The Time-Course of Attentional Bias to Symptom-Related Words in Functional Gastrointestinal Disorders: An EEG Study

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Abstract

Research has highlighted the role of psychological processes in functional gastrointestinal disorders (FGIDs). The presence of potentially unconscious attentional bias toward gastrointestinal symptom-related words might attest to the contribution of psychological factors in FGIDs, but few studies have addressed attentional bias in FGID-sufferers, specifically. This study aimed to use electroencephalography to examine unconscious and conscious attentional bias to symptom-related nouns in FGID-sufferers and explore how EEG indices of attention correlate with symptom severity and health anxiety. Thirty FGID-sufferers and 30 controls completed a fast-presentation task using an oddball paradigm to measure unconscious attention, a silent reading task measuring unconscious and conscious attention, and scales measuring health-related and psychosocial states. A series of symptom-related, negative, and neutral nouns were used in both EEG tasks. One-way *t*-tests, comparing the signal-to-noise ratio to 1.6, were used to analyse the fast presentation task data, while mixed ANOVAs were performed on event-related potentials indicative of unconscious attention (P100 and early posterior negativity) and conscious attention (N400 and late posterior positivity) in the silent reading task. An unconscious attentional bias was not observed in either EEG task. However, vigilance for negative nouns, followed by avoidance of negative and sustained processing of symptom-related nouns was observed across groups in the silent reading task, and the strength of this vigilance-avoidance pattern correlated with health anxiety. Conversely, symptom severity did not correlate with attentional bias. A deeper understanding of the time-course of attentional bias in FGID-sufferers could inform the design and application of psychological interventions aimed at treating FGIDs.

Keywords: attentional bias, functional gastrointestinal disorders, electroencephalography, silent reading, fast presentation.

Declaration

This thesis contains no material which has been accepted for the award of any other degree of diploma in any University, and, to the best of my knowledge, this thesis contains no material previously published except where due reference is made. I give permission for the digital version of this thesis to be made available on the web, via the University of Adelaide's digital thesis repository, the Library Search and through web search engines, unless permission has been granted by the School to restrict access for a period of time.

Sarah McKerchar

29/09/2020

Contribution Statement

This thesis was based on an existing dataset. My supervisor provided information about the dataset and variables included in the original study, from which I generated research questions. I conducted an initial literature search and aided in completing the required paperwork to be added to the ethics approval for the original project at Macquarie University. I was involved in the offline processing of the EEG data alongside my supervisor, which included the use of MATLAB to run an Independent Component Analysis and manually reject eyeblinks, as well as filtering, processing, and averaging the SNR data. My supervisor provided an initial R Markdown template for analysing the EEG data, which I extended and applied to meet the requirements of the research questions. I was also provided with a list of specifications regarding the words used in the stimulus set and the EEG recording apparatus. I was responsible for completing the data analysis and the thesis write-up.

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The Time-Course of Attentional Bias to Symptom-Related Words in Functional Gastrointestinal Disorders: An EEG Study

Functional Gastrointestinal Disorders (FGIDs) are a group of common and often debilitating conditions that are traditionally characterised by a combination of chronic gastrointestinal (GI) complaints with no identifiable organic cause (van Tilburg & Whitehead, 2018). Irritable Bowel Syndrome (IBS) and Functional Dyspepsia (FD) are the most common and recognisable FGIDs (van Tilburg & Whitehead, 2018), with estimated global prevalence rates of 10-25% and 5-11%, respectively (Canavan et al., 2014; Talley & Ford, 2015). FGIDs are a common reason for primary care visits around the world (Koloski et al., 2001), and account for up to 50% of referrals to gastroenterologists (Drossman, 2016). They are also associated with significant reductions in productivity and quality of life (Koloski et al., 2001; Van Oudenhove et al., 2016). Despite the high healthcare, economic, and psychological burden associated with FGIDs, there is, at present, no widely accepted unifying theory or treatment strategy for those affected (van Tilburg & Whitehead, 2018). Thus, there is a clear need for further research into the aetiology of FGIDs, as a more complete understanding could, in turn, improve approaches to diagnosis and treatment.

The Biopsychosocial Perspective: Psychosocial Factors in the Expression of FGIDs

In recent decades the literature on FGIDs has increasingly emphasised the role of psychological factors, in line with a biopsychosocial perspective (Van Oudenhove et al., 2016; van Tilburg & Whitehead, 2018). The shift toward a biopsychosocial model of FGIDs is reflected in the most recent iteration of the Rome Foundation's widely utilised diagnostic criteria, the *Rome IV*. The *Rome IV* diagnostic manual defines FGIDs as disorders of gut-brain interaction, one symptom of which is altered processing within the central nervous system (CNS) – that is, within the brain and spinal cord (Drossman, 2016). The proposed mechanism underlying this interaction is referred to as the brain-gut axis (BGA)—the bidirectional communication pathway between the enteric nervous system, located along the GI tract, and the CNS. The pathway integrates the endocrine, immune, and autonomic nervous systems, to which the enteric nervous system and CNS project (Van Oudenhove et al., 2016; Windgassen et al., 2017).

Psychosocial Factors

Several sources of evidence converge in suggesting a central role for the BGA in FGIDs. Epidemiological studies (studies of the incidence and distribution of symptoms and health behaviours; Coggon et al., 2003), demonstrate that FGIDs are highly comorbid with psychological disorders, such as anxiety and depression (Addolorato et al., 2008; Brook et al., 2012; Koloski et al., 2012; Riedl et al., 2008). They also indicate that, relative to healthy controls, FGID-sufferers demonstrate increased healthcare-seeking behaviour, as well as increased somatisation – a tendency to experience somatic (i.e., bodily) symptoms in response to psychological distress (Brook et al., 2012; Riedl et al., 2008; Van Oudenhove et al., 2016). There is also epidemiological evidence of a positive relationship between psychological distress and the likelihood of FGID onset and maintenance (Koloski et al., 2012; Van Oudenhove et al., 2016). Furthermore, intervention studies demonstrate the efficacy of psychological therapies in the treatment of FGIDs (Ford et al., 2014; Windgassen et al., 2017). Taken together, this evidence underlines the potential clinical benefits of gaining a more in-depth understanding of the way the BGA operates in these disorders.

Hypervigilance

Further evidence that supports the biopsychosocial model of FGIDs, is the presence of hypervigilance to pain during rectal and gastric balloon distension in FGID-sufferers (Van Oudenhove et al., 2016). Distension studies indicate that FGID-sufferers tend to display visceral (i.e., internal-organ-based) hypersensitivity during balloon distension, reporting discomfort at lower levels of pressure than healthy controls and those with organic GI complaints (Bouin et al., 2002; Van Oudenhove et al., 2007, 2010; Mertz et al., 1998). This tendency to report discomfort has been found to correlate with psychological distress but not neurosensory sensitivity (Dorn et al., 2007; Van Oudenhove et al., 2007). Collectively, these studies highlight the interaction between gut-driven hypersensitivity and psychological factors in FGIDs.

Hypervigilance as Attentional Bias in Psychopathology

Measures of attentional bias toward pain-related material may offer a less invasive method of quantifying hypervigilance in FGID-sufferers, enabling the study of hypervigilance towards even *potential* sources of pain. Attentional bias involves a tendency to preferentially attend threatening or otherwise salient information (Crombez et al., 2013). It is a robust phenomenon that has been extensively studied in the context of psychopathologies, such as anxiety disorders. Research suggests three related attentional processes – *orientation, maintenance, and avoidance* – contribute to attentional bias (Cisler et al., 2009; Schoth et al., 2012). Orientation refers to the unconscious initial allocation of attention to salient stimuli, and research indicates that attentional bias at this stage reflects hypervigilance driven by an automatic, threat-detection mechanism (Cisler & Koster, 2010; Schoth et al., 2012). The maintenance stage involves the facilitated processing and elaboration of salient stimuli (Mogg & Bradley, 2016). However, the extent to which the maintenance of attention reflects unconscious or conscious processes and facilitated attention or difficulty disengaging from stimuli remains unclear (Cisler & Koster, 2010; Cisler et al., 2009; Mogg & Bradley, 2016). Conversely, attentional avoidance refers to the preferential direction of attention away from the threat-cue (Cisler & Koster, 2010). It relies on conscious processes and may reflect an emotional regulation strategy aimed at mitigating distress by avoiding threatening stimuli (Cisler & Koster, 2010; Mogg & Bradley, 2016). At present, the extent to which attentional biases involve orientation, maintenance and avoidance remains uncertain, emphasising the need for further research aimed at disentangling the influence of these processes across the time-course of attentional bias.

Measurement Approaches

Two attentional bias measures have been dominant within research on attentional processes in psychopathology – the modified Stroop task and the dot-probe task (MacLeod et al., 1986). In the modified version of the original Stroop colour-naming task (Stroop, 1935) participants are instructed to read aloud the colour of displayed words that are either threat-related or neutral while ignoring their meaning. The dependent measure is reaction-time, with longer latencies for threat-related words indicative of more attention being paid to the meaning or valence of those words relative to neutral words (Todd et al., 2018). However, while the longer latencies produced by the modified Stroop task indicate that *something* has occurred, they are limited in their ability to provide information relating to the timing and nature of the different unconscious and conscious attentional processes (i.e., orientation, maintenance, and avoidance) that underlie the resultant reaction-time (Cisler et al., 2009). It has also been suggested that longer latencies for threatening words may indicate cognitive avoidance rather than facilitated attention (Dobson & Dozois, 2004).

In the dot-probe task (MacLeod et al., 1986), two cue stimuli, one threat-related and one neutral, are simultaneously presented at different spatial locations of a screen (i.e., at the top and bottom, or left and right). After a short duration, the cues disappear and a dot (probe) appears in one of the previously cued locations. Participants are instructed to respond as quickly and accurately as possible to the location of the probe. Faster reaction-times in congruent trials (when the threat-related cue is replaced by the probe) relative to incongruent trials (when the neutral cue is replaced by the probe) indicate an attentional bias to threat-related stimuli (Crombez et al., 2013). Conversely, faster reaction-times in incongruent trials, as opposed to congruent trials, indicate attentional avoidance (Cisler, 2009). Unlike the modified Stroop task, the dot-probe task allows for segmentation of the time-course of attentional bias by manipulating the stimulus exposure duration (i.e., 500 ms to investigate initial orientation and 1250 ms to investigate subsequent maintenance or avoidance; Schoth et al., 2012; Todd et al., 2018). However, the dot-probe task is limited in its ability to discriminate between the processes underlying attentional bias latencies – it can indicate what happened at 500 ms or 1250 ms but cannot account for what occurred between (Cisler et al., 2009). Collectively, as both the modified Stroop and dot-probe tasks rely on reaction-time indices of attention they are limited in their ability to provide information relating to the unconscious and conscious attentional processes that underlie the observed reaction-time data. This highlights the need for future research using alternative methods that are better-suited to capturing the continuous time-course of attentional bias.

Attentional Bias in Psychopathology and the Vigilance-Avoidance Hypothesis

Despite these limitations, the paradigms described above have been used extensively to investigate attentional bias within anxious populations. Reviews and meta-analyses have reported a robust attentional bias toward threatening and emotional stimuli (Bar-Haim et al., 2007; Cisler & Koster, 2010). However, concerning the time-course of the observed attentional bias, the results are not consistent across the modified Stroop and dot-probe paradigms. In a meta-analysis of 172 studies, Bar-Haim and colleagues (2007), found that effect size across the modified Stroop studies was larger for supraliminally presented stimuli relative to subliminally presented stimuli. The inverse pattern occurred with the effect size across supraliminal and subliminal exposures in dot-probe studies. Due to the inconsistent results and limitations of the modified Stroop and dot-probe paradigms, the extent to which reported attentional bias indices reflect vigilance, difficulty disengaging, or avoidance remains uncertain (Bar-Haim et al., 2007; Cisler & Koster, 2010; Cisler et al., 2009).

Several models of attentional bias have emerged based on the literature reviewed above. The vigilance-avoidance hypothesis (Mogg et al., 1987) has been particularly effective in accounting for the pattern of attentional bias results within the anxiety literature. Mogg et al.'s (1987) model argues that attentional bias to threatening information in anxious populations tends to follow a pattern of vigilance for threat cues during early, unconscious stages of attention, followed by avoidance during later stages of attention. They propose that the observed vigilance is driven by an unconscious, threat-detection mechanism, while subsequent avoidance reflects a conscious, cognitive strategy designed to mitigate distress by allocating attention away from the offending stimuli (Mogg et al., 1987, 2004). This model has been validated within anxious populations (Cisler & Koster, 2010; Mogg et al., 2004; Mogg & Bradley, 2016), however, evidence of attentional avoidance has been mixed within the wider literature, with patterns of facilitated attention, difficulty disengaging, and avoidance all reported (Bar-Haim et al., 2007; Cisler & Koster, 2010). Furthermore, it remains unclear which variables lead individuals to avoid or maintain attention on stimuli (Mogg & Bradley, 2016). Thus, there is a need for research that utilises alternative attentional bias measures to investigate individual differences in patterns of vigilance and avoidance over the time-course of attentional bias.

