

**An eye-tracking study examining the relationship between males' eating disorder
symptomatology, body mass index, and expectations about
character behavior in text**

Christina Ralph-Nearman, PhD*^{1,2} Madison A. Hooper, MA, MEd³, & Ruth Filik, PhD¹

¹School of Psychology, University of Nottingham, United Kingdom

Presently at: ²Department of Psychological and Brain Sciences, University of
Louisville, KY, United States

³ Department of Psychology, Vanderbilt University, Nashville, TN, United States

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***Correspondence to:**

Dr. Christina Ralph-Nearman

University of Louisville

Department of Psychological & Brain Sciences

Louisville, Kentucky

United States

Email: ChristinaRalphNearman@gmail.com

Tel: +1 502-852-7710

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Abstract

Eating disorder prevalence is increasing in males, perhaps more rapidly than in females. Theorists have proposed that cognitive biases are important factors underpinning disordered eating, especially those related to food, body, and perfectionism. We investigated these factors in relation to males' eating disorder symptomatology in the general population by using eye-tracking during reading as a novel and implicit measure. 180 males' eye movements were monitored while they read scenarios (third-person in Experiment 1 ($n=90$, 18-38($M_{age}=21.50$, $SD=3.65$)); second-person in Experiment 2 ($n=90$, 18-35($M_{age}=20.50$, $SD=2.22$)) describing characters' emotional responses (e.g., *upset*) to food-, body image-, and perfectionism-related events. Participants' eating disorder symptomatology was then assessed, and body mass index (BMI) was calculated. Results showed processing of characters' emotional responses (detected via eye-tracking) to body- and perfectionism-related events for third-person scenarios was related to eating disorder symptomatology. Processing of characters' emotional responses to body-related events for second-person scenarios was related to males' BMI. The moment-to-moment processing of characters' emotional responses to food-related scenarios was not related to eating disorder symptomatology or BMI. Findings support theories that include body- and perfectionism-related cognitive biases as underlying mechanisms of eating disorder symptomatology and the use of implicit measures of cognitive processes underlying males' eating disorder symptomatology.

Keywords: Eating disorders; perfectionism; body image; eye-tracking; reading; body mass index

An eye-tracking study examining the relationship between males' eating disorder symptomatology, body mass index, and expectations about character behaviour in text

Eating disorder prevalence and incidence rates are increasing in males, perhaps more rapidly than in females (Micali et al., 2013). Certain information processing strategies may be influential in the development and maintenance of eating disorders (see e.g., Ralph-Nearman et al., 2019 for a review). However, many current theories debate whether it is the way in which body-, food-, or perfectionism-related information is processed that is primarily associated with eating disorder symptomatology (e.g., Brooks et al., 2011; Fairburn et al., 2003; Shafran et al., 2007; Treasure & Schmidt, 2013). Furthermore, attentional biases with eating disorder salient stimuli have been shown to be related to body mass index (BMI). That is, higher or lower BMI in individuals with an eating disorder or in the general population has been shown to be related to attending toward or avoiding different types of foods (e.g., Calitri et al., 2012; Giel et al., 2011; Nummenmaa et al., 2011), and body images (e.g., Gao, et al., 2013). Still, there is a lack of examination of cognitive processing related to eating disorder symptomatology and BMI, especially in males. Better understanding of the cognitive mechanisms and information processing underlying eating disorders may be key to developing prevention and treatment methods.

Information processing strategies related to eating disorder symptoms

Current evidence in support of various information processing strategies is mixed. For instance, it has been suggested that attentional biases in the direction of negative and neutral body- and/or food-related stimuli and avoidance of positive food-

related stimuli are related to eating disorder symptoms (Brooks et al., 2011; Shafran et al., 2007). Further evidence points to an increased sensitivity toward or avoidance of stimuli related to fatty food and eating; these types of stimuli may be considered threatening to those over-concerned with weight gain (e.g., Waller & Meyer, 1997). Others point to perfectionism influencing a dichotomous perspective (i.e., perfect vs. flawed), which may create the perception that successfully attaining the rigid restrictive eating behaviour goals of anorexia nervosa, for instance, is being successful overall (see e.g., Slade, 1982). Some theorise that a perfectionistic, inflexible, focused information processing style makes an individual more prone to the development and maintenance of an eating disorder (Treasure & Schmidt, 2013), or that the over-evaluation of achieving (i.e., perfectionism) leads to over-concern with one's body shape and weight, where one's body becomes the focus of perfection and self-worth (Fairburn et al., 2003). Others suggest that general cognitive inflexibility or rigidity and heightened attention to detail are associated to increased eating disorder symptoms (e.g., Wang et al., 2019).

Lack of research examining disordered eating behaviour in males

Importantly, most theories based on cognitive processing in eating disorders do not differentiate between symptomatology of eating disorders in males and females. Also, studies investigating information processing strategies associated with eating disorder symptomatology rarely include male participants. For instance, Dobson and Dozois' (2004) meta-analysis of studies investigating cognitive biases underlying eating disorders using the Stroop task found that only three of the 26 studies reviewed included any male participants at all, with only one study (Green & McKenna, 1993) investigating gender differences in relation to body- and food-related stimuli. A recent

systematic review of methodologies used to investigate the visual information processing strategies associated with eating disorder symptomatology (Ralph-Nearman et al., 2019) also reported only one study which compared males and females (Mobbs et al., 2011) in a go/no-go task. In addition, no studies that were eligible for the review had used perfectionism-related stimuli.

Using eye-tracking to investigate information processing strategies

Eye-tracking is a noninvasive method for investigating cognitive processing, including direction, duration, and avoidance of eye fixations and movements. While this method is often utilised in other fields, there is a limited number of eye-tracking studies related to eating disorder symptomatology. However, specific cognitive biases have been detected with this tool related to both BMI and eating disorder symptoms (see e.g., Ralph-Nearman et al., 2019, for a review). One recent study aimed to investigate information processing strategies under more natural conditions, specifically, by tracking eye movement behaviour during a natural reading task (Ralph-Nearman & Filik, 2018a). In this prior study, female participants had their eye movements monitored while they read body-, food-, or perfectionism-related texts in third-person perspective (Experiment 1) or second-person perspective (Experiment 2). The texts ended with a sentence containing a critical emotion-based word that either “matched” or “mismatched” one’s expectations concerning how the character might react (e.g., *pleased* by losing fat^{match} / *pleased* by gaining fat^{mismatch}). Following the reading task, participants completed the Eating Disorder Examination Questionnaire (EDE-Q 6.0) and their body mass index (BMI) was calculated. Results suggested that processing of emotional responses in perfectionism- and body-related scenarios, but not food-related scenarios, was related to females’ eating disorder symptomatology and BMI.

When readers encounter unexpected information in text (such as an unexpected emotional response), there are a number of ways in which this processing difficulty may be reflected in their eye movement behaviour. For example, they might slow down immediately on encountering the unexpected emotion word (or shortly after) (e.g., Clifton et al., 2007; Rayner, 1998), they may go back and re-read earlier portions of the text in order to try and make sense of the word in the context in which it appears (e.g., Filik, 2008; Rayner et al., 2004; Warren et al., 2008), or they may generally spend longer reading and re-reading the emotion word and surrounding text. Later on, they may avoid certain areas of texts they have already processed; avoiding the emotional processing of disease-salient stimuli (e.g., Cisler & Koster, 2010; Giel et al., 2011). Ralph-Nearman et al. (2019) conclude in their review of attentional biases related to eating disorders, that studies utilizing implicit methods, such as eye-tracking, may detect subtle processing difficulty with disease-relevant information. Thus, we may expect to observe information processing difficulty with unexpected character responses (e.g., pleased by something that would not be pleasing) within disease-salient contexts (e.g., food, body, perfectionism) to be associated with more eating disorder symptoms by eye-tracking participants' reading of expected and unexpected scenarios.

