research on eating and appetite (Blechert, Meule, Busch, & Ohla, 2014). The four inner pictures always consisted of two low-calorie and two high-calorie pictures. All participants presented with the same matrices.

### 2.3. Procedure

The participants were tested individually in a quiet room. After signing the informed consent, the Hunger Scale was administered. Then, the participants were instructed to place their chin on the rest in front of them. Prior to each trial, the gaze drift was checked. For each matrix, participants had to gaze at a fixation dot in the center of the screen for 100 ms for that matrix to appear, to ensure a fixed starting point of participants' viewing of the matrix. Each matrix was visible for 6000 ms. After a subsequent 2000 ms interval, the next fixation dot appeared. There were 21 trials in total. After every seven matrices, the participant was prompted to move on to the next set of matrices by pressing any key on the keyboard. This allowed them to take a break if they wanted. The same order of matrix presentation was used for all participants to optimize the measurement procedure to index individual differences (Goodhew & Edwards, 2019). The set of pictures used in the eye tracking task was evaluated in terms of salience, appeal, and distress by the participants immediately after completing the attentional task. Then, the restraint scale, and the EDE-Q were administered, followed by the

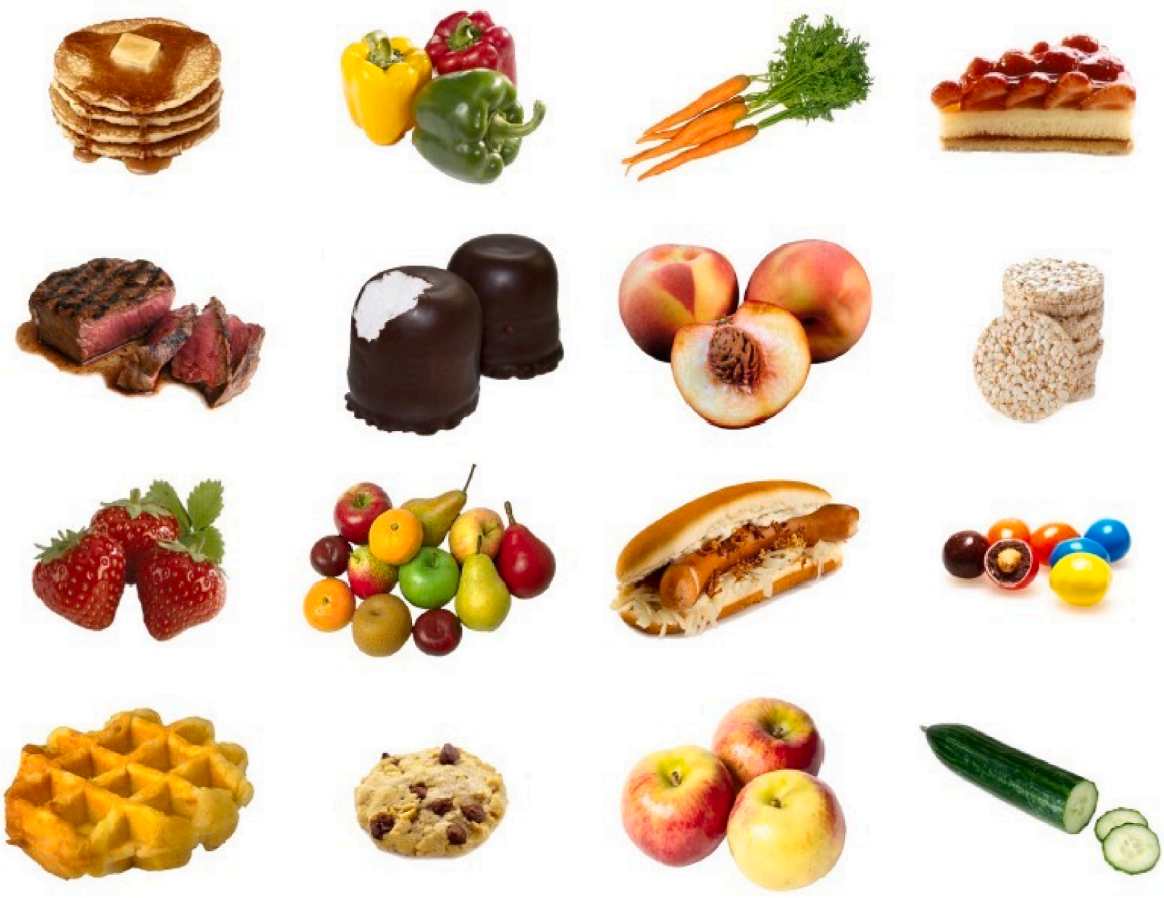

**Fig. 1.** Example of a single matrix, depicting eight high-calorie food items and 8 low-calorie food items.

RRS, and the RRS-ED. All measures were administered digitally. Then, participants gave their best estimate of their weight and height. Last, the participants were debriefed and thanked.