Hypervigilance as Attentional Bias in Chronic Pain

In recent years, the reviewed tasks and models have also been used to explore the occurrence of attentional biases outside of the context of psychopathology; most frequently, in relation to chronic pain conditions (Todd et al, 2018). It has been suggested that measures of attentional bias may provide an objective marker for symptom severity in chronic pain patients, including those with FGIDs (Crombez et al., 2013; Schoth et al., 2012). However, research investigating patients' performance on attentional bias measures has produced inconsistent results (Todd et al., 2018). In an initial meta-analysis of 10 dot-probe studies, Schoth and colleagues (2012) found that patients with chronic pain showed an increased bias toward pain-related stimuli compared to healthy controls, with a smaller effect size during the orientation stage (i.e., >500 ms exposure) and a larger effect size and more consistent results in later maintenance and avoidance stages (i.e., <1000ms exposure). A subsequent meta-analysis that included multiple attentional bias measures indicated a small attentional bias to sensory pain-related stimuli among chronic pain patients, but this did not differ significantly from healthy controls (Crombez et al., 2013). Finally, a more recent meta-analysis of 52 dot-probe studies found a small, but significant, effect indicating attentional bias toward sensory pain-related words in chronic pain sufferers, relative to controls, for exposure durations ranging between 500 and 1000 ms, but not for durations greater than 1000 ms (Todd et al., 2018). As with the anxiety literature, the inconsistencies and small effect sizes found across chronic pain studies, again, point to a need for attentional bias measures that are able to capture the complete pattern of attention. Also, given the heterogeneous nature of the chronic pain population, the use of pain-stimuli that are relevant to the target population would also be beneficial in resolving the inconsistencies described above (Crombez et al., 2013; Todd et al., 2018).

Attentional Bias to Symptom-Related Stimuli in FGIDs

Despite the need for tailored pain-related stimuli in determining the robustness of attentional bias in chronic pain populations, few studies have addressed attentional bias in FGID-sufferers. Furthermore, within the chronic pain literature presented above, the way unconscious processes (i.e., vigilance) and conscious processes (i.e., avoidance) contribute to the observed attentional bias indices remains unclear. The potential presence of an unconscious attentional bias is of additional interest in the context of FGIDs due to the proposed role of the BGA in their expression. As discussed above, gut-driven hypersensitivity has been reported in distension studies. Additionally, in a study of the neural correlates of distension hypersensitivity in FD patients, Van Oudenhove and colleagues (2010) elaborated on the interaction between gut-driven and psychological factors. They found that, relative to controls, FD patients failed to activate the pregenual anterior cingulate (pACC; a brain region involved in top-down pain modulation) and deactivate the dorsal pons (a brain region involved in regulating arousal) during distension. FD patients also failed to deactivate the amygdala (a brain region involved in emotion processing) during sham trials. Additionally, anxiety levels were negatively correlated with pACC activity and positively correlated with dorsal pons activity. Van Oudenhove et al. (2010) suggest their results indicate an unconscious anxiety-driven failure in top-down pain modulation. This study further justifies the need to investigate unconscious attentional processes in FGID-sufferers as such research may enhance our current understanding of the brain-gut interaction in FGIDs.

At present, only three studies have investigated attentional bias for symptom-related information in FGID-sufferers. Using the dot-probe method Martin and Chapman (2010) found increased attentional bias to social threat words after induced rumination in FGID-sufferers compared to controls, but no such effect was found for pain-related words. In a later masked dot-probe study, Chapman and Martin (2011) found that, relative to controls, IBS patients showed increased attentional bias for briefly presented (100ms) pain-related words relative to neutral words, indicating hypervigilance. During conscious attention, IBS patients maintained attention on symptom-related words, indicating vigilance or difficulty disengaging, while control participants allocated attention to neutral stimuli, indicating avoidance (Chapman & Martin, 2011). Additionally, Chapman and Martin (2011) reported a positive correlation between increased engagement with pain-related words during conscious attention and symptom severity in IBS patients.

Finally, utilizing a modified Stroop task, Afzal and colleagues (2006) investigated attention in IBS patients during a masked condition (stimuli presented for 14 ms then masked until response) and an unmasked condition (stimuli presented until response). They found IBS patients displayed vigilance for symptom-related words, relative to neutral words, during the masked condition but not the unmasked condition, and the opposite pattern occurred in controls (Afzal et al., 2006). Consequently, Afzal and colleagues (2006) concluded that IBS patients demonstrated an unconscious, but not conscious, attentional bias to symptom-related words. However, as the modified Stroop method relies on reaction-time as an index of attentional bias, it remains difficult to draw a solid conclusion based on their results. As within the general attentional bias literature, the FGID studies reviewed above have relied on reaction-time-based attentional bias measures. Consequently, the time-course of attentional bias in FGID-sufferers, and the extent to which unconscious processes and conscious processes contribute to it, remains unclear.

The Present Study

Within the FGID literature reviewed above, only one study has provided evidence of an association between attentional bias and symptom severity (Chapman & Martin, 2011), an area of particular importance in establishing the predictive and practical applications of attentional bias measures in FGIDs. Therefore, an aim of the present study is to determine the extent to which unconscious and conscious attentional bias indices predict symptom severity in FGID-sufferers.

Furthermore, there is presently little research addressing the extent to which patterns of attentional bias relate to individual differences in relevant health and psychosocial variables (Afzal et al., 2006; Martin & Chapman, 2010). In response to this limitation, the present study aims to explore the influence of individual differences in health anxiety on attentional bias in FGID-sufferers. FGIDs are highly comorbid with elevated levels of health anxiety (Crane & Martin, 2002) – that is, a fear of having an illness based on the misinterpretation of somatic symptoms, ranging from increased worry and healthcare seeking to clinically significant hypochondriasis (Hart & Björgvinsson, 2010). Increased health anxiety has been associated with attentional bias toward relevant threat-related information (i.e., negative health cues; Mier et al., 2017; Owens et al., 2004). As with the general anxiety literature, the extent to which unconscious processes (i.e., orientation and vigilance) and conscious processes (i.e., maintenance and avoidance) are implicated in this attentional bias is also debated (Jasper & Witthöft, 2011). Consistent with the vigilance-avoidance hypothesis (Mogg et al., 1987), studies have found that those with increased health anxiety tend to orient toward health-threat cues, and subsequently avert attention from them (Jasper & Witthöft, 2011; Lees et al., 2005). These results highlight the changing nature of attentional bias over time and demonstrate the need to further understand attentional processes within the context of the health and psychosocial variables that may influence them.

In order to effectively capture the time-course of attention, the present study aims to use electroencephalography (EEG), a neuroimaging method with high temporal resolution, to delineate the stages of attentional bias toward symptom-related nouns in FGID-sufferers. Firstly, to provide a detailed analysis of the unconscious and conscious stages of attention, a task better-suited to analysing the temporal sequence of attentional bias will be adapted for use in the present study. Wabnitz et al. (2016) used an EEG task that involved the conscious, silent reading of neutral, positive, physically threatening and socially threatening words to assess the pattern of attentional bias in participants with social anxiety disorder. Through the analysis of event-related potentials (ERPs), the authors found social-anxiety-sufferers exhibited increased vigilance-avoidance pattern across unconscious and conscious attention. A strength of the silent reading task is that, unlike the commonly used attentional-bias-measurement methods (i.e. the modified Stroop and dot-probe tasks), it does not involve an explicit behavioural or verbal task. It, thus, results in a pure measure of attention that minimises the need to disentangle response-related processes and task-specific processes (i.e.

switching spatial attention location in the dot-probe or reading demands in the modified Stroop; Wabnitz et al., 2016). When applied with EEG, the silent reading paradigm allows for detailed analysis of the stages of attention through the examination of the ERP components presented in Table 1. Therefore, it provides the opportunity to elaborate on the role of unconscious processes (i.e., vigilance, indicated during the P100 and EPN) and conscious processes (i.e. maintenance or avoidance during the N400 and LPP).

Table 1

EEG Indices of Attentional Bias and Their Underlying Processes.

Peak and additional references	Shape and time-course [interval in this study]	Region [electrode position on scalp in this study]	Underlying processes
P100 (Li et al., 2007; Sass et al., 2010; Scott et al., 2009)	Positive-going peak occurring 80 to 130 ms after stimulus onset [70-140 ms]	Occipital [O1, Oz, O2] and parieto-occipital: [P7, P8]	Larger P100 amplitudes indicate increased allocation of attention to a stimulus. Threatening words and words with positive and negative emotional valence tend to incite larger P100 amplitudes in anxious individuals. These patterns suggest the presence of vigilance for emotional content.
Early Posterior Negativity (EPN; Junghöfer et al., 2001; Kissler et al., 2009; Liu et al., 2018; Schupp et al., 2007)	Negative-going peak occurring 200 to 300 ms after stimulus onset. [160-300 ms]	Occipital and [O1, Oz, O2] parieto-occipital: [P7, P8] regions	The EPN is associated with automatic attention orienting and early lexical access. A robust emotion effect in which pleasant and unpleasant words result in larger EPN amplitudes compared to neutral words has been reported. This effect indicates that emotionally laden stimuli tend to capture attention and are automatically selectively processed.
N400 (Chronaki et al., 2012; Kanske & Kotz, 2007; Lau et al., 2008)	Negative-going peak, 300-500 ms [330-450 ms]	Frontal [F3, FC3, FZ, FCZ, F4, FC4] centro-parietal [C3, CP3, CZ, CPZ, C4, CP4] and occipital [O1, OZ, O2] regions	The N400 is an index of semantic analysis and contextual integration. Larger (i.e., more positive) amplitudes reflect greater difficulty consciously accessing the literal meaning of a word as it occurs in a context. Difficulties can arise for words that are incongruent within a sentence (e.g., “socks” – instead of “sugar” – in the sentence “I like coffee with milk and *socks*”). Words with neutral emotional valence tend to elicit a larger N400 than words with positive or negative valence. This emotion effect may arise because emotional words being compatible with a wider range of contexts or because their literal meaning being more accessible. Alternatively, a vigilance for emotional or threatening content may facilitate the processing of emotional content.

Peak and additional references	Shape and time-course [interval in this study]	Region [electrode position on scalp in this study]	Underlying processes
Late Positive Potential (LPP; Babkirk et al., 2015; Bunford et al., 2018; Hajcak et al., 2009; Kanske & Kotz, 2007; Weinberg & Hajcak, 2011)	Average EEG signal (without a specific peak) occurring between 500 and 800 ms [500-800 ms]	Parieto-central [CP3, P3, CPZ, PZ, CP4, P4], parieto-occipital [P7, P8], and occipital [O1, OZ, O2] regions	Larger average amplitude in this component is indicative of sustained attention, while lower amplitudes are associated with disengagement or avoidance. Words with positive and negative valence typically elicit a larger distributed LPP amplitude than neutral words. Indicating sustained attention for, or difficulty disengaging from, emotional content. However, decreased LPP amplitude, indicative of avoidance, has also been observed in anxious populations.

Note. The time interval used for each peak, described in the second column, was based on a literature review and subsequently refined based on plots of grand-averaged and individual ERP data used in the present study.

Determining whether an unconscious attentional bias toward GI-related information exists in FGID-sufferers is of particular importance as it may further validate and elaborate on the operation of the BGA in FGIDs. In order to confidently establish whether an unconscious bias is present, a second highly sensitive task will be employed to assess unconscious attention. This task will utilise an adapted form of a recent approach developed by Lochy and colleagues (2016), in which a fast periodic visual stimulation (FPVS) method is applied within an oddball paradigm. More specifically, a target stimulus (oddball) is inserted at a consistent rate amidst a series of neutral stimuli (base), and this sequence is presented subliminally (Lochy et al., 2016). Due to the rapid presentation of the stimuli, FPVS is highly sensitive to discriminative responses over a minimal number of short trials (Lochy et al., 2016), and the predetermined periodic frequency of the oddball stimuli allows for objective identification and analysis of the EEG data (Van der Donck et al., 2019). Furthermore, as the stimuli are presented subliminally, this method eliminates the possibility of conscious involvement in the resulting data. Despite being a relatively novel approach the method has already been used effectively to demonstrate unconscious discrimination between a range of subliminally presented stimulus types: linguistic stimuli (Lochy et al., 2015, 2016), symbolic stimuli (Lochy et al., 2016), and facial expressions (Van der Donck et al., 2019).

Research Questions

More specifically, this study aims to determine whether attentional bias to GI symptom-related nouns is present in FGID-sufferers, and, if so, to elaborate on the unconscious and conscious vigilance and avoidance processes that underlie it. Furthermore, the present study aims to explore the predictive potential of indices of attentional bias on symptom severity and the psychosocial variable of health anxiety in FGID-sufferers. In summary, the following research questions will be addressed:

1. Compared to healthy controls, do FGID-sufferers show altered patterns of unconscious attention to symptom-related nouns, as captured by the P100, the EPN, and, in the FPVS paradigm, the signal-to-noise ratio (SNR) for symptom-related oddball stimuli?
2. Compared to healthy controls, do FGID-sufferers show altered patterns of conscious attention – as captured by the N400 and LPP – in response to symptom-related nouns? Are the patterns suggestive of vigilance, avoidance or a combination of the two?
3. To what extent is there a positive correlation between EEG-based indices of conscious and unconscious attention and gastrointestinal symptom severity as well as health anxiety? In other words, which aspects of attentional bias – conscious or unconscious, vigilance or avoidance – are most predictive of symptom severity and poorer psychosocial adjustment, as indicated by elevated health anxiety?

Method

Participants

Participants were female undergraduate psychology students at Macquarie University in Sydney, Australia. Students were recruited through a departmental online system and received course credit for their participation. Prospective participants completed a screener questionnaire to ensure they met inclusion criteria for either the 'FGID-sufferers group' or the 'healthy controls group'. Students in the FGID-sufferers group met *Rome IV* diagnostic criteria (Whitehead et al., 2017) for IBS (95%), FD (55%), or both IBS and FD (15%). Students in the healthy controls group met no more than one of the four *Rome IV* criteria associated with IBS and FD. Overall, 30 participants were recruited into each group, and their demographic and psychosocial characteristics are presented in Table 2. Students who reported a current diagnosis of a chronic illness (e.g., fibromyalgia) or psychiatric disorder (e.g., depression) were not invited to take part.

The recruitment of 30 participants to each group was based on a power analysis that involved using Stata Version 15.1 to simulate, for a single analysis (e.g., with one ERP component as the outcome variable), the number of participants needed to have a 0.8 probability of detecting a significant interaction effect in a mixed ANOVA. The relevant interaction was between a two-level between-participant variable (group: FGID-sufferers vs. healthy controls) and a three-level within-participants repeated measure (noun type: symptom-related vs. neutral vs. negative). The power analysis assumed a significance threshold of 0.05, a correlation of 0.5 across repeated measures, and, for both symptom-related and negative nouns compared to neutral nouns, higher ERP amplitude among FGID-sufferers (more pronounced by 0.75 standard deviations) and moderately higher ERP amplitude among healthy controls (more pronounced by 0.5 standard deviations).