The current study

To start addressing the lack of eating disorder-related research in males, in the current study we conducted two eye-tracking experiments wherein male participants from the general population read food-, body-, and perfectionism-related texts, in which the last sentence included a word (e.g., *pleased*) that either “matched” or “mismatched” with what the reader would anticipate (following Ralph-Nearman & Filik, 2018a, see

Table 1 for example stimuli). After the eye-tracking task, participants' eating disorder tendencies were assessed and their BMI was calculated.

The cognitive theories discussed earlier do not distinguish between symptomatology of eating disorders in males and females. However, some recent evidence suggests that there may be information processing differences related to body image and food in males compared to females (e.g., Ralph-Nearman & Filik, 2018b). For instance, males and females may both be pleased to avoid weight from adiposity, and therefore both “match” being pleased not to get fatter, whereas they may process information relating to idealised bodies differently (e.g., Cho & Lee, 2012). Furthermore, males may display different nutritional attitudes and food selection than women (e.g., Beardsworth et al., 2002). Specifically, Beardsworth et al. (2012) found that women were more likely to implement dietary changes aimed at weight loss, to be preoccupied with a desire for thinness, and to report body dissatisfaction than men.

Aim and predictions

If males' information processing strategies were similar to those found for females in our previous eye-tracking experiment (Ralph-Nearman & Filik, 2018a), then we expected to find for males in the present study that only perfectionism and body image were the key factors, and not food, as this was the pattern of effects previously found for females. That is, the relative level of processing difficulty experienced for comprehending a *pleased* response to gaining weight and performing sub-optimally on a task, compared to a pleased response to losing weight and performing a task perfectly (for example), to be associated with EDE-Q and BMI. Specifically, the size of the “mismatch effect” (i.e., reading times for mismatch minus match conditions) during the reading of the critical sentence in perfectionism- and body-related stimuli, but not food

(see Table 1 for material examples), to be related to higher eating disorder symptomatology (higher EDE-Q scores). Secondly, that the size of the perfectionism- and body-related mismatch effects would be associated with males' BMI.

These results would support theories which suggest that perfectionism-related cognitive mechanisms (e.g., Treasure & Schmidt, 2013), body-related cognitive mechanisms (e.g., Shafran et al., 2007), and/or perfectionism and body information processing strategies together underlie eating disorder symptomatology in males (Fairburn et al., 2003). Alternatively, we would predict that mismatch effects while reading food-related stimuli would be related to higher eating disorder symptoms, if cognitive biases relating to food-related stimuli are key, as Brooks et al. (2011) suggest.

Experiment 1

Method

Participants

A community sample of native English-speaking males ($N=90$), with ages ranging from 18-38 ($M = 21.50$, $SD = 3.65$) were recruited with advertisements to take part in a reading/eye-tracking study. To thank them for their participation in the study, participants were entered in a £25 prize draw. Participants had normal or corrected-to-normal vision, reported no history of reading disabilities or neurological problems, and there were no self-reported eating disorder diagnoses (not an exclusion criterion). This study was approved by the appropriate Ethics Review Board (#567), and written consent was obtained from all participants prior to participation. Participants were not informed of the explicit aims of the study before taking part, in order to avoid biasing their reading behaviour, but were fully debriefed after participation.

Materials and Design

Thirty-six short texts which consisted of food-, body image-, or perfectionism-related third-person scenarios, based on those used in Ralph-Nearman and Filik's, (2018a) female eye-tracking studies, were slightly altered to include male characters instead of female characters. Materials were thoroughly pre-tested with two individual groups of men recruited from the same population as those who participated in the eye-tracking experiments. The first pre-test was used to determine that each scenario's three dimensions were interpreted as intended (i.e., principally related to food-, body-, or perfectionism). The second pre-test was to make sure that each dimension included an appropriate "Match" and "Mismatch" in each scenario, that is, that each scenario and dimension (food-, body-, or perfectionism-related items) had a version in which the character's emotional response would be *expected* by male participants ("Match"), and also a version that would be *unexpected* by the majority of participants ("Mismatch") (see Table 1 for material examples, and the Supplement for full details of the pre-tests).

Experimental stimuli were counterbalanced across six stimulus lists. Specifically, each participant saw each item in one of the six possible conditions, totaling 36 experimental items, along with 46 "distractor" items. A critical emotion-based word (e.g., *pleased*, *upset*) within a target sentence (e.g., *He is very pleased/upset to have done that.*) was displayed on the screen as the last sentence of each scenario, which "matched" (e.g., pleased with losing a lot of fat) or "mismatched" (e.g., pleased with gaining a lot of fat) with readers' expectations of how the character might react in the scenario. Therefore, the experiment had a 3 *dimension* (food vs. body image vs. perfectionism) x 2 *match* (match vs. mismatch) design, with both dimension and match as within-subjects and within-items factors. Participants' EDE-Q 6.0 score (Fairburn & Beglin, 2008) was obtained, and weight and height were measured to calculate BMI.

The EDE-Q is a 28-item scale, which assesses eating behaviours and attitudes in the past 28 days using response scales that range from 0 (no days/not at all) to 6 (everyday/markedly). There are four eating symptomatology subscales (Restraint, Shape, Weight, and Eating concerns). The Global EDE-Q score is the average of the four subscales, which indicates overall eating disorder symptomatology. A Global EDE-Q score of ≥ 1.68 threshold is shown to indicate clinically significant eating pathology in men (see Schaefer et al., 2018), with a Global EDE-Q score of 0 representing the absence of eating disorder symptoms, and 6 representing severe/extreme eating disorder symptoms. Community norms for young men are established ($M = 1.09$, $SD = 1.00$; Lavender et al., 2010).

----Insert Table 1 about here----

Procedure

Participants' viewing was binocular, and one eye position was tracked every millisecond (1000 Hz) by an SR Research EyeLink 1000 eye-tracker. The text materials were displayed on a 17-inch monitor 56 cm from the participants' eyes. Participants were given a written consent form and instructions, and any prior psychological diagnoses (such as an eating disorder) or neurological issues were self-reported by participants; none were identified. Then participants were instructed to read normally, as they sat at the eye-tracker, using a chin and forehead rest for optimal accuracy. Participants completed a full-screen 9-point calibration procedure with an average error of less than 0.5 degrees of visual angle, and two practice trials before the start of the experiment. Participants read each item naturally, at their own pace, and then continued to the next trial by pressing the right-hand trigger on a hand-held controller. After 25%

of trials, a comprehension question was displayed (e.g., *Did Kade take an exam in the scenario? Yes/No*). An average accuracy score of 92% indicated that participants were engaged in the task. Participants then completed the EDE-Q 6.0. This was followed by measuring participants' height and weight. Finally, participants were debriefed and given information about eating disorder and counseling resources.

Eye-tracking Data Analysis

The target sentence, which contained the emotional “match” or “mismatch” response from the character, was divided into analysis regions (see Table 1), and reading times are reported for these regions. *Region 1* was the initial segment of the target sentence (e.g., *He is very*), which led up to the critical emotional target word. *Region 2* contained the target word (e.g., *pleased, upset*). This emotion word was the first point at which participants would be able to interpret the emotional response as either matching or mismatching their expected response within the context. *Region 3* was composed of the final segment of the target sentence (e.g., *to have done that*). Fixations under 80 ms were integrated into larger adjacent fixations within one character and fixations under 40 ms which were not within three characters of another fixation were deleted, as were fixations over 1200 ms. Any trials in which the second sentence of the scenario (i.e., the sentence containing the contextual information that was necessary to infer whether the target sentence matched or mismatched the emotional response that would be expected) was not read, and those trials with zero first-pass reading times in two or more adjacent regions (i.e., any trials with significant track losses) were removed (8.24% of the data were removed).