### 2.4. Data reduction and analysis plan

A custom-built plugin for OpenSesame was used to calculate for each trial the time a participant spent looking at each of the predefined AOI (i.e., each picture). A fixation was defined as a gaze of over 100 ms in an AOI. The total amount of time that participants fixate within an AOI was defined as dwell time. Three variables were of interest when analyzing the output of the AOI analysis plugin: 1) First fixation location on high-calorie pictures. This variable indicates the number of trials that the first fixation occurred for high-calorie pictures. 2) The latency bias index was computed using the latency to first fixation scores, which is the time (in ms) between the onset of stimuli presentation and the first fixation recorded within one of the defined AOIs. The mean latency to the first fixation for high-calorie pictures was subtracted from the mean latency to the first fixation to low-calorie pictures. Hence, positive scores of the latency bias index are indicative of vigilance to high-calorie pictures. 3) Dwell time bias index was computed using the dwell time scores, which is the total amount of time a participant attended to each AOI category. The mean dwell time of low calorie pictures was subtracted from mean dwell time on high calorie pictures. Higher scores in dwell time bias thus indicate stronger AB for high-calorie foods.

As an estimate of reliability, we computed Cronbach's alpha and MacDonald's Omega for the 21 trial-level AB scores. As a second (and often used) index of reliability, we calculated the Spearman-Brown corrected bootstrapped correlation between the AB scores of the odd and even trials of the task (split-half reliability). To estimate the reliability of first fixation location (on the high or low-calorie pictures) we also computed Cronbach's alpha and MacDonald's Omega for all trials and assessed bootstrapped split-half reliability as indexed by the Spearman-Brown corrected correlation of the number of first high-calorie fixations between odd and even trials.

Relationships between variables were examined using Pearson's correlation method. For moderation analysis, the Hayes and Preacher method (Hayes & Preacher, 2014), and the PROCESS syntax were employed (Hayes, 2009). PROCESS model 1 was applied that estimates a moderation model with a single moderator of the association between a predictor variable (AB to high-calorie foods) with an outcome variable (eating disorders symptoms) by virtue of a moderating variable (ED-specific rumination). In addition, to increase the power of the statistical test (Miller & Chapman, 2001), we repeated the moderation model with general rumination, and the time since the last meal as covariates. Interpretation of moderator effects was facilitated through a simple slopes analysis.

## 3. Results

### 3.1. Descriptives

Table 1 presents a summary of the means (SDs) of all variables that were assessed.

### 3.2. Reliability measures

Reliability for the dwell-time bias score as indexed by Cronbach's alpha and McDonald's Omega was good (alpha = .78, and Omega = .77). It should be acknowledged, however, that this alpha score could be

**Table 1**
Descriptive Statistics of the results.

| Variables | Mean (SD) | Range |
|---|---|---|
| First fixation location (high calorie) [a] | 11.16 (2.66) | 2–18 |
| Latency bias score (ms) | −9.57 (269.84) | −941.93–722.74 |
| Dwell time bias score (ms) | −8.10 (911) | −2647.22–1888.42 |
| Eating Disorder Examination Questionnaire (EDE-Q)[b] | 1.64 (1.39) | 0.06–6.19 |
| Ruminative Response Scale for Eating Disorder (RRS-ED) | 12.88 (5.46) | 0–21 |
| Ruminative Response Scale – short form (RRS) | 5.58 (5.60) | 1–26 |
| Restraint Scale (RS) | 12.39 (5.54) | 3–27 |
| Self-reported BMI | 22.21 (2.83) | 16.85–30.11 |

[a] Number of trials.
[b] Based on the study of Aardoom et al. (2012), the following EDEQ scores provided for different samples as follows: Mean and (SD) in general population: 0.93 (0.86); eating disorder:4.02 (1.28); anorexia nervosa: 4.17 (1.30); bulimia nervosa: 4.34 (1.04); binge eating disorder: 3.46 (0.98); eating disorder not otherwise specified: 3.83 (1.40).

inflated duo to the fixed order of presentation in our free viewing task. Therefore, to further index reliability, we assessed split-half reliability following a bootstrapping method with 1000 random splits. Based on the Confidence Interval level of 95.0%, lower and upper scores were 0.44 and 0.72, respectively ($p < 0.001$) and the average split-half correlation coefficient was $r = .60$. Reliability for the first fixation location as indexed by Cronbach's alpha scores was 0.32. The same bootstrapping method used to investigate the reliability of first fixations on high calorie foods between odd and even trials Based on Confidence Interval level of 95.0%, lower and upper scores were −0.11 and 0.26, respectively, and correlation coefficient was $r = .08$, which shows weak reliability.