Procedure and Materials

Psychosocial Measures

After the initial screening survey, eligible participants completed an online questionnaire seven to ten days before the EEG recording session. The questionnaire was administered through Qualtrics and consisted of demographic questions and various health and psychosocial measures. The measures are described in Table 2 and Appendix A.

EEG Measures

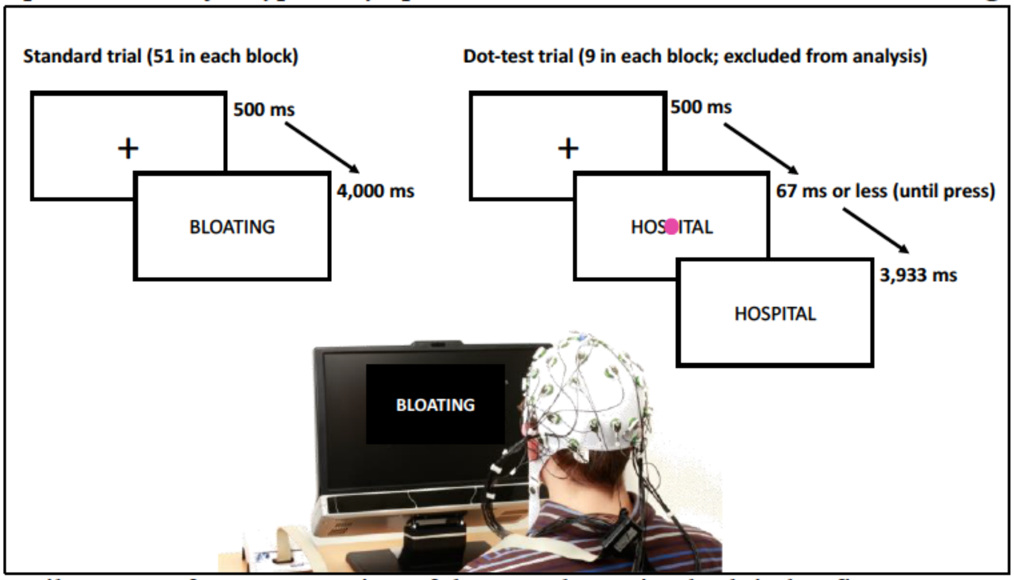
The EEG session lasted approximately 150 minutes (including time to prepare and remove the recording apparatus). It comprised the two tasks described below.

Task 1: Silent Reading. The silent reading task was modelled on Wabnitz et al.'s (2016) study. The first step in the development of the study's stimulus set was consultation with the research team to identify 20 symptom-related nouns (e.g., "hospital", "bloating", and "constipation"). The English Lexicon Project database (Balota et al., 2007) was then used to select 20 negatively valenced ("negative") nouns with the same mean and variance as the set of symptom-related nouns with respect to length, orthographic neighbourhood, and frequency of occurrence in English text corpora. A database of valence and arousal ratings for 15,000 English words (Warriner et al., 2013) was used to ensure that, on average, the selected negative nouns also matched symptom-related nouns with respect to valence and arousal. The 20 neutral nouns were selected from the same databases to produce a valence distribution around the mid-point of the nine-point valence rating scale used by Warriner and colleagues (2013). Neutral nouns matched the sets of symptom-related and negative nouns on length, orthographic neighbourhood, frequency of occurrence in the English text corpora, and arousal. A list of the nouns and their related characteristics is presented in Appendix B.

Each trial of the task involved viewing one of 60 nouns for 4,000 ms[1] after a 500 ms fixation cross, as depicted in Figure 1. To increase the validity of recorded EEG signals, participants viewed the nouns six times (i.e., in six blocks), and were allowed to rest for as long as required between blocks. To ensure participants continuously attended to the stimuli, they were instructed to press the spacebar on the keyboard whenever they saw a red dot appear at the centre of the screen, superimposed over a newly appearing word. Participants were further instructed to react before the dot disappeared and informed that they would be able to see if they reacted in time, since the dot would change colour (to grey) as soon as they pressed the spacebar. In each block, the dot appeared in nine random trials and disappeared after 67 ms. At the end of each block, participants received feedback about the percentage of dots they reacted to in time.

Figure 1

Visual Representation of a Typical Symptom-Related Noun Trial in the Silent Reading Task



Note. "Until press" refers to a pressing of the spacebar using both index fingers.

[1]A 4,000 ms exposure was used because that duration is required to analyse alpha desynchronisation, another EEG index of attentional bias (Wabnitz et al., 2016). This index was examined in a broader project, but not here.

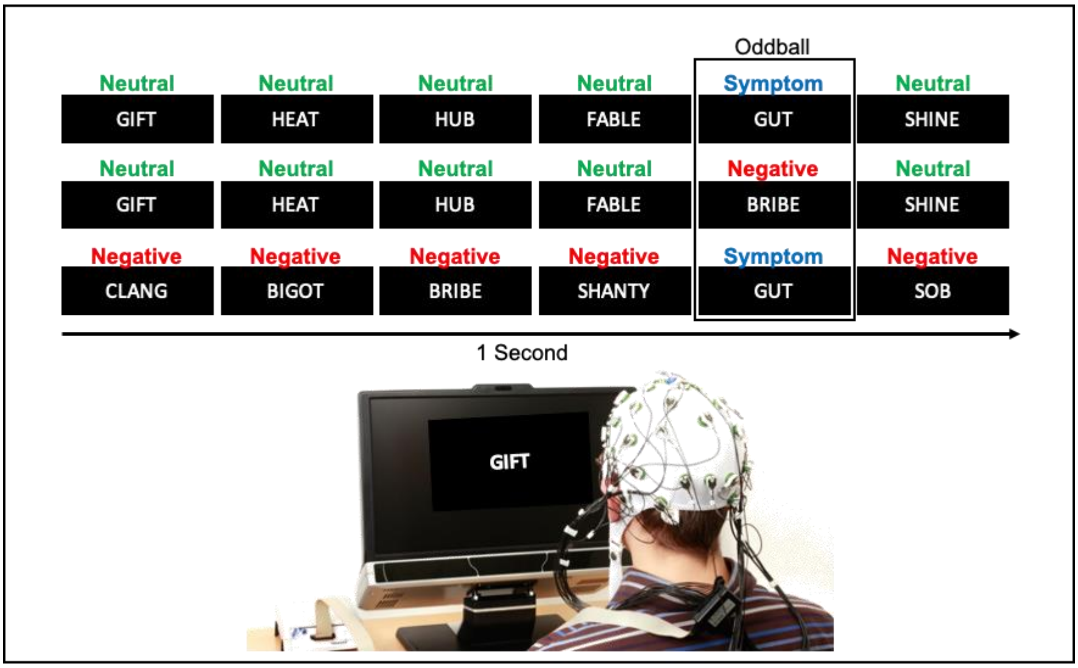
Task 2: Fast Presentation. This task borrowed the stimulus presentation program from Lochy et al.'s (2016) study; the structure of their task was preserved, but stimuli were adapted. As in Task 1, the nouns used in this task fell into three categories: symptom-related, neutral, and negative. However, the noun set was completely new, and all nouns were no more than 7 characters in length. The list of nouns is presented in Appendix C. There were 30 nouns of each type, and noun types were matched on the same characteristics as in Task 1.

This task consisted of four conditions, presented to participants in random order: (1) a control condition in which reshuffled pixels from photos of faces were the base stimuli and images of faces were the oddball; (2) neutral nouns were the base stimuli and symptom-related nouns were the oddball; (3) neutral nouns were the base stimuli and negative nouns were the oddball, and (4) negative nouns were the base stimuli and symptom-related nouns were the oddball.

The PsychToolbox v. 3.0.14 (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997) extension to MATLAB (The Mathworks) was used to display the task. The FPVS sequence started with a fixation cross, displayed for 2-5 s, followed by 2 s of gradual stimulation fade-in, 60 s of stimulation sequence, and 2 s of gradual fade-out. The stimulation fade-in and fade-out phases were included to minimise abrupt eye movements and blinks at the beginning and end of each sequence. As is depicted in Figure 2, the stimulation sequence involved 6 nouns being presented per 1 s at a base frequency of 6Hz (i.e., one noun every 167 ms). Every fifth noun was the oddball stimulus – so the oddball frequency was 1.2 Hz (i.e., every 835 ms). Participants completed three trial blocks, and each block consisted of conditions 1-4 presented in a randomised order. To encourage attention, participants completed a parallel task during the stimulation sequence in which they were instructed to fixate on the central cross and press the space key on the keyboard to indicate any brief colour changes of the cross (from blue to red). Six changes – 200 ms in duration – occurred in each condition.

Figure 2

Depiction of the Stimulation Sequence in the Fast Presentation Task



Note. The FPVS sequence is depicted for conditions: (2) symptom-related amongst neutral nouns, (3) negative amongst neutral nouns, and (4) symptom-related amongst negative nouns.

Manipulation Check

The EEG session concluded with a manipulation check that involved rating the valence and arousal of all the symptom-related and negative nouns encountered in Tasks 1 and 2, as well as the valence and arousal of six emotionally neutral nouns (“coupling”, “underdog”, “aspiration”, “chandelier”, “cleverness”, and “firecracker”). Two questions were asked with respect to each noun: “How happy, pleased, satisfied, contented, and/or hopeful do you feel reading this word?” and “How aroused, stimulated, frenzied, jittery, wide-awake, and/or excited do you feel reading this word?”. Participants responded on a scale ranging from 1 (very unhappy [very calm]) to 9 (very happy [very aroused]).

EEG Acquisition and Processing

EEG Recording Apparatus

EEG signals were recorded using a 1000-Hz sampling rate and an online bandpass filter of 0.05-200 Hz, supported by a Neuroscan EasyCap 32-electrode cap and Curry 7.0 software. The electrode layout corresponded to the International 10-20 system. The left mastoid (M1) was the online reference and the right mastoid (M2) was the offline reference. Electrodes placed above and below the left eye were used to measure vertical eye movements, while electrodes placed on the outer canthi of each eye were used to measure horizontal eye movements. The ground electrode was positioned between FPz and Fz. The raw data was stored offline for processing.

Offline Processing

Task 1: Silent Reading. MATLAB Version R2020a (The Mathworks) with EEGLAB Version 14.1.2b (Delorme & Makeig, 2004) was used to conduct offline processing. The processing consisted of four steps: (1) bandpass filtering (0.1-Hz high pass and 30-Hz low pass); (2) referencing the recorded signal to M2; (3) running an Independent Components Analysis and manually rejecting components reflecting eyeblinks for each participant; and (4) dividing the data into 900-ms epochs, including a 100-ms pre-event interval, with three possible events corresponding to the three noun types. Events coinciding with the appearance of a dot for attention-enhancement purposes (see Figure 1) were excluded from analysis. Any epoch that contained a voltage change exceeding ±150 μV was also removed from further analysis.

The resultant ERPs for each noun type were averaged across blocks for each participant, and peak amplitudes within designated time bands served as indices of the P100, EPN, and N400. For the LPP, the index of interest was the average amplitude within the 500 – 800 ms time band, rather than the peak amplitude. Time bands are presented in Table 1 and were determined based on a review of the past literature (see: Citron, 2012) and plots of grand averaged (group x noun type) and individual ERPs.

Task 2: Fast Presentation. All offline EEG analysis was carried out using MATLAB Version R2020a (The Mathworks) with the Letswave 6 extension (see: https://www.letswave.org/). The aim of offline processing was to isolate the SNR at the oddball frequency and its harmonics (1.2 Hz, 2.4 Hz, 3.6 Hz, 4.8 Hz), as well as at the base frequency (6 Hz). This process involved the following steps: (1) data underwent fast Fourier transform (FFT) bandpass filtering (at 0.1 Hz and 100 Hz); (2) data was segmented to include 2 s before and after each sequence (resulting in 64 s segments); (3) all EEG channels were referenced to electrode M2; (4) data was segmented again to include only the 60 s stimulation sequence; (5) a grand average for conditions 1-4 (consisting of the three instances of each condition across the trial blocks) was then produced for each participant; and (6) a FFT was applied to the grand averages.

The left occipital region (at electrode O1) was the area of interest for this task, as existing literature has found left posterior hemispheric dominance in the early processing of letter strings (Cohen et al., 2002; Lochy et al., 2015, 2016). To produce the SNR for the oddball frequency at electrode O1, a grand average for conditions 1-4 was produced for FGID-sufferers and healthy controls. From this grand average, the amplitude at each frequency bin was divided by the average amplitude of the 20 surrounding bins, which were determined based on the screen refresh rate for each participant.

Statistical Analyses

Preliminary Analyses

Preliminary analyses were conducted to compare participant groups on demographic and psychosocial measures, and as part of a manipulation check. Independent-samples *t*-tests, and chi-square tests for counts, were performed for each group to identify any significant group differences. For the manipulation check mixed ANOVAs with group as the between subject variable and noun type as the within subject variable were performed on participants' valence and arousal ratings.

Task 1: Silent Reading

To address Research Questions 1 and 2 – involving the tracking of unconscious and conscious hypervigilance and avoidance – mixed ANOVAs, with group as the between subject variable (FGID-sufferers vs. healthy controls) and noun type as the within subject variable (symptom-related vs. negative vs. neutral), were performed on relevant ERPs (P100, EPN, N400, LPP) at each of the electrode regions specified in Table 1. All ERP data underwent assumption checks using the Shapiro-Wilk test of normality (Shapiro & Wilk, 1965), Levene's homogeneity of variance test (Levene, 1960), and Box's M homogeneity of covariance test (Box, 1949). All ANOVAs were checked for sensitivity to outliers with Cook's distances greater than 0.4 ($4/N = 4/60 = 0.4$; Cook, 1977).