We report a number of standard measures of reading time, as reported in our similar study with female participants (Ralph-Nearman & Filik, 2018a). Specifically,

we report *first fixation duration* (i.e., the duration of the initial fixation within a region of interest) and *first-pass reading time* (i.e., the summed duration of all fixations within a region of interest, from first fixation until the reader moves to a different region) in Regions 2 and 3. This allows us to capture participants' immediate responses to the emotion word, and any "spillover effects" (e.g., Clifton et al., 2007), that is, reflective processing that may occur after the reader's eye movements have continued to the region just after the critical target word (Rayner, 1998).

To capture behaviours which involve going back to re-read earlier parts of the scenario to make sense of unexpected responses described within the target sentence we report *regression path reading times* (i.e., the sum of the duration of all the fixations from when the eyes first enter the region of interest, until they pass to the right of the region, including any time re-reading earlier text before continuing forward) in Regions 2 and 3. To capture overall processing difficulty, we report the *total reading time* (i.e., the sum of the duration of all fixations within a region of interest) for each region within the target sentence.

All trials with zeros for each reading time measure in each region were removed prior to analysis, which resulted in a normal range of data loss (e.g., Rayner, 2009): 12.95% of data in *Region 1*, 10.83% in *Region 2*, and 0.24% in *Region 3*, for first fixation duration, first-pass reading time, and regression path reading time; and 1.88% of data in *Region 1*, 7.33% in *Region 2*, and 0.20% in *Region 3* for total reading times.

Relationship Between Reading Behaviour and Eating Behaviour

We calculated a mismatch effect score (mismatch – match reading times) for each measure of reading time in each region for each dimension, and to determine which variables were associated with BMI and EDI-Q, we utilised a penalty-based

model selection approach called GAMSEL (Generalized Additive Model Selection; Chouldechova & Hastie, 2015). GAMSEL uses overlap group lasso penalties for fitting sparse generalized additive models and is well-equipped to handle situations with many potential predictors. GAMSEL provides several advantages over classic regressions. Most importantly, GAMSEL selects between fitting each component as a zero, linear, or nonlinear effect. Traditional regression procedures assume linearity between the response variable and covariate, however, in practice this assumption is often violated, and more flexible approaches are needed to capture the true underlying nonlinear relationship. GAMSEL is able to capture strong non-linear relationships that may have been overlooked if traditional regression procedures are used (Chouldechova & Hastie, 2015). For a detailed description of the GAMSEL procedure we direct the interested reader to Chouldechova and Hastie (2015).

Twenty-seven predictors representing the size of the mismatch effect (mismatch – match) for each dimension (food, body, and perfectionism) were entered as potential predictor variables, and the participant's EDE-Q score and BMI served as the criterion variables. Statistical analyses were performed in R (R Core Team, 2020) using the `gamsel` package (Chouldechova et al., 2018). Final models were fit using the `mgcv` package (Wood, 2021) to determine the fit of the model. Residual plots were also examined to ensure that model assumptions were met.

Results

Eye-tracking results

Prior to analysis, the distributions of the dependent variables were examined. As is typical of reading time data, the distributions were right skewed, however, the type I

error rates associated with F-tests are relatively robust to non-normality¹ (Myers et al., 2010). Two 3 *dimension* (food vs. body image vs. perfectionism) x 2 *match* (match vs. mismatch) repeated-measures ANOVAs, one treating participants ($F1$) and one treating items ($F2$) as random variables, in order to generalize effects across both participants and materials (see Clark, 1973), were used to analyze the data from each of the three regions in the target sentence (see Table 2 for descriptive statistics; Table 3 for ANOVA results). If sphericity could not be assumed, according to Mauchly's Test of Sphericity, then Greenhouse-Geisser was used. Post-hoc Bonferroni corrected ($p = .05/6 = .008$) paired t-tests were performed on the average score independent of the match ($(\text{match} + \text{mismatch})/2$) for any fully significant main effects of dimension. A power analysis using G*Power3 (Faul et al., 2007) was performed with results from a previous study (Ralph-Nearman & Filik, 2018a) that found significant associations between mismatch scores and dimensions with females. With our proposed group sample size of $n = 90$ in each present experiment, $\alpha = 0.05$, and with similar effect sizes as the previous study ($1 - \beta > 0.95$), we will maintain sufficiently acceptable statistical power.

As expected, there were longer total reading times in mismatching than matching conditions in all three regions of the target sentence (e.g., *He is very*^{Region 1}, *pleased*^{Region 2}, *to have done that.*^{Region 3}), and in first-pass and regression path reading times in Region 3. The mismatch effect was not significant in early reading time measures (first fixation duration, first-pass) in Region 2 (the region containing the emotion word), which demonstrates that the readers did not immediately pick up on the mismatch. Rather, the effects appearing in first-pass and regression path reading times in Region 3, and total reading times in Regions 1, 2, and 3 suggests that participants

¹ The dependent variables were log transformed and the ANOVA analyses for Study 1 and 2 were repeated. Identical results were obtained in both analyses.

detected the mismatch relatively late, and then re-read all parts of the text in mismatching conditions to try to make sense of the scenarios that described an emotional response that did not match what they expected.

Regression path reading times for Region 3 also showed a main effect of dimension. Paired samples *t*-tests with Bonferroni correction ($p < .008$) indicated that the average for the match and mismatch conditions for the perfectionism dimension ($M = 1377$, $SE = 102.5$) was significantly higher than the food dimension ($M = 1103$, $SE = 68.2$), $t_1(89) = 4.28$, $p < .001$; $t_2(35) = 4.62$, $p = .001$, and also higher than the body image dimension ($M = 1139$, $SE = 65.7$), $t_1(89) = 2.67$, $p = .001$; $t_2(35) = 2.80$, $p < .01$ by participants and by items. There were no significant differences between food and body image dimensions ($ts < .79$, $ps > .43$). No other effects were significant by both participants and items.

In sum, there were significantly longer total reading times for mismatching than matching dimensions across all analysis regions, as well as for first-pass and regression path reading times in Region 3. This did not interact with dimension (e.g., food vs. perfectionism vs. body).

-----Insert Table 2 about here-----

-----Insert Table 3 about here-----

BMI and EDE-Q 6.0 Score Analysis

Participants' BMI (Kg/M^2) ranged from 17.17 (underweight) to 39.97 (obese) ($M = 24.51$, $SD = 4.14$). Participants' Global EDE-Q 6.0 scores (four subscales summed and averaged) which may range from 0 (absence of eating disorder symptomatology) to

6.0 (extreme/severe eating disorder symptomatology), ranged from 0 to 3.81 ($M = 1.03$, $SD = .76$). This average is similar in the current study to reported community norms for young men ($M = 1.09$, $SD = 1.00$; Lavender et al., 2010). Despite no prior formal eating disorder diagnoses being self-reported, 15 participants (16.7% of the sample) met the ≥ 1.68 threshold for clinically significant eating pathology in males (see Schaefer et al., 2018), with the high end of the participants' range of Global EDE-Q scores (3.81) exceeding the established clinical eating disorder norms for men with an eating disorder diagnosis ($M=3.02$, $SD=1.64$; Smith et al., 2017). The Cronbach's Alpha coefficient for the EDE-Q was 0.87, indicating a high level of internal consistency.