### 3.3. Correlation analyses

Table 2 presents a summary of the bivariate correlations. No significant bivariate correlations were found between attentional indices (dwell-time bias, latency bias, and frequency of the first fixation on high-calorie foods) and indices of eating disorder symptoms, dieting, rumination, level of satiation, subjective stimulus ratings, and BMI. Table 3 shows the correlations between self-reported measures.

### 3.4. Moderation analyses

To test the hypothesis that ED-specific rumination moderates the association between dwell-time bias to high-calorie foods and eating disorder symptoms, a moderation model was conducted across all participants. The RRS-ED was incorporated as a continuous moderator variable in the model. The predictor variable was dwell-time bias index, and the outcome variable was EDEQ scores. Moderation effects of the model are reported in Table 4.

As can be seen, the entire effect of the model as well as the interaction effect were significant .[1] Exploration of the conditional effects revealed no significant relationship between AB to high-caloric foods and eating disorder symptoms at *low* and *average* levels of ED-specific rumination with [$B = -0.0001$, $se = 0.0001$, 95% CI [− 0.0003, 0.0001], $t = -0.79$, $p = 0.43$] and [$B = 0.0001$, $se = 0.0001$, 95% CI [−0.0001, 0.0003], $t = 1.12$, $p = 0.26$], respectively. However, at higher levels of RRS-ED, there was a significant positive relationship between AB to high-caloric foods and eating disorder symptoms [$B = 0.003$, $se = 0.0001$, 95% CI [0.0001, 0.0005], $t = 2.72$, $p = 0.008$]. The potential impact of influential observations (i.e., observations with a disproportionate impact on the values of the model parameters) was examined using Cook's distance. The significant moderation effect, as well as the significant association between AB to high-calorie foods and eating disorder symptoms were not driven by any specific cases or influential data points. Fig. 2 demonstrates the conditional effects described above.

#### 3.4.1. Post-hoc moderation analysis

As the ED rumination and the general rumination are two close and partly overlapping constructs, we ran an exploratory moderation model to test if general rumination plays the same moderating role between AB and eating disorder symptoms. The model was similar to the main tested model with the only difference that instead of ED-rumination, general rumination was entered as the potential moderator variable. The interaction effect of this model was non-significant. The detailed information of this model is reported in the supplementary material.

## 4. Discussion

The current study was designed to examine the reliability of a new paradigm to measure attention to food-related stimuli. We also addressed the hypothesis that ED-specific rumination moderates the association between AB to high-calorie foods and eating disorder symptoms. The reliability analyses showed the task as a reliable paradigm for measuring AB to food-related stimuli. The results also supported the hypothesis, by confirming that the strength of the association between AB to high-calorie foods and eating disorder symptoms varied as a function of participants' ED-specific rumination. Specifically, there was a significant positive correlation between AB to high-calorie foods and eating disorder symptoms only among those with higher ED-specific rumination. No such association was observed among participants with relatively lower ED-specific rumination. In what follows, the results relevant to reliability and moderation analyses will be discussed in turn.

A serious limitation with the currently available RT-based AB measures is their low reliability as estimated by indices of internal consistency and stability (e.g., Cisler, Bacon, & Williams, 2009; Field et al., 2016). This poor reliability poses serious limitations in conducting robust research and hinders the scientific progress in this field of research (see Jones, Christiansen, & Field, 2018; Rodebaugh et al., 2016). Therefore, the present study examined the reliability indices of a recently developed free-viewing eye-tracking paradigm within the eating disorder context. The same free-viewing paradigm has been employed within the context of social anxiety (Lazarov et al., 2016), depression (Lazarov et al., 2018), and alcohol consumption (Soleymani et al., 2020) and has shown good to excellent reliability for the dwell-time based indices. The current study was the first that examined the reliability of this paradigm in the eating-disorder context using food-related stimuli. The current results were in line with the previous findings of Lazarov et al. (2016, 2018), and Soleymani et al. (2020). Specifically, the AB measure based on dwell-time showed good reliability while the measures based on the first fixation i.e., first fixation location and latency bias to high-calorie foods indicated low reliability. The pattern of low reliability for the outcome measures based on the early attention such as the first fixation location and latency bias has shown in numerous studies (e.g., Price et al., 2015; Skinner et al., 2018; Soleymani et al., 2020; Waechter, Nelson, Wright, Hyatt, & Oakman, 2014). The low reliability of the early attention outcome measures has been attributed to the fact that less data of the available stimuli presentation time is used to compute them, which in turn leads to less variance between participants for these measures compared to measures based on the late attention outcome such as total dwell-time (Skinner et al., 2018).