Correlations. To address Research Question 3 – relating to correlations between EEG-based indices of attentional bias and psychosocial factors – with respect to Task 1, Spearman rank correlations were used to establish whether scores on the Whiteley Index (health anxiety) and Gastrointestinal Symptom Severity Index correlated with indices of attentional bias. Correlation coefficients were examined for each noun type (symptom-related, negative, and neutral) for each of the relevant ERPs and their corresponding electrode regions across groups (see Table 1).

Task 2: Fast Presentation

To address Research Question 1 relating to unconscious attentional vigilance one-tailed single sample *t*-tests comparing the observed SNR to 1.6 were conducted for each group and condition. A comparison value of 1.6 was selected as it corresponds to a 60% increase in signal relative to noise. This standard was previously used by Lochy and colleagues (2015, 2016) to indicate a sufficient discriminative response. It was expected that the SNR for the oddball frequency and its harmonics (1.2 Hz, 2.4 Hz, 3.6 Hz, 4.8 Hz), as well as the base frequency (6 Hz), would be significantly greater than 1.6 if unconscious discrimination between nouns occurred.

Results

Preliminary Analyses

Preliminary analyses were conducted to compare participant groups on demographic and psychosocial measures, and as part of a manipulation check. As can be seen in Table 2, participant groups were well-matched on age and medical history variables. At the same time, as expected, compared to healthy controls, FGID-sufferers reported higher levels of health anxiety, gastrointestinal symptom severity, and probability of diagnosis with an FGID. A full description of all included measures and their resultant group scores can be found in Appendix A.

Table 2

Participants' Demographics and Clinical Characteristics, by Group, as well as Details of Associated Measures

Characteristic and measure	Description: Calculation, example item, number of items, and Likert scale bounds	Internal consistency (α)	*M* (*SD*) or percentage	
			Healthy controls (*n* = 28)˜	FGID-sufferers (*n* = 29)#
Age		NA	22.69 (7.75)	21.7 (6.58)
Health anxiety: Whiteley Index (Pilowsky, 1967)	Sum of 14 yes/no questions regarding health generally (e.g., "Do you often worry about the possibility that you have got a serious illness?") (1) Yes, (0) No	NA (binary responses)	4.07 (2.53)	6.90 (3.04)***

Characteristic and measure	Description: Calculation, example item, number of items, and Likert scale bounds	Internal consistency (α)	*M* (*SD*) or percentage	
			Healthy controls (*n* = 28)˜	FGID-sufferers (*n* = 29)#
Gastrointestinal symptom severity (past week): Gastrointestinal Symptom Severity Index (Kulich et al., 2008)	Mean of 15 items regarding the past week (e.g., "Have you been bothered by *rumbling* in your stomach during the past week? Rumbling refers to vibrations or noise in the stomach.") (1) No discomfort… (7) Very severe discomfort	.93	1.93 (0.97)	3.30 (1.12)***
Past diagnosed psychiatric disorder (% yes)		NA	26.7% (*n* = 8)	13.3% (*n* = 4)
Past chronic illness (% yes)		NA	0% (*n* = 0)	3.3% (*n* = 1)
Currently diagnosed functional gastrointestinal condition (% yes)		NA	0% (*n* = 0)	23.3% (*n* = 7)*

Note. *p*-value in independent-samples *t*-test or chi-square test for counts is indicated by: ***$p \leq .001$, **$.001\ p \leq .01$, * $p \leq .05$. This table only presents the subset of measures used in the current analyses. Group scores on additional measures are presented in the Appendix A. ˜Due to a technical issue, two participants in this group were missing measures of all psychosocial variables.

As regards the manipulation check, it can be seen in Table 3, that valence was successfully manipulated and arousal was effectively controlled for in both tasks. That is, noun conditions did not differ significantly on arousal, and neutral nouns were rated significantly more positively in terms of valence than both other noun types. Unexpectedly, however, symptom words in Task 1 were rated even more negatively in terms of valence than were negative words.

Table 3

Mixed ANOVA and Post Hoc Results for Valence and Arousal Scores Across Noun Types and Between Groups

Task	Variable	FGID-sufferers			Healthy controls			ANOVA Results *Post Hoc Test Results*
		Symp.	Neutr.	Neg.	Symp.	Neutr.	Neg.	
Task 1	Valence	3.26 *(0.73)*	6.15 *(0.92)*	3.79 (0.56)	3.73 (1.33)	6.29 (1.17)	3.89 (1.16)	Group: $F(1, 56) = 1.64$, $p = .21$, $\eta^2 = .01$ Noun type: $F(1.27, 70.85) = 154.84$, $p < .001$, $\eta^2 = .60$* Interaction: $F(1.27, 70.85) = 0.71$, $p = .44$, $\eta^2 = .01$ *Post Hoc:* *Neutral nouns were rated more positively valenced than symptom-related and negative nouns, and symptom-related nouns were rated more negatively valenced than negative nouns.*
	Arousal	5.63 (0.88)	5.41 (0.96)	5.44 (0.56)	5.36 *(1.36)*	5.72 *(1.61)*	5.50 *(1.25)*	Group: $F(1, 56) = 0.02$, $p = .89$, $\eta^2 < .001$ Noun type: $F(1.24, 69.72) = 0.19$, $p = .72$, $\eta^2 = < .01$ Interaction: $F(1.24, 69.72) = 1.73$, $p = .19$, $\eta^2 = .01$
Task 2	Valence	3.51 *(0.67)*	5.91 *(0.66)*	3.79 *(0.60)*	3.96 *(1.19)*	5.94 *(0.86)*	3.92 *(1.15)*	Group: $F(1, 56) = 1.51$, $p = .22$, $\eta^2 = .01$ Noun type: $F(1.33, 74.66) = 158.28$, $p < .001$, $\eta^2 = .57$ * Interaction: $F(1.33, 74.66) = 1.25$, $p = .27$, $\eta^2 = .01$ *Post Hoc:* *Neutral nouns were rated more positively valenced than symptom-related and negative nouns.*
	Arousal	5.44 *(0.87)*	5.11 *(0.66)*	5.48 *(0.58)*	5.28 *(1.31)*	5.20 *(1.58)*	5.35 *(1.35)*	Group: $F(1, 56) = 0.07$, $p = .79$, $\eta^2 < .01$ Noun type: $F(1.3, 72.68) = 2.20$, $p = .14$, $\eta^2 = .01$ Interaction: $F(1.3, 72.68) = 0.53$, $p = .51$, $\eta^2 < .01$

Note. Sympt. = Symptom-related vs. Neutr. = Neutral vs. Neg. = Negative. Group means and standard deviations for valence and arousal scores are presented for Task 1 and Task 2. Significant *F*-ratios are indicated by *. Pairwise post-hoc *t*-test results are presented for models with significant effects involving noun type.

†Each ANOVA was checked for sensitivity to outliers using Cook’s distances greater than .04 (4/60; Cook, 1977).

Task 1: Silent Reading

The first question addressed in Task 1, Research Question 1, was concerned with whether higher amplitudes in response to symptom-related nouns at the P100 and EPN in FGID-sufferers would indicate an unconscious attentional bias. The mixed ANOVA (see Table 4) did not indicate a significant main or interaction effect for the P100 or EPN. Thus, noun type did not have an effect in either group during the early, unconscious stages of attention.

Our second research aim, in line with Research Question 2, was to explore patterns of conscious attention as captured by the N400 and LPP, with the expectation that symptom-related nouns would elicit lower N400 amplitudes and higher average LPP amplitudes in FGID-sufferers if a conscious attentional bias was present. As can be seen in Table 4, results from the mixed ANOVA for the N400 and LPP did not indicate a significant group or interaction effect. However, a significant condition effect in all regions of interest for the N400 and LPP was observed, suggesting that noun type has an effect during later, conscious stages of attention. Post-hoc analyses indicated that negative nouns elicited lower N400 amplitudes than symptom-related or neutral nouns, while symptom-related nouns elicited higher average LPP amplitudes than negative nouns. These results suggest a pattern of vigilance toward negative (but not symptom-related) nouns during the N400 and avoidance of negative nouns during the LPP in favour of sustained processing of symptom-related nouns.

Table 4

Descriptive Statistics, Factorial Mixed ANOVA (2 Between-Subject Groups X 3 Within-Subject Noun Conditions) and Post-Hoc Test Results by ERP Component and Brain Region

ERP	Region	Healthy Controls			FGID-Sufferers			ANOVA Results
		Sympt	Neutr.	Neg.	Sympt	Neutr.	Neg.	*Post Hoc Test Results*
P100	Occipital	3.01 (3.75)	3.15 (3.42)	2.89 (3.82)	3.81 (3.61)	3.35 (3.98)	3.87 (3.68)	Group: $F(1, 58) = 0.51$, $p = .48$, $\eta^2 = .01$ Noun type: $F(2, 116) = 0.33$, $p = .72$, $\eta^2 <.01$ Interaction: $F(2, 116) = 1.99$, $p = .14$, $\eta^2 <.01$
EPN	Occipital	5.25 (4.05)	5.32 (3.78)	4.59 (3.80)	6.83 (3.47)	6.49 (3.26)	6.82 (3.16)	Group: $F(1, 58) = 3.55$, $p = .07$, $\eta^2 = .05$ Noun type: $F(2, 116) = 0.83$, $p =.44$, $\eta^2 <.01$ Interaction: $F(2, 116) = 2.18$, $p = .12$, $\eta^2 <.01$
	Parieto-Occipital	4.33 (3.62)	4.77 (3.64)	3.79 (3.11)	4.93 (3.70)	4.62 (3.31)	4.57 (3.55)	Group: $F(1, 57) = 0.10$, $p = .75$, $\eta^2 = 0.002$ Noun type: $F(2, 114) = 2.79$, $p = .07$, $\eta^2 <.01^{\dagger}$ Interaction: $F(2, 114) = 1.63$, $p = .20$, $\eta^2 <.01$
N400	Occipital	0.41 (3.84)	0.18 (3.12)	-1.00 (3.91)	1.02 (2.97)	0.66 (2.76)	0.26 (3.01)	Group: $F(1, 58) = 1.00$, $p = .32$, $\eta^2 = .01$ Noun type: $F(2, 116) = 7.71$, $p <.001$, $\eta^2 = .02$* Interaction: $F(2, 116) = 1.06$, $p =.35$, $\eta^2 <.01$ *Post-Hoc* *Negative nouns elicited lower amplitudes (indicating greater vigilance) than symptom-related nouns (t(59)= 3.81, p <.001) and neutral nouns (t(59)=2.94, p = .01).*
	Centro-Parietal	1.70 (4.33)	1.42 (3.90)	0.67 (4.51)	1.73 (3.75)	1.70 (3.66)	0.83 (3.63)	Group: $F(1, 58) = 0.02$, $p = .87$, $\eta^2 = <.01$ Noun type: $F(1.73, 100.22) = 6.26$, $p =.004$, $\eta^2 = .01$* Interaction: $F(1.73, 100.22) = 0.09$, $p = .89$, $\eta^2 = <.01$ *Post-Hoc* *Negative nouns elicited lower amplitudes (indicating greater vigilance) than symptom-related nouns (t(59)=3.20, p = .007) and neutral nouns (t(59)=3.53, p = .002).*
	Frontal	1.10 (3.66)	0.97 (3.56)	0.26 (3.77)	1.31 (4.06)	1.06 (3.76)	0.19 (3.54)	Group: $F(1, 58) = 0.01$, $p = .94$, $\eta^2 = <.01$ Noun type: $F(2, 116) = 7.97$, $p <.001$, $\eta^2 = .01$* Interaction: $F(2, 116) = 0.137$, $p = .87$, $\eta^2 = <.01$ *Post-Hoc* *Negative nouns elicited lower amplitudes (indicating greater vigilance) than symptom-related nouns (t(59)=3.56, p = .001) and neutral nouns (t(59)=3.69, p = .002).*
LPP	Occipital	1.80 (3.62)	1.29 (3.18)	0.46 (3.05)	2.55 (3.27)	2.00 (2.79)	2.19 (2.98)	Group: $F(1, 58) = 1.97$, $p = .17$, $\eta^2 = .03$ Noun type: $F(2, 116) = 5.43$, $p = .006$, $\eta^2 = .01$* Interaction: $F(2, 116) = 2.43$, $p = .09$, $\eta^2 = .01$ *Post-Hoc* *Symptom-related nouns were associated with higher average amplitudes (indicating greater sustained attention) compared to negative nouns, t(59)=3.34, p = .004.*

ERP	Region	Healthy Controls			FGID-Sufferers			ANOVA Results
		Sympt	Neutr.	Neg.	Sympt	Neutr.	Neg.	*Post Hoc Test Results*
	Parieto-Occipital	2.87 (3.30)	2.52 (3.12)	1.89 (2.53)	2.81 (3.34)	2.50 (2.66)	2.28 (2.89)	Group: *F*(1, 58) = 0.02, *p* = .87, η^2 = <.01 Noun type: *F*(2, 116) = 5.75, *p* =.004, η^2 = .011* Interaction: *F*(2, 116) = 0.60, *p* = .55, η^2 <.01 *Post-Hoc:* *Symptom-related nouns were associated with higher average amplitudes (indicating greater sustained attention) compared to negative nouns, t(59)=3.32, p = .005.*
	Parieto-Central	3.60 (4.06)	2.97 (4.01)	2.49 (3.95)	3.470 (3.77)	3.11 (3.51)	2.77 (3.23)	Group: *F*(1, 58) = 0.01, *p* = .92, η^2 = <.001 Noun type: *F*(1.75, 101.75) = 6.69 , *p* =.003, η^2 = .01* Interaction: *F*(1.75, 101.75) = 0.36, *p* = .67, η^2 <.01 *Post-Hoc* *Symptom-related nouns were associated with higher average amplitudes (indicating greater sustained attention) compared to negative nouns, t(59)=3.41, p = .004.*

Note. Sympt. = Symptom-related vs. Neutr. = Neutral vs. Neg. = Negative nouns. * indicates a significant *F*-ratio.[†] This main effect became non-significant when one outlying observation with a Cook's distance greater than .04 was removed. The results with the outlier removed are reported here.