Examining the Relationship Between Reading Behaviour and Eating Behaviour

Pre-analysis checks indicated no concerns for EDE-Q 6.0 related regression (Cook's Distance $\leq .010$; Durbin-Watson = 1.955; Variance Inflation Factor (VIF) = 1.022). Cook's Distance revealed one outlier (value = 14.52), which was removed for the BMI-related regression, after which tests indicated there were no other concerns (Cook's Distance $\leq .115$; Durbin-Watson = 2.034; VIF = 1.136). Three of the 27 potential predictor variables submitted to the GAMSEL procedure were retained in the prediction of eating disorder symptomatology (EDE-Q) (Figure 1). Two of the fitted functions were shrunk to a linear fit (mismatch effects for body image-related materials in total reading time for *Region 1* and perfectionism-related materials in first fixation duration for *Region 3*). In contrast, the functional form of the relationship between eating disorder symptomatology and mismatch scores for perfectionism-related materials in total reading time for *Region 3* was found to be nonlinear and best described by a concave curve. Participants with smaller mismatch effects for body image-related materials in total reading time for *Region 1* showed greater levels of

eating disorder symptomatology, which would be in contrast to the prediction of a larger mismatch effect related to higher eating disorder symptomatology levels. However, in first-fixation duration for *Region 3*, larger perfectionism-related mismatch effect scores were associated with higher eating disorder symptomatology, which is in the expected direction. The relationship between mismatch effects for perfectionism-related materials in total reading time in *Region 3* and eating disorder symptomatology was found to be nonlinear, such that participants who similarly spent larger amounts of time attending to both the mismatch and match conditions demonstrated greater levels of eating disorder symptomatology (Table 4 and Figure 2). Inspection of residual plots indicated that there were no serious departures from normality and homoscedasticity.

The GAMSEL procedure did not retain any of the mismatch scores in the prediction of BMI.

---Insert Figure 1 about here---

----Insert Table 4 about here----

---Insert Figure 2 about here---

In summary, results from Experiment 1 suggest that the way in which participants process perfectionism- and body image-related information is associated with eating disorder symptomatology and BMI, which was not the case for food-related information. Possible interpretations of specific findings will be discussed in the General Discussion.

As noted in Ralph-Nearman and Filik (2018a), evidence suggests that second-person perspective (i.e., “You”) may increase emotional personalization of scenarios, because the scenario is directed at the reader rather than being about a fictional character (see Brunyé et al., 2011). Therefore, to be more assured that our readers were

relating with the scenarios, we exchanged third-person fictional characters (i.e., “Kade”) with second-person-perspective in Experiment 2 (i.e., we replaced “Kade” and “He” with “You”).

Experiment 2

Method

Participants

Fitting the same criteria as Experiment 1, 90 different males aged 18-35 ($M = 20.50$, $SD = 2.22$) participated in Experiment 2.

Stimulus Materials, Design, Procedure & Eye-tracking Analysis

The stimulus materials from Experiment 1 were slightly altered to be directed at the participant in second-person (i.e., “You” replaced “He”) (see Table 5). Otherwise, the design and procedure were all identical to Experiment 1.

----Insert Table 5 about here----

Prior to analysis, 10.83% of the data were removed due to track losses, following the same procedure as in Experiment 1. All trials with zeros for each reading time measure in each region (only prior to each of the individual analyses) were removed: 23.96% of data in *Region 1*, 10.38% in *Region 2*, and 1.90% in *Region 3* for first fixation duration, first-pass, and regression path reading time; and 6.27% in *Region 1*, 6.99% in *Region 2*, and 1.87% in *Region 3* for total reading times, which is in the normal range (Rayner, 2009). An average accuracy score of 92% for the comprehension

questions that were presented following 25% of trials confirmed that the participants were engaged in the task.

Results

Eye-tracking results

Eye-tracking analysis was also identical to Experiment 1 (see Table 6 for descriptive statistics; Table 7 for ANOVA results). Again, results showed longer total reading times for mismatching than matching conditions in all three regions of the target sentence (e.g., *You are very^{Region 1} pleased^{Region 2} to have done that.^{Region 3}*), and in regression path reading time in Region 3. Regression path reading time also showed a main effect of dimension in Region 3. Post-hoc paired samples *t*-tests with Bonferroni correction ($p < .008$) indicated that the mean score averaged over match and mismatch conditions for the perfectionism dimension ($M = 1440, SE = 93.7$) was significantly higher than the food dimension ($M = 1169, SE = 78.8$), $t_1(89) = 4.92, p < .001$; $t_2(35) = 3.87, p < .001$, and the body dimension ($M = 1189, SE = 74.9$), $t_1(89) = 3.76, p < .001$; $t_2(35) = 2.90, p = .006$. There were no differences between food and body dimensions ($ts < .40, ps > .692$). No other effects reached significance by both participants and items.

---Insert Table 6 about here---

---Insert Table 7 about here---

BMI and EDE-Q 6.0 Score Analysis

BMI ranged from 15.6 (underweight) to 35.4 (obese) ($M = 23.86, SD = 3.85$), and Global EDE-Q 6.0 scores ranged from 0 to 3.79 ($M = 1.00, SD = .86$), again similar to male community norms ($M = 1.09, SD = 1.00$) (Lavender et al., 2010). Despite no self-reported prior eating disorder diagnoses, six participants (6.7% of the sample) met

the ≥ 1.68 threshold for males' clinically significant eating pathology on the EDE-Q (see Schaefer et al., 2018). As with Experiment 1, the high end of participants' range of Global EDE-Q scores (3.79) exceeded the clinical norms average (3.02) for males diagnosed with an eating disorder (e.g., Smith et al., 2017). The Cronbach's Alpha coefficient was 0.91, indicating a high level of internal consistency.

Examining the Relationship Between Reading Behaviour and Eating Behaviour

Mismatch scores were calculated, and then the GAMSEL procedure was used to determine which variables are associated with EDE-Q and BMI. No concerns for EDE-Q 6.0 or BMI regressions were identified in pre-analysis checks (Cook's Distance < 1; Durbin-Watson = 2.074; 2.610). No mismatch scores were selected in the prediction of EDE-Q, but the GAMSEL procedure selected one of the 27 potential covariates in the prediction of BMI (Figure 3). Mismatch effects for body image-related materials in total reading time for *Region 3* were found to have a linear effect on BMI, such that larger mismatch effects were associated with higher BMI (Table 8 and Figure 4).

---Insert Figure 3 about here---

---Insert Table 8 about here---

---Insert Figure 4 about here---

General Discussion

There were several key findings in the current study. Firstly, a significant mismatch effect was observed for all three dimensions (food-, body image-, and perfectionism) in both experiments. These results support and extend the findings of our previous study with female participants (Ralph-Nearman & Filik, 2018a). It appears that similarly to females, males also generally expected a negative emotional response

related to eating unhealthy food, gaining fat/weight, and making slight mistakes, and a positive response related to losing fat/weight, eating healthier/less, and not making mistakes. These results also support a recent study investigating implicit and explicit anti-fat bias including 19,534 males, which suggested that males and females possessed both implicit and explicit anti-fat bias, or negative views about higher weight (Elran-Barak & Bar-Anon, 2018).