The present study also extends our knowledge of the eating disorder literature in important ways, by empirically showing for the first time that ED-specific rumination moderates the association between AB to high-calorie foods and eating disorder symptoms. Specifically, while

[1] Entering the general rumination as the covariate into the model did not change the pattern of results.

**Table 2**
Bivariate correlations between indices of attentional bias and other (criterion) measures.

| | EDEQ | RRS-ED | RRS | RS | Time since last meal | Salience | Appeal | Distress | Self-reported BMI |
|---|---|---|---|---|---|---|---|---|---|
| Dwell-time bias | .04 | -.07 | .11 | -.10 | .14 | .01 | -.07 | -.13 | .00 |
| Latency Bias | -.17 | -.12 | -.19 | -.11 | .07 | -.05 | -.03 | .01 | -.14 |
| First fixation location High-calorie foods | -.03 | -.06 | .06 | -.04 | .07 | -.07 | -.13 | .01 | -.12 |

Note. EDEQ = Eating Disorder Examination Questionnaire, RRS-ED = Ruminative Response Scale for Eating Disorders, RRS = Ruminative Response Scale-short form, RS = Restraint Scale.

**Table 3**
Bivariate correlations between self-reported measures.

| | EDE-Q | RRS-ED | RRS | RS |
|---|---|---|---|---|
| RRS-ED | .84 | | | |
| RRS | .41 | .37 | | |
| RS | .79 | .74 | .41 | |

Note. EDEQ = Eating Disorder Examination Questionnaire, RRS-ED = Ruminative Response Scale for Eating Disorders, RRS = Ruminative Response Scale-short form, RS = Restraint Scale.

**Table 4**
Output of the tested moderation model.

| Variable | Coefficient | SE | *t* | *p* | *CI* |
|---|---|---|---|---|---|
| Entire model $R^2 = 0.73$, $F = 90.50$, $p < 0.001$ | | | | | |
| Dwell-time bias index | −0.00007 | 0.0001 | −0.58 | 0.56 | −0.0003, 0.0001 |
| RRS-ED | 0.21 | 0.013 | 16.16 | <.001 | 0.184, 0.235 |
| Interaction $R^2$ change for the interaction = 0.018 | 0.00003 | 0.00001 | 2.59 | 0.011 | 0.00001, 0.00006 |

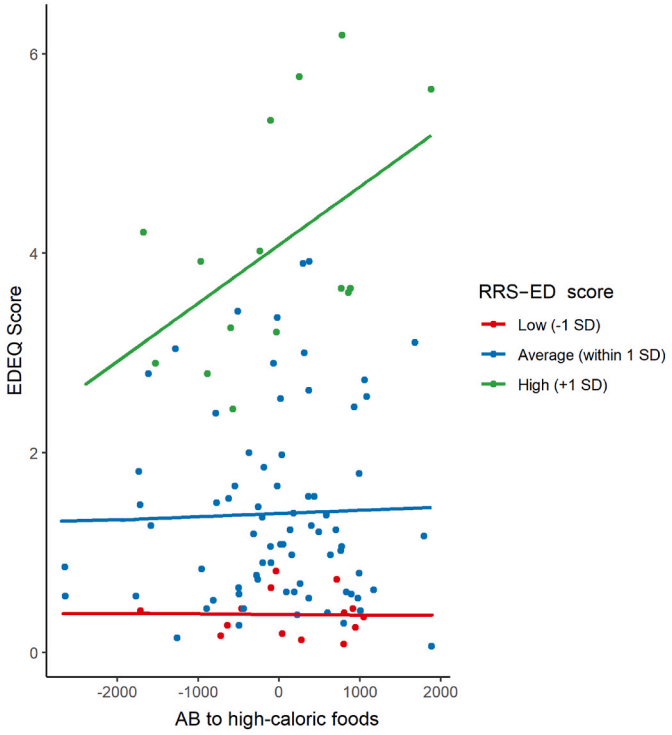


**Fig. 2.** Simple slope of ED-specific rumination moderation effect on eating disorder symptoms and AB to high-calorie foods.