Indices of Attentional Bias and Psychosocial Variables

Symptom Severity

Also addressed by the analyses associated with Task 1 was Research Question 3, a question motivated by the expectation that attentional bias to symptom-related nouns in FGID-sufferers would be positively – and, in the case of the N400, negatively – correlated with ratings of symptom severity. However, symptom severity scores generally did not correlate with indices of unconscious or conscious attentional bias. Table 5 presents the two significant correlations – both observed among FGID-sufferers. Symptom severity among FGID-sufferers positively correlated with LPP amplitude, but only for neutral nouns. For the N400, the relationship was also for neutral nouns – and it was a positive one, perhaps indicating, with increasing symptom severity, greater recognition of neutral words as being "odd-ones-out" amidst otherwise negatively valenced words. Overall, however, correlations between GI symptom severity and ERP amplitude were generally absent.

Table 5

Spearman Rank Correlations by Group (Healthy Controls vs. FGID-Sufferers) Between ERP Amplitude for Noun Type and Symptom Severity and Health Anxiety

		FGID-sufferers *Healthy Controls*					
		Symptom Severity			Health Anxiety		
ERP	Region	Symptom	Neutral	Negative	Symptom	Neutral	Negative
P100	Occipital	.24	.33	.24	-.18	-.08	-.16
		.12	-.05	.04	-.04	-.06	-.10
EPN	Occipital	-.06	-.01	-.06	-.47**	-.41*	-.42*
		-.22	-.31	-.27	-.41*	-.22	-.35
	Parieto-occipital	-.15	-.012	-.09	-.59***	-.56**	-.64***
		-.19	-.24	-.15	-.50**	-.35	-.50**
N400	Occipital	.23	.42*	.23	-.15	-.042	-.02
		.01	-.21	-.06	-.32	-.34	-.28
	Centro-parietal	.04	.07	-.01	-.49**	-.50**	-.56**
		.07	-.04	.01	-.59**	-.52**	-.47*
	Frontal	.07	.07	.04	-.37*	-.28	-.24
		.17	.043	.06	-.37	-.31	-.39*
LPP	Occipital	.13	.46*	.27	-.40*	-.28	-.35
		-.17	-.24	-.08	-.46*	-.32	-.39*
	Parieto-occipital	.08	.19	.12	-.45*	-.41*	-.45*
		-.25	-.29	-.15	-.52**	-.35	-.45*
	Parieto-central	.06	.14	.10	-.33	-.33	-.31
		-.10	-.07	-.05	-.54**	-.33	-.49**

Note. Correlation coefficients for healthy controls are italicised. Significance is denoted by: *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$.

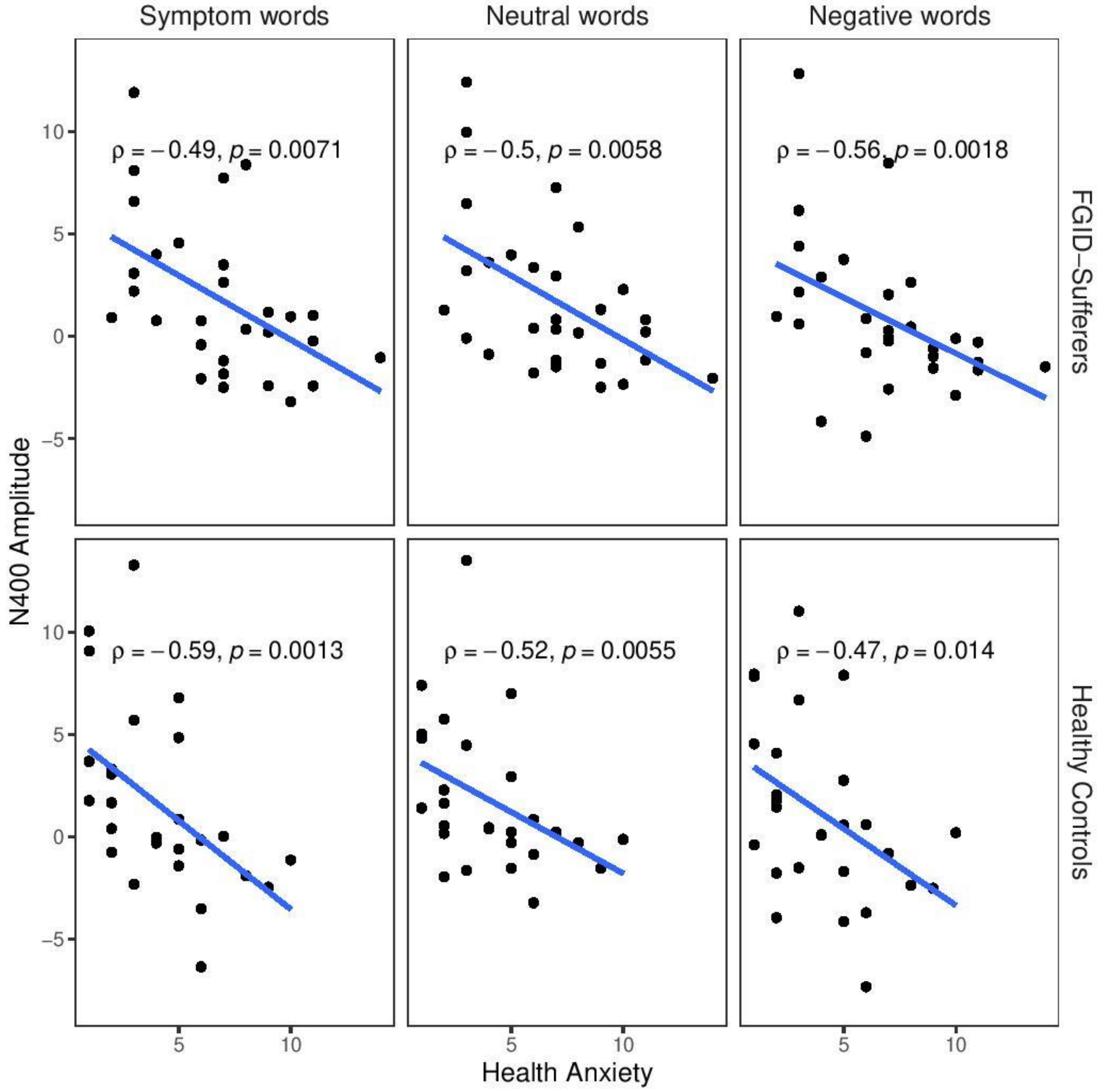
Health Anxiety

Research Question 3 also addressed the relationship between attentional bias to symptom-related nouns and health anxiety. It was expected that increased health anxiety would be associated with a vigilance-avoidance pattern of attention. As can be seen in Table 5, health anxiety scores did not correlate with P100 amplitude in either group. However, a moderate negative correlation between health anxiety and EPN amplitude was observed in both groups and across all noun types, with the exception of neutral nouns in healthy controls. A moderate negative correlation between health anxiety and the centroparietal N400 was also observed, and this effect – illustrated in Figure 3 – was stable across groups and noun type. Moderate negative correlations between health anxiety and frontal N400 were also observed for symptom-related nouns in FGID-sufferers and negative nouns in healthy controls. For the LPP, as Table 5 shows, negative correlations were observed across all noun types and both groups in multiple regions.

Overall, while consistent group and noun type differences did not emerge from the correlational data, the pattern of results suggests that higher health anxiety scores are typically associated with lower amplitudes, implying avoidance during the EPN, vigilance during the N400, and avoidance during the LPP. This result is consistent with the pattern of results observed in relation to Research Question 2 and suggests that health anxiety contributes to vigilance-avoidance processes during conscious attention.

Figure 3

Spearman Rank Correlation Between Health Anxiety and Centroparietal N400 Amplitude Across Groups and Noun Type



Note. Health Anxiety measured using the Whiteley Index (Pilowsky, 1967).

Task 2: Fast Presentation

Research Question 1 was additionally concerned with whether SNR would be higher for symptom-related oddball stimuli in FGID-sufferers during Task 2 if an unconscious attentional bias for symptom-related information was present. As can be seen in Table 6, the results for condition 1 (the control condition in which face stimuli were the oddball amongst 'blobs') indicate that the FPVS method is sensitive to unconscious discriminative responses, as the SNR was significantly higher than 1.6 at the oddball frequency (1.2 Hz) and its harmonics (2.4 Hz, 3.6 Hz, 4.8 Hz). The SNR was also significantly higher than 1.6 at the base frequency (6 Hz) across all conditions, indicating that participants were detecting changes in stimuli.

However, as can be seen in Table 6, the SNR at the oddball frequency and its harmonics for conditions 2-4 was either not significant (e.g., $t(19) = -1.53$, $p = .14$) or significant in the wrong direction (i.e., significantly *lower* than 1.6 [e.g., $t(19) = -6.15$, $p < .001$]). Figure 4 contrasts the results from condition 1, in which increased SNR at the oddball frequency and its harmonics was observed, and condition 2, in which SNR did not meet the significance threshold at the oddball frequency and its harmonics. These results are consistent with the findings for the P100 and EPN in Task 1, as they are not indicative of an unconscious attentional bias toward symptom-related nouns in FGID-sufferers.

Table 6

One-Way t-Test Results by Condition and Group

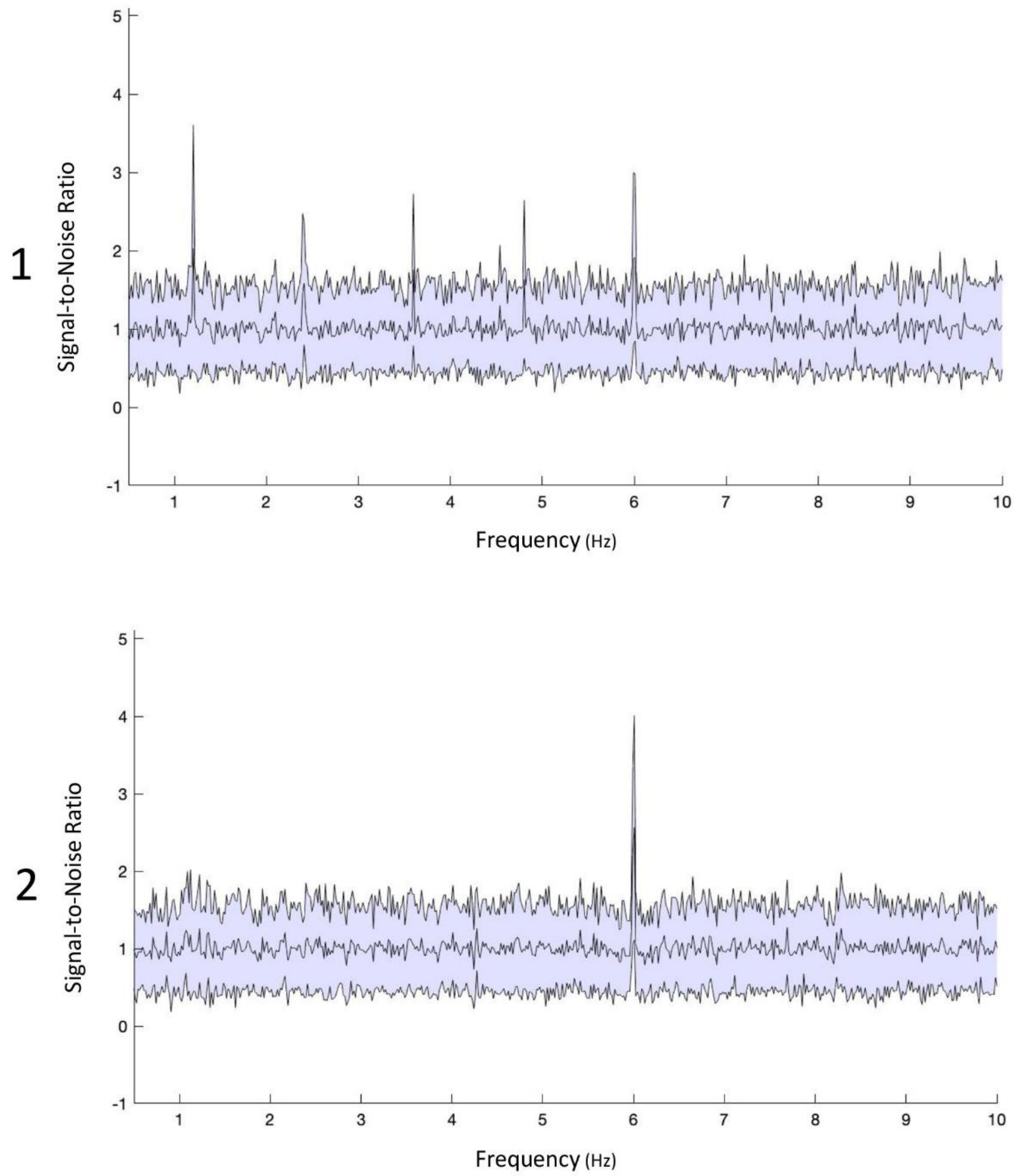
Condition	Group‡	Hz	M	SD	CI	*t*	df	*p*	Cohen's d
Condition 1 Faces (oddball) vs. Blobs (base)	FGID-Sufferers	1.2	2.81	1.53	2.13 - 3.49	3.58	21	.002	.76
		2.4	2.26	1.22	1.72 - 2.80	2.37	21	.03	.51
		3.6	3.42	2.14	2.48 - 4.37	3.90	21	<.001	.83
		4.8	2.86	1.58	2.16 - 3.56	3.61	21	.002	.77
		6	5.35	3.67	3.72 - 6.98	4.73	21	<.001	1.01