Effects relating to body image

Results of analyses examining the relationship between reading behaviour for body image related scenarios and eating behaviour revealed a number of findings. Firstly, in Experiment 1, the size of the mismatch effect in total reading times for Region 1 was related to higher eating disorder symptomatology. Specifically, a *smaller* mismatch effect in total reading times for Region 1 in body-related texts was associated with participants' *higher* scores on the EDE-Q. As total reading times include re-reading, this may demonstrate that male participants have avoided re-reading early portions of the critical sentence when the text did not fit with their expectations (e.g., pleased with gaining fat). A similar avoidant pattern was reported for females, but with perfectionism-related texts (Ralph-Nearman & Filik, 2018a). Together, these findings support the suggestion that people may avoid stimuli perceived as threatening to their self-image (Waller & Meyer, 1997). However, results suggest a difference between the current males' information processing and a prior females' information processing related to eating disorder symptomatology (Ralph-Nearman & Filik, 2018a). Specifically, that males are more avoidant of negative body image related stimuli, whereas females may be more avoidant of stimuli referring to imperfection.

Furthermore, in Experiment 2, a *larger* mismatch effect in total reading times for Region 3 (the text immediately following the emotion word) in body-related texts was associated with participants' *higher* BMI. These findings support those from other studies that report a positive association between higher BMI and more eating disorder symptoms (e.g., Ralph-Nearman et al., 2020; Rø et al., 2012; Stice et al., 2002), as well as the relationship between BMI and attentional biases (e.g., Gao, et al., 2013).

Together, these results suggest that eye-tracking may detect reading behaviours of body-related texts that are associated with severity of eating disorder symptomatology and BMI in males (see Grilo et al., 2005), and this relationship may change depending on how the reader relates to the scenario (i.e., second-person-perspective vs. third-person-perspective). Specifically, when males processed unexpected (compared to expected) negative body image related texts about another character (Experiment 1), they may have avoided re-reading portions of the target sentence, which was related to more eating disorder symptoms. In contrast, when males processed unexpected negative body image related information about themselves (Experiment 2), they reflected for a longer period of time just after the unexpected emotional word (e.g., *pleased* about gaining fat). This extended reflection was related to participants' higher BMI.

Effects relating to perfectionism

The size of the mismatch effect for perfectionism-related materials was associated with participants' eating disorder symptomatology in Region 3 in Experiment 1 (that is, for third-person scenarios). Specifically, results for perfectionism-related materials showed that a larger mismatch effect in first-fixation duration for Region 3 were associated with higher EDE-Q scores. Therefore, those with higher levels of eating disorder symptomatology spent longer processing emotional responses that do not fit

with what was anticipated (e.g., being pleased about failures). This processing difficulty pattern shown in males for third-person perfectionism-related scenarios was also reported in females for second-person perfectionism-related materials in relation to eating disorder symptoms (see Ralph-Nearman & Filik, 2018a). In addition, our analyses had the ability to detect a non-linear relationship between total reading time for perfectionism-related materials for Region 3 and higher EDE-Q scores. These non-linear results suggest that participants with higher levels of eating disorder symptomatology reflected longer on both those perfectionistic scenarios that agreed with their worldview and those that were unexpected than those with fewer symptoms. These reading behaviours may support eating disorder theories, such as the Cognitive Interpersonal Model (Treasure & Schmidt, , 2013), which propose that higher levels of perfectionistic processing are demonstrated in individuals with an eating disorder. Lastly, inspection of residual plots indicated that the model assumptions were reasonably satisfied.

Together, these results suggest both sex and perspective-taking differences (third-person vs. second-person) when processing unexpected emotional perfectionism-related responses, which is related to eating disorder symptomatology (see Glenberg et al., 2009).

Limitations

It is important to consider some of the potential limitations of the current study. Firstly, although there were some differences in the pattern of effects that were observed between third-person (Experiment 1) and second-person perspectives (Experiment 2), we cannot be certain of which perspective participants were actually taking while they were reading the scenarios. Additionally, although we observed a significant mismatch

effect for food-, body-, and perfectionism-related materials, we cannot rule out that it may be easier to imagine contexts in which someone is pleased with putting on a few pounds or eating a tub of ice cream, but harder to imagine a context in which someone is pleased to make a mistake. Further investigation may be directed by these limitations. For example, examining perspective differences more deeply, and investigating context effects. Finally, it is important for future studies to generalise beyond native-English speakers, and to extend this research within clinically diagnosed populations.

Conclusions and implications for theory

These experiments are the first to our knowledge to utilize moment-to-moment measures of language processing to investigate cognitive mechanisms related to eating disorder symptomatology and BMI in males. The results support theories which include perfectionistic cognitive mechanisms and information processing style may be related to the development and maintenance of eating disorder symptoms, such as the Cognitive Interpersonal Model (Treasure & Schmidt, 2013). As findings suggest both general perfectionism and body image related information processing are important underlying cognitive mechanisms of eating disorder symptomatology in males, and extend the Transdiagnostic Model of Eating Disorders (Fairburn et al., 2003) and proposed overall cognitive rigidity conceptualizations (e.g., Wang et al., 2019). The current results are supportive of similarities in the factors underlying eating disorder symptoms reported in female studies, including both perfectionism- and body image. Interestingly, for both males and females, the moment-to-moment processing of characters' emotional responses to food-related scenarios was not related to eating disorder symptomatology or BMI. Together, results provide further evidence that eye-tracking during reading may

be informative regarding the cognitive mechanisms related to eating disorder symptomatology and BMI generally, but also in males specifically.

The current results also further support previous research suggesting that males with higher levels of eating disorder symptomatology: 1) have trouble shifting attention during early information processing (e.g., larger perfectionism-related first-fixation mismatch effect scores being related to increased eating disorder symptoms) (e.g., Lang et al., 2014; Roberts et al., 2007), and 2) tend to avoid disease-salient information in later information processing (e.g., smaller body-related total reading times mismatch effect scores in Region 1 being related to increased eating disorder symptoms) (e.g., Cisler & Koster, 2010). The present work is an initial step in examining this issue and further work is needed, such as replication and extension of this work to examine other cultures and clinical samples. Next steps are to examine whether these results replicate, and if these processing difficulties may identify males in the general population who are at risk for an eating disorder as a preventative measure. Also, to investigate if these specific processing styles may be altered to reduce eating disorder symptomatology, in order to be implemented into clinical practice for males.

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Upon reasonable request, the data will be shared.

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Tables

Table 1.

Example Material from Experiment 1 with Analysis Regions.

Scenario Type	Example
<i>Food-related Match</i>	Kade stops by the shop on his way home from work. He gets a large tub of ice cream, and goes home and eats a small portion./ He is very <small>Region 1</small> / pleased <small>Region 2</small> / to have done that. <small>Region 3</small> /
<i>Food-related Mismatch</i>	Kade stops by the shop on his way home from work. He gets a large tub of ice cream, and goes home and eats the whole thing./ He is very <small>Region 1</small> / pleased <small>Region 2</small> / to have done that. <small>Region 3</small> /
<i>Body image-related Match</i>	Kade goes in for a regular check-up. His doctor comments that he has lost quite a bit of fat since his last appointment./ He is very <small>Region 1</small> / pleased <small>Region 2</small> / to have done that. <small>Region 3</small> /
<i>Body image-related Mismatch</i>	Kade goes in for a regular check-up. His doctor comments that he has gained quite a bit of fat since his last appointment./ He is very <small>Region 1</small> / pleased <small>Region 2</small> / to have done that. <small>Region 3</small> /
<i>Perfectionism-related Match</i>	Kade works on creating music and sounds for a soundtrack. He listens to what he created and he notices that every note flows together perfectly./ He is very <small>Region 1</small> / pleased <small>Region 2</small> / to have done that. <small>Region 3</small> /
<i>Perfectionism-related Mismatch</i>	Kade works on creating music and sounds for a soundtrack. He listens to what he created and he notices that not every note flows together perfectly./ He is very <small>Region 1</small> / pleased <small>Region 2</small> / to have done that. <small>Region 3</small> /

Table 2.
Descriptive Statistics for Experiment 1.