participants with high levels of ED-specific rumination exhibited a positive association between AB to high-calorie foods and eating disorder symptoms, this association was not present among participants with relatively lower levels of ED-specific rumination. It is appropriate to consider how higher ED-specific rumination might results in a positive association between AB to high-calorie foods and eating disorder symptoms. ED-specific rumination has been theorized as an emotion regulation strategy that is characterized by repetitive thinking and introspective focus on negative eating-related thoughts and feelings (Dondzilo et al., 2016; Smith et al., 2018). Therefore, those who excessively engage in rumination specific to eating disorders might find it more difficult to disengage from food-related stimuli such as high-calorie foods that are associated with their concerns and this in turn may increase their eating disorder symptoms (Donaldson et al., 2007).

Our finding that ED-specific rumination moderates the association between AB to high-calorie foods and eating disorder symptoms, even when general rumination is considered, does not exclude the possibility that this general form of rumination might itself also play a role in moderating the association between AB to high-calorie foods and eating disorder symptoms. To assess this possibility, we replaced our measure of ED-specific rumination within the moderation analysis with our measure of general rumination. The moderation effect of the alternative model was non-significant. This indicates that the moderation was carried specifically by ED-specific rumination rather than by the general form of rumination and emphasizes the role of ED-specific rumination in eating disorder symptoms. However, it should be noted that although the interaction of the dwell-time bias index and RRS-ED significantly improved the regression model, the R square change was small.

The present study was the first that examined the reliability of an ecologically valid free-viewing task to assess AB to food-related stimuli, and the first that showed the moderating role of ED-specific rumination in the association between AB to high-calorie foods and eating disorder symptoms. A large sample size was used for the study, however, there are some limitations that should also be noted. First, our participants were unselected female students. It is critical that future studies test whether the current findings replicate among both genders and individuals with a clinically diagnosed eating disorder. Second, our reliability analyses were restricted to a single assessment and stability of the measure in terms of test-retest reliability of the task remains to be determined by future studies. Third, in our free viewing task, the matrices were presented in a fixed order, which renders the task sensitive to individual differences in temporal effects (e.g., learning, fatigue) which may give rise to artificial consistency (inflated Cronbach's alpha). To minimize such biasing effect (i.e., artificial consistency) on Cronbach's alpha, it is recommended to use a random presentation order in future research, as this would turn this artificial consistency effect into random noise. Finally, some studies have shown that a preferential attentional allocation to a particular stimulus type could be due to different AB components i.e., increased attentional engagement or difficulty disengagement from those stimuli (see Dondzilo, Mills, & Rodgers, 2021; Jonker et al., 2020). The current study was not designed to differentiate between these different components; however, an AB toward high-calorie foods could be due to increased attentional engagement with high-calorie food images, reduced attentional disengagement from high-calorie food images, or both. Future studies can

address the question about the specific component(s) of AB that may contribute to elevated eating disorder symptoms. The paradigm used in the current study can be modified to optimally examine different AB components (see Chen, Clarke, MacLeod, Hickie, & Guastella, 2016).

In conclusion, the current findings add to the growing body of empirical work about the reliability of AB measures derived from the new free-viewing paradigm. The present study replicated and extended the findings of previous studies about this paradigm by indicating good reliability of the dwell-time based AB measures in the context of eating disorders. In addition, it contributed to the literature by showing the critical role of ED-specific rumination in eating disorder symptoms. Specifically, the current findings suggested for the first time that elevated ED-specific rumination might be the risk factor for the adverse effects of AB to high-calorie foods on lowering the threshold for developing eating disorder symptoms. As such, we hope the present findings pave the way for future research that further extends our understanding of the role of ED-specific rumination and AB in eating disorder symptomatology, by using reliable measures for the assessment of the relevant constructs.

## Author contributions

All authors have been involved throughout the research process, including the conceptualization, analysis, and discussion of the work. AS and RN also contributed to data collection. All authors have approved the final version of this study.

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## Data accessibility

All data used in the study is available under request and the lead author has full access to the data reported in the manuscript.

## Ethical statement

I hereby confirm that following submitted research article approved by the ethical committee of Psychology department of the University of Groningen (ECP approval code = 18820-S) and all participants received informed consent before taking part in this research.

## Declaration of competing interest

None.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2022.105934.

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