Condition	Group[‡]	Hz	M	SD	CI	*t*	df	*p*	Cohen's d
	Healthy Controls	1.2	2.84	1.36	2.21 - 3.48	3.95	19	<.001	.88
		2.4	2.85	1.49	2.15 - 3.55	3.60	19	.002	.81
		3.6	4.14	2.10	3.16 - 5.12	5.30	19	<.001	1.20
		4.8	3.29	2.10	2.30 - 4.27	3.50	19	.002	.78
		6	5.43	2.33	4.34 - 6.51	7.26	19	<.001	1.62
Condition 2 Symptom-related nouns (oddball) vs. neutral nouns (base)	FGID-Sufferers	1.2	0.909	0.561	0.66 - 1.16	-6.15	21	<.001	1.31
		2.4	0.963	0.593	0.70 - 1.23	-5.39	21	<.001	1.15
		3.6	1.083	0.508	0.86 - 1.31	-5.19	21	<.001	1.11
		4.8	1.042	0.651	0.75 - 1.33	-4.34	21	<.001	.93
		6	4.236	1.458	3.59 - 4.88	8.34	21	<.001	1.78
	Healthy Controls	1.2	0.906	0.603	0.62 - 1.19	-5.49	19	<.001	1.23
		2.4	1.075	0.558	0.81 - 1.34	-4.56	19	<.001	1.02
		3.6	1.274	0.679	0.96 - 1.59	-2.45	19	.02	.55
		4.8	1.414	0.675	1.10 - 1.73	-1.53	19	.14	.34
		6	4.799	2.163	3.79 - 5.81	6.52	19	<.001	1.46
Condition 3 Symptom-related nouns (oddball) vs. negative nouns (base)	FGID-Sufferers	1.2	1.11	0.64	0.83 - 1.39	-3.93	21	<.001	.84
		2.4	1.29	0.69	0.98 - 1.59	-2.44	21	.02	.52
		3.6	1.06	0.81	0.70 - 1.42	-3.41	21	.003	.73
		4.8	1.19	0.79	0.84 - 1.54	-2.68	21	.01	.57
		6	4.76	2.14	3.81 - 5.71	6.82	21	<.001	1.46
	Healthy Controls	1.2	0.96	0.68	0.65 - 1.28	-4.52	19	<.001	1.01
		2.4	1.02	0.75	0.67 - 1.37	-3.72	19	.001	.83
		3.6	1.22	0.57	0.96 - 1.49	-3.31	19	.004	.74
		4.8	1.03	0.59	0.76 - 1.31	-4.65	19	<.001	1.04
		6	4.64	1.82	3.78 - 5.49	7.34	19	<.001	1.64
Condition 4 Negative nouns (oddball) vs. neutral nouns (base)	FGID-Sufferers	1.2	0.91	0.60	0.64 - 1.18	-5.71	21	<.001	1.22
		2.4	1.05	0.59	0.79 - 1.31	-4.79	21	<.001	1.02
		3.6	1.08	0.50	0.85 - 1.30	-5.28	21	<.001	1.13
		4.8	1.27	0.57	1.02 - 1.52	-3.08	21	.006	.66
		6	4.087	1.739	3.32 - 4.86	6.59	21	<.001	1.40
	Healthy Controls	1.2	0.95	0.60	0.68 - 1.23	-5.18	19	<.001	1.16
		2.4	1.05	0.42	0.85 - 1.24	-6.35	19	<.001	1.42
		3.6	1.07	0.56	0.81 - 1.33	-4.59	19	<.001	1.03
		4.8	1.45	0.73	1.11 - 1.79	-1.22	19	.24	.27
		6	4.77	2.32	3.68 - 5.85	6.02	19	<.001	1.35

Note. Results for one-way t-test comparing mean SNR scores at the oddball frequency and its harmonics (1.2 Hz, 2.4 Hz, 3.6 Hz, 4.8Hz) as well as the base frequency to 1.6. A score significantly higher than 1.6 would indicate a 60% increase in signal. [‡]Further one-way t-tests were also performed for the full sample (irrespective of group), results were consistent with those presented above for each group and can be found in Appendix D.

Figure 4

Average SNR for All Participants in Conditions 1 (Faces Amongst 'Blobs') and 2 (Symptom-Related Nouns Amongst Neutral Nouns)



Note. Average SNR is represented by the middle line, while the outer lines define the confidence interval. The discriminative response to stimuli can be seen at the base frequency (6 Hz) in both conditions, while the oddball response at 1.2 Hz and its harmonics is only seen in condition 1 (top).

Discussion

The current study explored the time-course of attentional bias to symptom-related nouns in FGID-sufferers compared to healthy controls. The influence of unconscious and conscious attentional processes was of particular interest. Our results did not provide evidence of an unconscious attentional bias to symptom-related, negative, or neutral nouns in FGID-sufferers or controls. However, variation in attention was observed across noun type during the latter, conscious stages of attention. While group differences did not emerge at either stage, the N400 and LPP results suggest a pattern of vigilance for negative nouns, followed by avoidance of negative nouns in favour of sustained attention on symptom-related nouns. Furthermore, correlation results indicated that health anxiety was typically associated with lower amplitudes across attentional indices, and the pattern of results provided preliminary support for health anxiety as a contributing factor in the vigilance-avoidance pattern observed for negative nouns during the N400 and LPP. Conversely, a relationship between indices of attentional bias and symptom severity was not found. The following section will review these key findings in the context of existing literature, with the aim of highlighting directions for future research.

Indices of Unconscious Attentional Bias in FGID-Sufferers

Research Question 1 aimed to determine whether an unconscious attentional bias toward symptom-related nouns occurred in FGID-sufferers. This question was of particular interest, as an unconscious attentional bias to symptom-related stimuli would highlight the interaction between bottom-up, gut-driven hypervigilance and psychological processes, thereby providing support for the role of the BGA in FGIDs. Additionally, the presence of an unconscious attentional bias would inform the psychological treatment of FGIDs, as interventions that involve the conscious modification of thought processes may be less effective in treating automatic, unconscious attentional bias (Mobini & Grant, 2007).

However, the present results were not indicative of an unconscious attentional bias for symptom-related, neutral, or negative nouns in either group. The inclusion of two EEG measures in this study strengthened the findings, as both the ERP results for the P100 and EPN in Task 1 and the SNR results at the oddball frequency is Task 2 were consistent. The FPVS method used here has not previously been applied within emotion-word research. However, it demonstrated the ability to capture unconscious discrimination during the control condition (faces amongst 'blobs') and produced results consistent with the more well-established silent reading method used in Task 1. As no effect was found in this study, further research, perhaps within the context of a more robust emotion-word effect (i.e., unconscious vigilance to threatening words in anxious populations; Bar-Haim et al., 2007) would be required to establish whether this novel method can effectively capture discrimination between subliminally presented emotion-words. Relative to standard EEG tasks the FPVS method requires a minimal number of short trials to detect unconscious discrimination signals. Thus, extending the application of this method within neurocognitive research would be a worthwhile avenue for future investigation.

As previously discussed, the literature relating to unconscious attentional bias in chronic pain populations, including FGIDs, is inconclusive. Our results were consistent with Crombez and colleagues' (2013) meta-analysis in which they reported no unconscious attentional bias for pain-related stimuli in chronic pain patients. However, they were inconsistent with studies of unconscious attentional bias in FGID-sufferers, specifically. Using a masked modified Stroop task, Afzal and colleagues (2006) found an FGID-specific attentional bias to subliminally presented symptom-related words. Similarly, using a masked dot-probe task, Chapman and Martin (2011) reported an attentional bias to subliminally presented pain-words in FGID-sufferers. The inconsistency across the results of our study and two reviewed above may stem from methodological differences. Firstly, both Afzal et al. (2006) and Chapman and Martin (2011) relied on reaction-time-based indices of unconscious attentional bias, which are limited in their ability to infer what attentional processes underlie the resulting latencies (Cisler et al., 2009). In contrast, our study utilised two distinct EEG attentional bias measures with high temporal resolution. Thus, our study was able to provide a more direct, and continuous, measure of attention as it occurred, limiting the influence of behavioural task-demands and the need for inference based on response latencies (Lochy et al., 2015, 2016; Wabnitz et al., 2016).

Secondly, in selecting their word stimuli, both Afzal et al. (2006) and Chapman and Martin (2011) selected words that were matched for frequency and length, but they did not account for word type (i.e., noun, adjective), valence, arousal, or orthographic neighbourhood. Given that unconscious attentional bias to negatively valenced words has been widely reported in both sub-clinically and clinically anxious populations (Bar-Haim et al., 2007), valence is particularly relevant in attentional bias research. As valence wasn't considered across their stimulus sets, it is possible that symptom-related words were perceived more negatively or threatening than the negative words used in their studies. Therefore, making it difficult to ascertain if the unconscious attentional bias they reported was a response to threat or valence, rather than hypervigilance for symptom-related content.

Based on the above review and the present findings, it remains unclear whether an unconscious attentional bias toward symptom-related stimuli occurs in FGID-sufferers. The inconsistencies point toward a need for replication of results. In particular, future studies utilising alternative attentional bias measures and carefully selected symptom-related stimuli would be beneficial in clarifying the presence, or robustness, of an unconscious attentional bias to symptom-related information in FGID-sufferers.

Indices of Conscious Attentional Bias in FGID-Sufferers

Concerning the conscious stages of attentional bias, the second aim of the study was to explore how FGID-sufferers consciously engage with symptom-related stimuli over time. In particular, we sought to determine the extent to which FGID-sufferers engaged in vigilance, avoidance or difficulty disengaging during the later stages of attention. During the LPP, sustained attention for symptom-related nouns was observed across both groups. This pattern is consistent with conscious attentional bias findings in the chronic pain literature, as both Crombez and colleagues' (2013) and Todd et al.'s (2018) meta-analyses reported a bias of similar magnitude for supraliminally presented pain-related stimuli in chronic pain patients. However, unlike in the present study, the bias for pain-related stimuli was not observed in healthy controls. In relation to FGIDs, Chapman and Martin (2011) reported sustained attention for pain-related words in FGID-sufferers and avoidance in healthy controls during the conscious stages of attention. In contrast, Afzal et al. (2006) found a bias for symptom-related words in healthy controls but not FGID-sufferers. Thus, aside from the lack of a group difference in the present study, the pattern of sustained attention toward symptom-related nouns is largely consistent with what has been reported within the literature.

However, it should be noted that our participants were aware that the present study related to gastrointestinal complaints (i.e., through the recruitment advertisement and the online questionnaire, see Appendix E and F, respectively). Therefore, during the later stages of conscious attention participants may have been primed to attend symptom-related stimuli to a greater degree. This could have potentially skewed the results or minimised group differences. Again, the above inconsistencies and limitations highlight the need for further research and replication in this area of attentional bias research.

Regarding negative nouns, a second pattern emerged across both groups during the conscious stages of attention. The N400 amplitude was lower for negative nouns compared to neutral and symptom-related nouns, indicating vigilance. Conversely, average LPP amplitude was lower for negative nouns compared to symptom-related nouns, indicating avoidance. Thus, our results reflect a vigilance-avoidance pattern of attention for negative nouns across both groups. This is largely consistent with the vigilance-avoidance model of attentional bias (Mogg et al., 1987), which posits that initial hypervigilance toward threat, driven by an unconscious threat-detection mechanism, is followed by avoidance of threatening stimuli in an attempt to mitigate distress. However, our results indicated a conscious, rather than unconscious, attentional bias. The vigilance-avoidance model is based on research of attentional bias in anxious populations; thus, this unexpected finding may provide preliminary evidence for alternative patterns of attentional bias across pain and anxiety populations. Alternatively, it may reflect a general grey area within attentional bias literature, as the extent to which different stages of attention (i.e., orientation, maintenance and avoidance) as well as the influence of vigilance and avoidance across these stages remains a point of contention (Cisler & Koster, 2010; Crombez et al., 2013). Despite the inconsistent timing, our results appear to reflect a vigilance-avoidance pattern for negative nouns that occurs frequently within anxious populations in response to threatening information. Given that no group differences emerged in our study, it is possible individual differences in anxiety may have contributed to the pattern observed across the N400 and LPP in response to negative words.

Attentional Bias Indices, Health Anxiety and Symptom Severity

This study has taken a preliminary step in understanding the role of individual differences in attentional bias toward symptom-related information in FGID-sufferers. Given that FGID-sufferers tend to report elevated levels of health anxiety (Crane & Martin, 2002), Research Question 3 aimed to explore the relationship between indices of attentional bias and health anxiety. Research suggests increased health anxiety is associated with attentional bias toward health-threat cues (Mier et al., 2017; Owens et al., 2004) and, as within the general anxiety literature discussed above, a pattern of increased vigilance for such cues, followed by strategic avoidance has also been observed for health anxiety (Jasper & Witthöft, 2011; Lees et al., 2005). Similarly, we found that health anxiety was associated with lower ERP amplitudes, indicating a pattern of avoidance during the EPN, vigilance during the N400, and avoidance during the LPP. Thus, health anxiety may have played a role in the vigilance-avoidance pattern that emerged in response to negative words during the conscious stages of attention in Task 2, though the present study lacks the scope and power to fully explore this relationship. This preliminary evidence highlights the need to investigate attentional bias in FGID-sufferers within the context of individual differences in relevant psychosocial variables.

Research Question 3 also sought to determine the extent to which indices of attentional bias correlated with, or potentially predicted, symptom severity in FGID-sufferers. Our results did not provide evidence of a relationship between unconscious indices of attentional bias and symptom severity. This is consistent with Crombez et al.'s (2013) review, in which a relationship between attentional bias to pain-related stimuli and pain-severity in chronic pain patients was not observed. However, in a study of FGID-sufferers Chapman and Martin (2011) observed a positive correlation between engagement with pain-words during the conscious stages of attention and symptom severity ratings. The ability to predict symptom severity based on an objective attentional bias measure may be limited by the difficulty in gaining an accurate reflection of fluctuating FGID symptoms.