Region	Measure (ms)	Food Match <i>M</i> [95% <i>CI</i>]	Food Mismatch <i>M</i> [95% <i>CI</i>]	Perfectionism Match <i>M</i> [95% <i>CI</i>]	Perfectionism Mismatch <i>M</i> [95% <i>CI</i>]	Body Match <i>M</i> [95% <i>CI</i>]	Body Mismatch <i>M</i> [95% <i>CI</i>]
1	TT	486 [444.0, 528.3]	499 [458.0, 539.0]	496 [452.8, 538.3]	545 [498.8, 591.5]	488 [444.0, 532.1]	490 [454.5, 525.4]
2	FF	209 [200.5, 217.4]	208 [199.4, 217.2]	203 [193.5, 212.9]	214 [204.8, 223.8]	206 [197.4, 214.0]	214 [204.8, 223.6]
	FP	236 [221.0, 250.2]	230 [216.2, 243.5]	230 [215.7, 244.4]	239 [224.8, 252.7]	236 [220.7, 252.0]	239 [223.0, 255.5]
	RP	317 [290.4, 344.1]	326 [297.6, 354.4]	351 [297.8, 337.2]	327 [300.1, 352.9]	346 [301.8, 391.2]	331 [296.7, 366.2]
	TT	320 [288.2, 352.2]	324 [296.0, 352.5]	311 [284.6, 337.2]	391 [334.5, 448.2]	328 [298.5, 357]	356 [322.3, 390.3]
3	FF	177 [163.2, 190.4]	184 [169.4, 198.9]	166 [151.7, 180.2]	183 [168.2, 198.2]	176 [160.0, 191.8]	177 [162.3, 190.9]
	FP	566 [527.8, 605.0]	588 [542.7, 632.6]	551 [507.8, 594.7]	619 [570.7, 668.1]	560 [515.8, 604.2]	582 [544.4, 620.4]
	RP	989 [863.6, 1113.7]	1218 [1046.1, 1389.4]	1116 [929.6, 1302.5]	1638 [1387.4, 1889.3]	1020 [859.4, 1180.4]	1258 [1120.6, 1395.6]
	TT	680 [627.2, 732.7]	709 [659.5, 758.6]	692 [635.7, 748.0]	800 [739.6, 859.9]	677 [614.5, 740.3]	760 [711.6, 809.1]

Notes. ms = Measure in millisecond; FF = First-fixation; FP = First-pass; RP = Regression path; TT = Total Reading Time

Table 3.
ANOVA results for Experiment 1.

Region	Measures (ms)	Match		Dimension		Match x Dimension	
		<i>F1</i>	<i>F2</i>	<i>F1</i>	<i>F2</i>	<i>F1</i>	<i>F2</i>
Region 1	Total time	4.14*	7.30**	4.51*	2.81+	1.98	1.32
Region 2	First-fixation	5.58*	3.00+	.09	.12	1.32	1.13
	First-pass	.23	.16	.41	.08	.87	.78
	Reg path	.53	.07	.70	.37	.53	.73
	Total time	9.67**	15.12***	2.02	.63	3.54*	5.73**
Region 3	First-fixation	2.21	4.54*	.61	.94	1.17	.22
	First-pass	8.53**	8.01**	.41	.67	1.76	.90
	Reg path	50.96***	52.47***	9.43**	8.78***	5.16**	3.21+
	Total time	16.44***	43.05***	5.07**	2.72+	2.37	2.21

Notes. *** $p < .001$; ** $p < .01$; * $p < .05$; + $p < .10$; Two 3 dimension (food vs. body image vs. perfectionism) x 2 match (match vs. mismatch) ANOVA results, one treating participants (*F1*) and one treating items (*F2*) as random variables

Table 4.

Regression Model: EDE-Q 6.0 Experiment 1 (N = 90).

Parametric Terms			
	<i>b</i>	<i>95% CI</i>	
Constant	0.985***	[0.8324, 1.1375]	
Total Reading Time mm Region 1 Body	-0.001*	[-0.0021, -0.0001]	
First-fixation mm Region 3 Perfectionism	0.003**	[0.0004, 0.0046]	
Smooth Terms			
	<i>Effective degrees of freedom</i>	<i>Reference degrees of freedom</i>	<i>F</i>
Total Reading Time mm Region 3 Perfectionism	2.097	2.588	2.567

Notes. Adjusted $R^2 = 0.13$ for Model; $p = 0.025^*$, $p = 0.019^{**}$, $p = 0.001^{***}$

Table 5.

Example Material from Experiment 2 with Analysis Regions.

Scenario Type	Example
<i>Food-related Match</i>	You stop by the shop on your way home from work. You get a large tub of ice cream, and go home and eat a small portion./ You are very _{Region 1} / pleased _{Region 2} / to have done that. _{Region 3} /
<i>Food-related Mismatch</i>	You stop by the shop on your way home from work. You get a large tub of ice cream, and go home and eat the whole thing./ You are very _{Region 1} / pleased _{Region 2} / to have done that. _{Region 3} /
<i>Body image-related Match</i>	You go in for a regular check-up. Your doctor comments that you have lost quite a bit of fat since your last appointment./ You are very _{Region 1} / pleased _{Region 2} / to have done that. _{Region 3} /
<i>Body image-related Mismatch</i>	You go in for a regular check-up. Your doctor comments that you have gained quite a bit of fat since your last appointment./ You are very _{Region 1} / pleased _{Region 2} / to have done that. _{Region 3} /
<i>Perfectionism-related Match</i>	You work on creating music and sounds for a soundtrack. You listen to what you created and you notice that every note flows together perfectly./ You are very _{Region 1} / pleased _{Region 2} / to have done that. _{Region 3} /
<i>Perfectionism-related Mismatch</i>	You work on creating music and sounds for a soundtrack. You listen to what you created and you notice that not every note flows together perfectly./ You are very _{Region 1} / pleased _{Region 2} / to have done that. _{Region 3} /

Table 6.
Descriptive Statistics of Reading Measures (ms) for Each Region of Interest for Experiment 2

Region	Measure (ms)	Food Match <i>M</i> [95% <i>CI</i>]	Food Mismatch <i>M</i> [95% <i>CI</i>]	Perfectionism Match <i>M</i> [95% <i>CI</i>]	Perfectionism Mismatch <i>M</i> [95% <i>CI</i>]	Body Match <i>M</i> [95% <i>CI</i>]	Body Mismatch <i>M</i> [95% <i>CI</i>]
1	TT	397 [358.9, 434.3]	439 [391.5, 487.2]	402 [366.6, 438.2]	481 [434.0, 528.1]	385 [352.4, 418.2]	414 [381.1, 446.5]
2	FF	204 [194.8, 213.7]	202 [192.7, 211.4]	199 [190.0, 208.0]	204 [195.8, 212.4]	195 [186.9, 202.6]	203 [194.8, 211.5]
	FP	238 [223.6, 251.9]	247 [230.0, 264.3]	249 [230.8, 268.0]	243 [228.4, 257.7]	229 [214.3, 242.9]	258 [239.1, 277.2]
	RP	401 [321.0, 480.8]	382 [339.4, 425.0]	391 [337.6, 443.4]	382 [340.3, 422.9]	347 [315.0, 378.2]	400 [360.9, 439.1]
	TT	335 [303.3, 365.9]	375 [341.7, 409.2]	344 [309.2, 378.9]	402 [368.9, 436.1]	332 [301.1, 362.2]	408 [359.1, 457.5]
3	FF	224 [214.9, 232.9]	225 [215.0, 235.2]	229 [218.2, 240.2]	223 [213.6, 233.0]	229 [218.0, 240.6]	226 [217.7, 234.6]
	FP	595 [540.7, 649.7]	603 [535.2, 670.9]	588 [536.9, 639.3]	634 [571.9, 696.1]	579 [525.5, 632.8]	634 [564.8, 702.6]
	RP	1008 [878.3, 1138.0]	1330 [1107.9, 1551.6]	1154 [1002.9, 1305.8]	1725 [1476.4, 1973.3]	1009 [874.8, 1142.4]	1369 [1169.9, 1568.3]
	TT	723 [652.2, 793.1]	801 [707.0, 894.5]	701 [639.3, 763.2]	855 [778.2, 930.9]	719 [648.3, 789.5]	820 [740.0, 900.6]

Notes. ms = Measure in millisecond; FF = First-fixation; FP = First-pass; RP = Regression path; TT = Total Reading Time

Table 7. ANOVA results for Experiment 2.

Region	Measures (ms)	Match		Dimension		Match x Dimension	
		<i>F1</i>	<i>F2</i>	<i>F1</i>	<i>F2</i>	<i>F1</i>	<i>F2</i>
Region 1	Total time	20.47***	11.54**	4.39*	2.43+	1.87	.42
Region 2	First-fixation	2.66	.27	.81	1.20	1.23	3.78*
	First-pass	4.10*	2.04	.14	.36	3.23*	2.71+
	Reg path	.30	1.21	.39	.33	2.90+	.64
	Total time	26.90***	25.39***	.91	.81	.99	.83
Region 3	First-fixation	.46	.38*	.36	.52	.35	.50
	First-pass	5.55*	3.58+	.23	.58	.94	1.60
	Reg path	48.82***	73.18***	13.69***	7.57***	2.89+	4.53*
	Total time	34.25***	26.97***	.38	.41	1.83	2.86+

Notes. *** $p < .001$; ** $p \leq .01$; * $p < .05$; + $p \leq .10$; Two 3 dimension (food vs. body image vs. perfectionism) x 2 match (match vs. mismatch) ANOVA results, one treating participants (*F1*) and one treating items (*F2*) as random variables

Table 8.

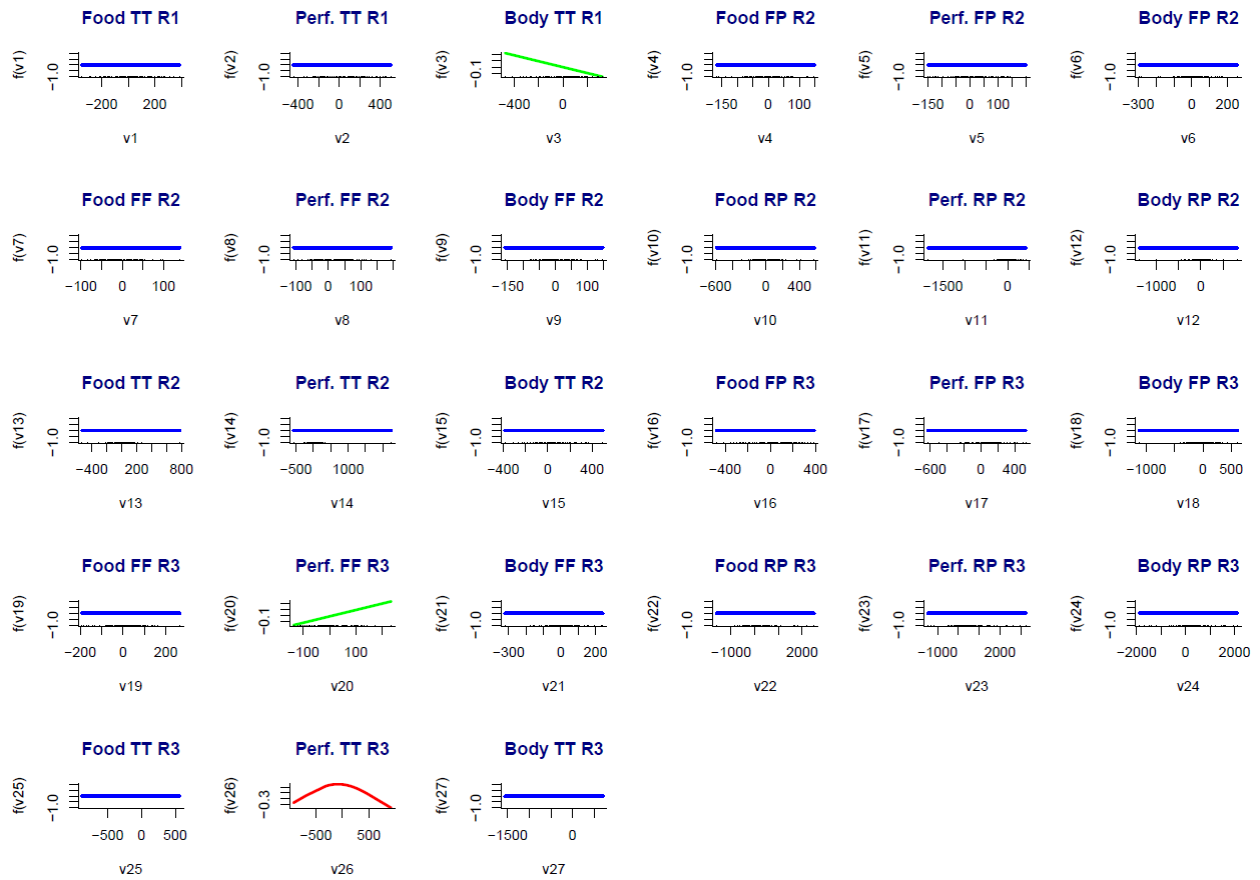
Regression Model: BMI Experiment 2 (N = 90).

Model	<i>b</i>	<i>95% CI</i>
Constant	23.420**	[22.5860, 24.2548]
Total Reading Time mm Region 3 Body	0.004*	[0.0013, 0.0074]

Notes. Adjusted $R^2 = 0.07$ for Model; $p = 0.006^*$, $p < 0.001^{**}$

Figures

Figure 1. Components of the fit from the GAMSEL procedure: EDE-Q Study 1



Notes. FF = First-fixation; FP = First-pass; RP = Regression path; TT = Total Reading Time; R1 = Region 1; R2 = Region 2; R3 = Region 3; Perf. = Perfectionism

Figure 2. Relation between Global EDE-Q Score and total reading time mismatch scores for body-related text in Region 3, first fixation mismatch scores for perfectionism-related text in Region 3, and total reading time mismatch scores for perfectionism-related text in Region 3. Estimated linear and smooth function components and 95% confidence intervals. Each component function is vertically centered about zero.