For example, research suggests individuals with IBS typically experience up to 4 episodes of symptoms per month, lasting on average 5 days each, and long periods in which sufferers are symptom-free may also occur (Canavan et al., 2014). In their study, Chapman and Martin, (2011) utilised a measure of symptom-severity (the Somatic Symptom Scale;

Martin & Crane, 2003) that asked participants to rate, on average, how often they have been bothered by GI symptoms over the past seven days, similar to the Gastrointestinal Symptom Rating Scale (Kulich et al., 2008) used in the present study. Given that the symptom severity of FGID-sufferers can vary over periods as short as five days, these measures may not provide an accurate reflection of FGID symptoms.

Furthermore, such retrospective measures could be influenced by recall bias (Mujagic et al., 2015). Experience sampling (in which participants are randomly prompted to complete a short questionnaire throughout the day) may be a particularly promising alternative to retrospective symptom severity measures. In a study exploring various self-report symptom rating methodologies Mujagic and colleagues (2015) found that symptom severity ratings in FGID-sufferers were significantly higher using the retrospective GSRS compared to the average of daily ratings collected using experience sampling. Therefore, future research in this area would benefit from applying measures that accurately reflect the typical variation in symptom severity in FGID-sufferers, as a more accurate reflection could lead to a more consistent and robust correlation.

Limitations and Directions for Future Research

Upon review, there are limitations within the present study that should be addressed in future research within this field. Firstly, while our word selection method was more rigorous than previous studies, there are still potential limitations inherent within our stimulus set. As already mentioned, symptom-related nouns in Task 1 were rated more negatively than negative nouns. The nouns were matched on valence using the database established by Warriner and colleagues (2013) which was validated within a United States population. It is possible that the symptom-related nouns used within Task 1 are perceived more negatively in an Australian context. On a related note, due to differences in mean valence (see: Appendix B), participants may have perceived neutral nouns as a distinct category, apart from symptom-related and negative nouns. Consequently, the uniqueness of neutral words amongst more negatively valenced words might have captured participants' attention. The N400 component would be particularly susceptible to such an influence as it is sensitive to words that appear out of context (Kanske & Kotz, 2007). The stimuli used in Task 1 were also vulnerable to potential repetition effects, as participants viewed the 60 words a total of 6 times. Research indicates that ERP amplitudes tend to decrease after repeated exposure to emotion words, particularly during the N400 component, as repeated exposure facilitates semantic integration (Herbert et al., 2008). Thus, it is possible the repeated exposure to the same series of nouns may have modulated the ERP amplitude.

Taken together, these limitations highlight the need for careful stimulus selection in future research. The use of pilot studies using a representative sample, as well as post hoc manipulation checks, would assist in ensuring valence remains constant across word-type. The use of positively valenced words may also be beneficial in reducing the distinctness of neutral words amongst symptom-related and negative words; and finally, minimising stimulus repetition where possible is necessary to counteract potential repetition effects.

Our study was additionally limited in the extent to which it could address questions regarding correlations between attentional bias and both symptom severity and health anxiety. While we were able to provide preliminary evidence of a relationship between health anxiety and patterns of conscious attention, we did not have the statistical power required to further explore the correlational data to gain a better understanding of that relationship. Thus, further study of the influence of individual differences in relevant psychosocial and health variables on attentional bias in FGID-sufferers would be beneficial. The use of longitudinal designs, such as experience sampling, would also be useful in determining whether attentional bias to symptom-related information, if present, precedes symptom onset or develops over time, as well as the extent to which it is predictive of symptom severity in FGID-sufferers (Chapman & Martin, 2011).

A final notable limitation of the present study is the use of a sub-clinical, undergraduate student sample. As is a common problem within psychology research, the use of a student sample limits the generalisability of the results (Shen et al., 2011). Furthermore, as well as limiting the generalisability of the results, the use of a sub-clinical FGID population may have contributed to the lack of group differences observed in our study. Only 7 participants in the FGID-sufferers group reported a current FGID diagnosis. A large study of both diagnosed and undiagnosed individuals who met the criteria for IBS diagnosis found that diagnosed participants were more likely to report severe GI symptoms and impaired quality of life compared to undiagnosed participants (Sayuk et al., 2017). Thus, our sample may be representative of less severe instances of FGID. However, at present, the literature relating to attentional bias in FGID-sufferers is limited and the findings remain inconclusive. It is clear further research aimed toward establishing the presence and nature of such an attentional bias is required. Due to the increased time and financial cost of conducting studies within clinical populations and settings, consistent replication of an attentional bias in accessible FGID samples may be required before such an undertaking can be considered viable.

Conclusion

The present study aimed to investigate the time-course of attentional bias toward symptom-related nouns in FGID-sufferers by employing EEG – a method with high temporal resolution that has not previously been used in this area. Our results were not indicative of an FGID-specific attentional bias to symptom-related words. However, the use of ERP indices of attention allowed for the identification of a vigilance-avoidance pattern of attention during conscious attention. This pattern correlated with health anxiety and highlighted the importance of considering individual differences in attentional bias research. It is hoped the results and related review of the literature presented here will inspire future research in this area. Considering the high prevalence and debilitating nature of FGIDs, research efforts must continue to be directed toward these disorders from a biopsychosocial perspective. The potential role of psychosocial factors in the presentation and maintenance of FGIDs allows for the possibility of developing effective psychological interventions. Consequently, an understanding of the way in which cognitive processes, such as attention, operate in the context of the brain-gut interaction could inform the development of such interventions, and, in turn, improve outcomes for FGID-sufferers.

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Appendix A: Participants' Psychological and Clinical Characteristics by Group as well as Details of Associated Measures

Characteristic and measure	Description: Calculation, example item, number of items, and Likert scale bounds	Internal consistency (α)	*M*(*SD*) or percentage	
			Healthy controls (*n* = 28)~	FGID-sufferers (*n* = 29)#
Age		NA	22.69 (7.75)	21.7 (6.58)
Depression symptoms: Depression, Anxiety and Stress Scale 21 (Lovibond & Lovibond, 1995)	Mean of 7 items regarding past week (e.g., "I couldn't seem to experience any positive feeling at all"); (0) Did not apply to me at all… (3) Applied to me very much or most of the time	.87	0.29 *(0.37)*	0.66** *(0.53)*
Anxiety symptoms: Depression, Anxiety and Stress Scale 21	Mean of 7 items regarding past week (e.g., I was aware of dryness of my mouth")	.75	0.41 *(0.36)*	0.72** *(0.49)*
Stress: Depression, Anxiety and Stress Scale 21	Mean of 7 items regarding past week (e.g., "I found it hard to wind down")	.84	0.71 *(0.41)*	1.19** *(0.62)*
Neuroticism: International Personality Item Pool (Goldberg, 1999)	Mean of 10 items regarding current moment (e.g., "I am very pleased with myself" – reverse scored); (1) Very inaccurate… (5) Very accurate	.84	2.44 *(0.44)*	2.65 *(0.36)*
Pain catastrophizing: Pain Catastrophizing Scale (Sullivan et al., 1995)	Mean of 13 items regarding thoughts and behaviours when in pain (e.g., "I become afraid that the pain will get worse"); (0) Not at all… (4) All the time	.95	1.21 *(0.91)*	1.29 *(0.89)*
Somatic symptoms: PHQ-15 (Kroenke et al., 2002)	Sum of 10 items regarding degree of bother by a range of non-gastrointestinal symptoms (e.g., "Headaches") in past 4 weeks; (0) Not bothered, (1) Bothered a little, (2) Bothered a lot	NA (categorical responses)	3.30 *(2.55)*	7.24*** *(4.05)*
Health anxiety: Whiteley Index (Pilowsky, 1967)	Sum of 14 yes/no questions regarding health generally (e.g., "Do you often worry about the possibility that you have got a serious illness?") (1) Yes, (0) No	NA (binary responses)	4.07 (2.53)	6.90 *** (3.04)
Active coping: Brief Cope (Carver, 1997)	Mean of 2 items regarding experiences of stressful events (e.g., "I've been taking action to try to make the situation better") (1) I haven't been doing this at all… (4) I've been doing this a lot	.72	2.98 *(0.71)*	2.72 *(0.71)*

Characteristic and measure	Description: Calculation, example item, number of items, and Likert scale bounds	Internal consistency (α)	*M*(*SD*) or percentage	
			Healthy controls (*n* = 28)~	FGID-sufferers (*n* = 29)#
Coping through planning: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been thinking hard about what steps to take")	.79	2.83 *(0.82)*	2.79 *(0.86)*
Coping through acceptance: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been learning to live with it")	.65	2.98 *(0.75)*	2.64 *(0.71)*
Coping through seeking instrumental support: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been getting help and advice from other people")	.89	2.89 *(0.82)*	2.59 *(1.01)*
Coping through seeking emotional/ social support: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been getting emotional support from others")	.87	2.85 *(0.92)*	2.74 *(0.96)*
Coping through positive reframing: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been looking for something good in what is happening")	.50	2.70 *(0.79)*	2.59 *(0.84)*
Coping through humour: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been making jokes about it")	.90	1.89 *(1.10)*	2.02 *(0.84)*
Coping through denial: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been saying to myself, 'this isn't real'")	.56	1.24 *(0.42)*	1.26 *(0.59)*
Coping through distraction: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been turning to work or other activities to take my mind off things.")	.79	2.85 *(0.78)*	2.81 *(0.87)*
Coping through disengagement: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been giving up trying to deal with it")	78	1.28 *(0.42)*	1.45 *(0.63)*
Coping through venting: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been expressing my negative feelings")	.57	2.09 *(0.79)*	2.24 *(0.83)*
Coping through self-blame: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been criticising myself")	.82	1.85 *(0.76)*	2.60** *(1.08)*

Characteristic and measure	Description: Calculation, example item, number of items, and Likert scale bounds	Internal consistency (α)	*M*(*SD*) or percentage	
			Healthy controls (n = 28)[~]	FGID-sufferers (n = 29)[#]
Coping through substance-use: Brief Cope	Mean of 2 items regarding experiences of stressful events (e.g., "I've been using alcohol or other drugs to help me get through it")	.97	1.20 *(0.44)*	1.59* *(0.86)*
Self-efficacy: Generalized Self-Efficacy Scale (Schwarzer & Jerusalem, 1995)	Mean of 10 items regarding general thoughts and feelings (e.g., "I can solve most problems if I invest the necessary effort"); (1) Not at all true… (4) Exactly true	.86	2.81 *(0.57)*	2.78 *(0.45)*
Gastrointestinal symptom severity (past week): Gastrointestinal Symptom Severity Index (Kulich et al., 2008)	Mean of 15 items regarding the past week (e.g., "Have you been bothered by *rumbling* in your stomach during the past week? Rumbling refers to vibrations or noise in the stomach.") (1) No discomfort… (7) Very severe discomfort	.93	1.93 (0.97)	3.30*** (1.12)
Past diagnosed psychiatric disorder (% yes)		NA	26.7% (n = 8)	13.3% (n = 4)
Past chronic illness (% yes)		NA	0% (n = 0)	3.3% (n = 1)
Currently diagnosed functional gastrointestinal condition (% yes)		NA	0% (n = 0)	23.3%* (n = 7)

Note. p-value in independent-samples t-test or chi-square test for counts is indicated by: *** $p \leq .001$, ** $\leq .01$, * $p \leq .05$.

[~]Due to a technical issue, two participants in this group were missing measures of all psychosocial variables.

[#]Due to a technical issue, one participant in this group was missing measures of all psychosocial variables, and an additional participant was missing a pain catastrophizing score.

Appendix B: Characteristics of Nouns Included in the Silent Reading Task (Task 1)

Symptom-related						Neutral						Emotionally negative					
Noun	English lexicon project			Warriner et al.		Noun	English lexicon project			Warriner et al.		Noun	English lexicon project			Warriner et al.	
	Length	Freq.	Orth.	Valence mean	Arousal mean		Length	Freq.	Orth.	Valence mean	Arousal mean		Length	Freq.	Ort h.	Valence mean	Arousal mean
laxative	8	267	0	3.10	4.14	aspiration	10	358	0	6.26	5.00	lobbyist	8	263	0	2.15	5.00
soreness[1]	8	413	0	2.40	3.95	catchphrase	11	66	0	4.89	4.06	swastika	8	484	0	2.81	4.15
discomfort	10	2,000	0	2.84	4.43	chandelier	10	166	0	6.47	3.88	extinction	10	1,774	0	3.13	4.89
constipation	12	442	0	2.45	3.83	choreography	12	510	0	5.95	5.82	hopelessness	12	394	0	2.38	4.78
intestine	9	680	0	3.37	4.50	cleverness	10	251	0	6.95	5.55	centipede	9	664	0	4.10	4.61
discomfort	10	2,000	0	2.84	4.43	coupling	8	1,218	0	5.40	4.61	extinction	10	1,774	0	3.13	4.89
hospital	8	19,468	0	3.52	5.07	decisiveness[6]	12	72	0	6.78	3.95	violence	8	19,852	0	2.90	4.48
excrement[2]	9	543	0	3.85	4.64	flamboyance	11	22	0	5.00	5.52	vandalism	9	501	0	2.92	4.29
flatulence	10	227	0	3.79	5.95	hieroglyph	10	28	0	6.14	3.33	infidelity	10	245	0	3.33	4.62
stomachache	11	15	0	2.16	5.21	housewife	9	726	0	5.42	3.73	beggarwoman	11	0	0	3.24	4.36
sickness	8	1,765	0	3.23	4.18	serenade	8	277	0	6.43	3.32	takeover	8	1,791	0	3.55	3.54
defecation	10	131	0	2.23	4.35	stimulant	9	542	0	6.00	5.95	debauchery	10	203	0	2.75	5.37
syndrome	8	7,055	0	4.33	4.68	strategy	8	19,202	0	5.95	4.15	collapse	8	5,499	0	3.24	4.56
affliction	10	392	0	3.76	5.10	transistor	10	1,748	0	4.71	3.90	castration	10	393	0	3.68	5.00
sluggishnes[3]	12	68	0	4.05	3.20	triangle	8	5,436	0	5.21	3.50	blabbermouth	12	15	0	3.76	6.26
queasiness[4]	10	17	0	2.74	4.82	underdog	8	391	0	5.10	5.38	dreariness	10	6	0	3.29	4.96
medication	10	3,624	2	3.65	4.56	concession	10	801	2	5.32	3.71	repression	10	2,067	2	3.32	3.73
colonoscopy	11	0	0	2.60	4.05	commuter	8	890	3	4.63	3.60	bullfighter	11	33	0	3.32	4.44
diarrhea	8	1,214	0	2.10	6.85	firecracker	11	223	0	5.70	6.67	disgrace	8	1,264	0	3.14	4.56
bloating[5]	8	564	3	2.80	3.00	dynamite	8	1,724	0	4.79	6.40	scuffle	7	128	3	2.33	5.26
Mean	*9.50*	*2,04*	*0.25*	*3.09*	*4.55*		*9.55*	*1,73*	*0.25*	*5.66*	*4.60*		*9.45*	*1,87*	*0.25*	*3.12*	*4.69*
(SD)	*(1.36)*	*(4,43)*	*(0.79)*	*(0.67)*	*(0.86)*			*(4,28)*		*(0.71)*	*(1.08)*		*(1.43)*	*(4,42)*		*(0.49)*	*(0.59)*