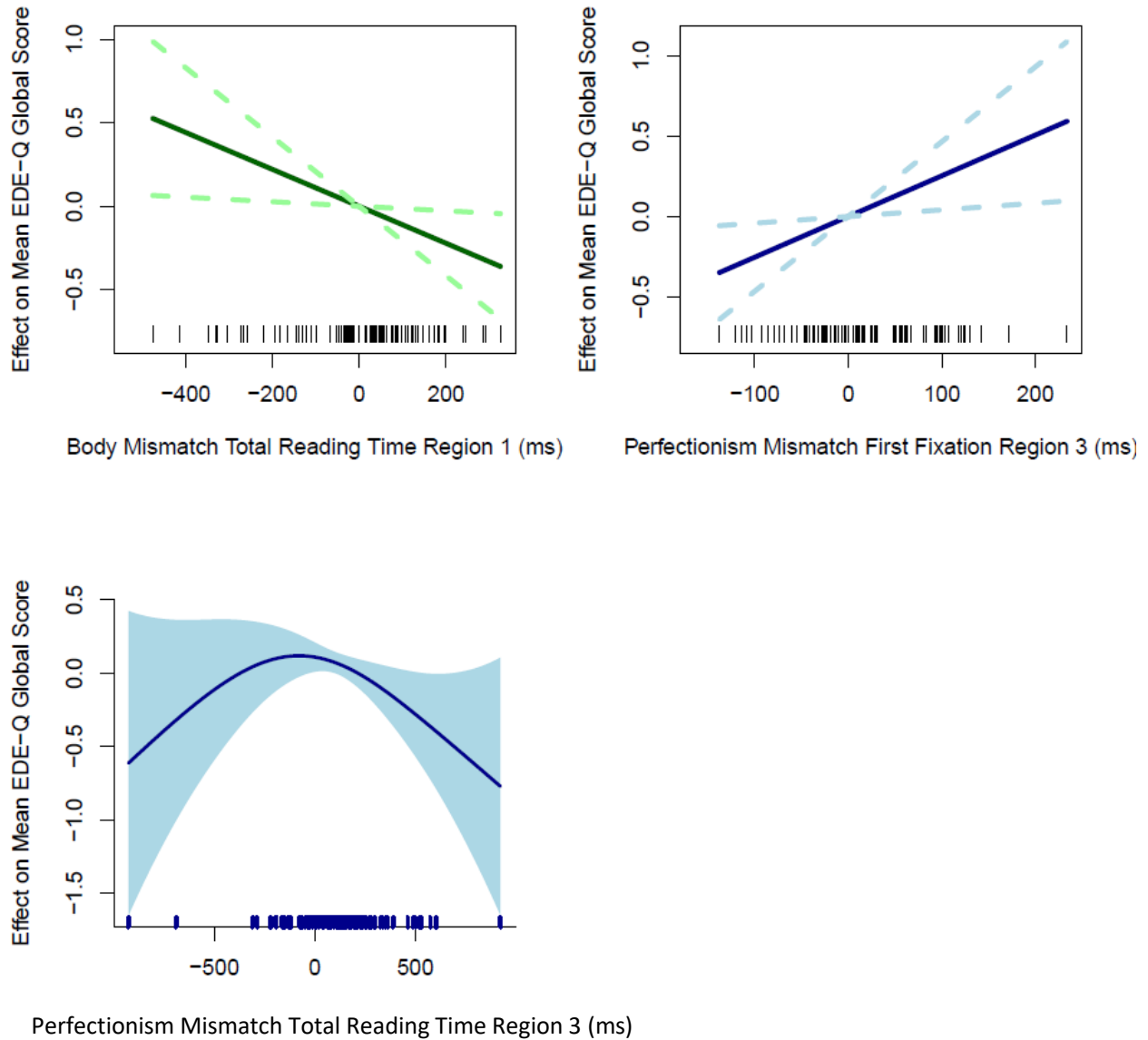
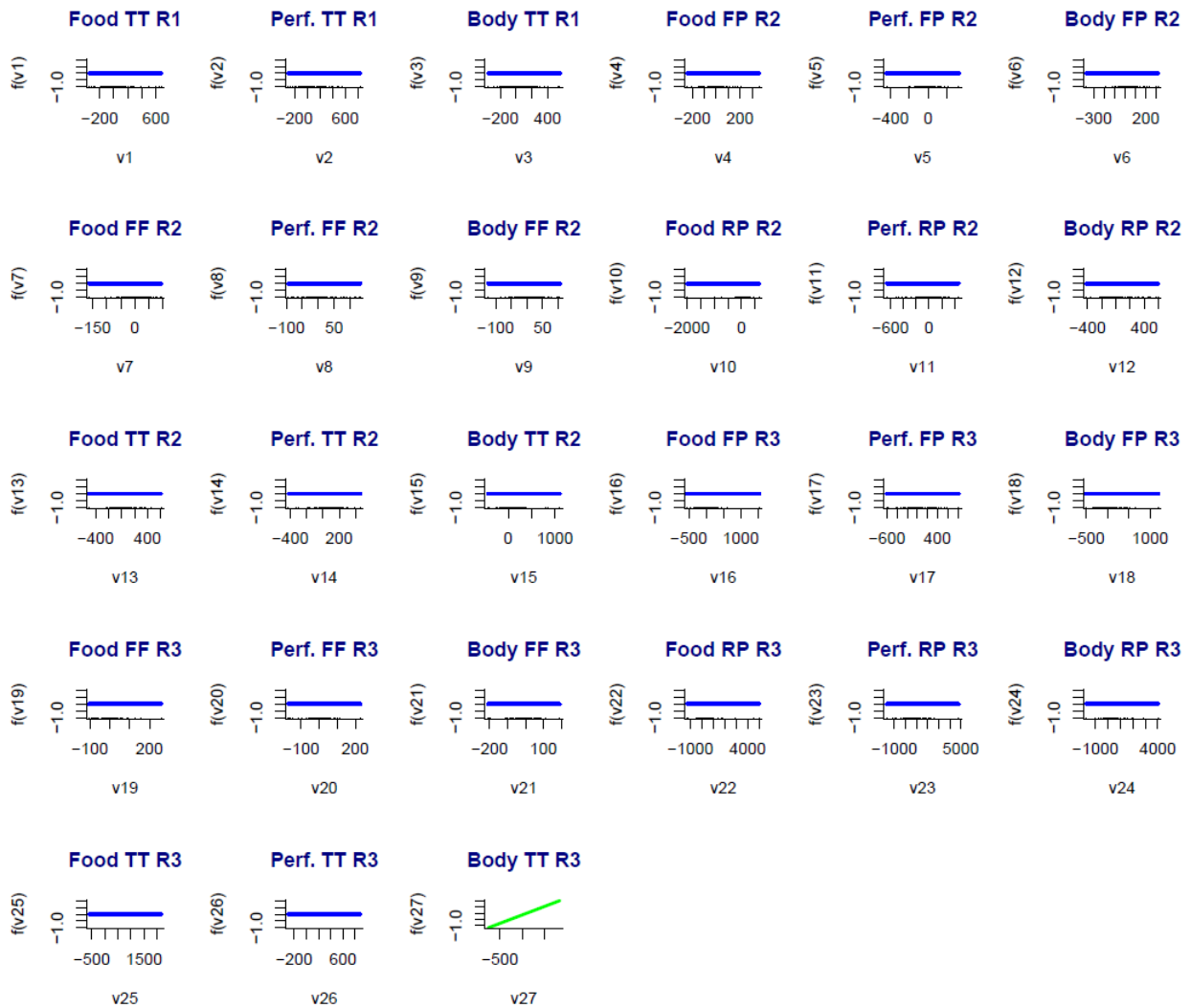


Figure 3. Components of the fit from the GAMSEL procedure: BMI Study 2



Notes. FF = First-fixation; FP = First-pass; RP = Regression path; TT = Total Reading Time; R1 = Region 1; R2 = Region 2; R3 = Region 3; Perf. = Perfectionism

Figure 4. Relation between BMI and mismatch scores for body-related text in Region 3. Estimated linear function component and 95% confidence interval. The component function is vertically centered about zero.