Note. The three noun types used in the silent reading task, their lexical properties in the English lexicon project (Balota et al., 2007), and valence and arousal in the dataset assembled by Warriner et al. (2013) Freq. refers to the Hyperspace Analogue to Language (HAL) frequency norms, based on the HAL corpus, which consists of approximately 131 million words gathered across 3,000 news articles published in February, 1995. Orth. is the number of words that can be obtained by changing one letter while preserving the identity and positions of the other letters (e.g., for "CAT": OAT, COT, VAT, CAB, MAT, CAM, BAT, RAT, CAD, HAT, CAP, PAT, FAT, SAT, EAT, CAR, CUT, CAN).[1-6]Variation on word in Warriner et al.'s (2013) database: (1) sore, (2) faeces, (3) sluggish, (4) queasy, (5) bloated, and (6) decisive.

Appendix C: Characteristics of Nouns used in the Fast Presentation Task (Task 2)

Symptom-related						Neutral						Emotionally negative					
Noun	English lexicon project			Warriner et al.		Noun	English lexicon project			Warriner et al.		Noun	English lexicon project			Warriner et al.	
	Length	Freq.	Orth.	Valence mean	Arousal mean		Length	Freq.	Orth.	Valence mean	Arousal mean		Length	Freq.	Orth.	Valence mean	Arousal mean
Pain	4	36596	11	1.68	4.59	hub	3	4,474	13	4.95	3.4	shot	4	42,214	11	2.25	5.25
gut	3	3726	13	3.9	3.67	heat	4	28,372	11	4.77	5.75	sob	3	1,631	13	3.1	5
ache	4	846	3	2.46	4.3	rein	4	791	3	4.79	2.77	thug	4	831	3	3.94	4.61
hurt	4	28018	5	2.45	4.72	gift	4	11,722	5	7.27	4.64	trap	4	9,424	5	3.86	4.65
anus	4	2067	2	3.27	4.39	oval	4	1,754	2	5.14	3.5	sect	4	1,666	2	3.37	6.14
enema	5	805	2	3.29	4.13	knack	5	630	2	5.68	3.77	sneer	5	555	2	4.21	5.28
agony	5	2245	0	2.46	5.78	nanny	5	787	5	5.86	4.05	swarm	5	2,223	0	2.1	5.7
spasm	5	524	0	2.8	4.06	conga	5	147	1	5.9	4.57	scowl	5	131	0	3.71	4.73
bowel	5	953	5	3.21	3.57	pinup	5	102	0	5.74	4.91	noose	5	309	5	2.87	4.7
vomit	5	1313	0	1.98	4.82	shine	5	3,206	8	7.27	5.19	bigot	5	2,055	0	2.82	6.48
belly	5	5,986	8	4.37	3.75	recap	5	705	0	5.33	3.26	shark	5	3,255	8	3.95	4.82
twinge	6	220	0	4.29	4.35	fable	5	314	4	5.75	4.09	alibi	5	333	0	2.65	1.81
cramp	5	383	4	2.91	4.73	jewel	5	1,980	0	6.68	3.83	clang	5	275	4	3.3	4.36
throb	5	309	1	3.68	5.64	rhino	5	1,897	1	6.25	4.1	felon	5	469	1	2.9	3.24
bulge	5	1264	3	3.74	4.05	slant	5	1,431	3	4.84	4.1	bribe	5	1,123	3	2.43	5.38
colon	5	1986	1	4.04	3.64	scuba	5	2,174	0	5.86	3.86	libel	5	2,577	1	3	3.61
nausea	6	1406	0	3.1	4.14	medley	6	948	0	6.6	4.48	menace	6	1,308	0	3.84	4.14
rectum	6	862	0	2	6.27	lagoon	6	668	0	6.23	3.56	orphan	6	844	0	3.78	4.41
toilet	6	5523	1	3.71	4.78	throne	6	5,951	1	5.45	5.22	poison	6	5,095	1	2.45	4.28
shudder	7	1,770	0	4.1	4.48	suntan	6	158	1	6.05	4.25	misery	6	2,895	0	4.26	3.86
flatus	6	49	0	3.79	5.95	cougar	6	1,401	0	5.67	5.7	holdup	6	94	0	2.2	4.82
faeces	6	0	3	2.23	1.31	seesaw	6	28	0	6.5	4.58	shanty	6	190	1	2.15	4.56
glutton	7	115	0	3.53	4.4	hangout	7	389	1	6.45	4.81	killjoy	7	112	0	3.26	3.2
anguish	7	975	0	3.14	5.41	recount	7	337	1	4.89	4.1	whaling	7	902	0	2.2	4.52
ailment	7	287	0	3	3.68	chiffon	7	104	0	6	4.68	copycat	7	221	0	2.2	4.95
Cubicle	7	286	1	3.8	3.05	grammar	7	6,044	0	6.25	4.21	coroner	7	269	1	4.16	4.5
symptom	7	2367	0	3.33	4.17	blossom	7	890	0	7.05	4.75	anxiety	7	2,664	0	2.52	5.48
innards	7	371	1	3.11	3.29	captain	7	21,156	0	5.71	3.86	blister	7	423	1	4.02	5.27

Symptom-related						Neutral						Emotionally negative					
Noun	English lexicon project			Warriner et al.		Noun	English lexicon project			Warriner et al.		Noun	English lexicon project			Warriner et al.	
	Length	Freq.	Orth.	Valence mean	Arousal mean		Length	Freq.	Orth.	Valence mean	Arousal mean		Length	Freq.	Orth.	Valence mean	Arousal mean
illness	7	5875	0	1.95	5.11	gazelle	7	254	0	6.47	4.05	removal	7	5,673	0	2.71	5.95
disease	7	23168	0	1.68	5.5	eclipse	7	2,658	1	6.76	5.12	failure	7	23,998	0	2.16	6.01
Mean	*5.53*	*4343.2*	*2.13*	*3.1*	*4.39*		*5.53*	*3382.4*	*2.1*	*5.94*	*4.31*		*5.53*	*3791.97*	*2.07*	*3.08*	*4.72*
(SD)	*(1.1)*	*(8792.7)*	*(3.34)*	*(0.79)*	*(0.99)*		*(1.14)*	*(6379.2)*	*(3.3)*	*(0.72)*	*(0.7)*		*(1.14)*	*(8564.56)*	*(3.34)*	*(0.74)*	*(0.97)*

Note. The three noun types used in the silent reading task, their lexical properties in the English lexicon project (Balota et al., 2007), and valence and arousal in the dataset assembled by Warriner et al. (2013) Freq. refers to the Hyperspace Analogue to Language (HAL) frequency norms, based on the HAL corpus, which consists of approximately 131 million words gathered across 3,000 news articles published in February, 1995. Orth. is the number of words that can be obtained by changing one letter while preserving the identity and positions of the other letters (e.g., for "CAT": OAT, COT, VAT, CAB, MAT, CAM, BAT, RAT, CAD, HAT, CAP, PAT, FAT, SAT, EAT, CAR, CUT, CAN).

Appendix D: One-Way *t*-Test Across Conditions and the Full Sample

Condition	Hz	M	SD	t	df	*p*	CI	Cohen's d
Condition 1	1.2	2.83	1.43	5.343	41	<.001	2.38 - 3.27	0.825
Faces (oddball) vs.	2.4	2.54	1.37	4.227	41	<.001	2.11 - 2.97	0.652
Blobs (base)	3.6	3.76	2.13	6.46	41	<.001	3.10 - 4.43	0.997
	4.8	3.06	1.84	5.006	41	<.001	2.49 - 3.64	0.772
	6	5.39	3.07	7.897	41	<.001	4.43 - 6.34	1.218
Condition 2	1.2	0.91	0.574	-8.323	41	<.001	0.73 - 1.09	1.284
Symptom words	2.4	1.02	0.573	-7.111	41	<.001	0.84 - 1.20	1.097
(oddball) vs. neutral	3.6	1.17	0.596	-5.123	41	<.001	0.99 -1.36	0.79
words (base)	4.8	1.22	0.681	-4.055	41	<.001	1.01 - 1.43	0.626
	6	4.50	1.827	10.143	41	<.001	3.94 - 5.07	1.565
Condition 3 Symptom	1.2	1.04	0.65	-6.011	41	<.001	0.84 - 1.24	0.928
words (oddball) vs.	2.4	1.16	0.72	-4.351	41	<.001	0.94 - 1.39	0.671
negative words (base)	3.6	1.14	0.70	-4.694	41	<.001	0.92 - 1.36	0.724
	4.8	1.12	0.70	-4.906	41	<.001	0.90 - 1.33	0.757
	6	4.70	1.97	10.039	41	<.001	4.09 - 5.32	1.549
Condition 4 Negative	1.2	0.93	0.59	-7.8	41	<.001	0.75 - 1.12	1.204
words (oddball vs.	2.4	1.05	0.51	-7.632	41	<.001	0.89 - 1.21	1.178
neutral words (base)	3.6	1.07	0.53	-7.053	41	<.001	0.91 - 1.24	1.088
	4.8	1.36	0.65	-2.907	41	0.006	1.15 - 1.56	0.449
	6	4.41	2.04	8.791	41	<.001	3.78 - 5.05	1.357

Note. results for one-way t-test comparing mean SNR scores at the oddball frequency and its harmonics (1.2 Hz, 2.4 Hz, 3.6 Hz, 4.8Hz) as well as the base frequency to 1.6. A score significantly higher than 1.6 would indicate a 60% increase in signal.

Appendix E: Participant Recruitment Advertisement

A research team in the Department of Psychology is currently running a study about how we might track tummy symptoms using EEG technology (a cap connected to electrodes) and a mobile app that asks people 3-minutes-worth of questions once a day. The study consists of an online questionnaire (20 minutes), a neurophysiological recording session at the University's Hearing Hub (90 minutes), and the use of a mobile phone app to report on symptoms once a day for two weeks.

We are currently looking for people18-65 years of age with [without] tummy symptoms who would consider themselves native speakers of English. If you are interested in taking part, we invite you to complete our 5-minute online screener survey (link) and leave an e-mail address or phone number where there's space to do that in the survey. A member of our research team will then get back to you within 24 hours. Please don't hesitate to contact the lead researcher, Dr Anastasia Ejova (anastasia.ejova@mq.edu.au; 9850 8108), if you have any questions. We'd love to hear from you!

Appendix F: Online Survey

Survey intro

Project title
An EEG study of health: Part A, Preliminary online survey

[redacted]

Study information
This study, investigating the role of attention in gut physiology, is being conducted by Dr Anastasia Ejova (postdoctoral research associate), under the supervision of Prof. Mike Jones.

The study has two parts, and this 30-minute online questionnaire about your stress levels and coping strategies is the first part, Part A. Part B involves coming into our lab at the Hearing Hub for an experimental session in which you will be fitted with an electroencephalogram (EEG) before spending about 60 minutes on some word-reading tasks (that is, tasks where you will be asked to silently read words from the medical literature on gastrointestinal disorders and words unrelated to gastrointestinal issues).

Since the EEG can take 45 minutes to set up and you need to wipe your hair down afterwards and complete a short survey, the recording session is expected to take 150 minutes. During the recording session, we will assist you with downloading a smartphone app, which will then send you a short set of questions (1 to 2 minutes) every day for two weeks. We encourage you to answer the questions as soon as you get the reminder, but you will have until the end of the day to complete them.

If you agree to participate, you will receive 7 credits for PSYC104.

Health psychology researchers are becoming particularly interested in how symptoms develop over time, so, in a completely voluntary part of the study, we will send you an e-mail in 3 months' and 6 months' time, each time asking 10 minutes-worth of questions about your current symptoms.

It is possible that, in asking about personal issues around pain and anxiety management, some of the survey and diary questions might cause distress. We ask that you advise us by e-mail (anastasia.ejova@mq.edu.au) if this occurs, so that we can discuss what services are available on campus for finding the appropriate referral pathway. Should you wish to personally research referral pathways, we recommend contacting Campus Wellbeing (9850 7497; campuswellbeing@mq.edu.au) or your GP.

Ethics, confidentiality and dissemination of findings

Participation in this study is entirely voluntary. You are not obliged to participate and if you decide to participate, you are free to withdraw at any time without having to give a reason and without consequence.

Any information or personal details gathered in the course of the study are confidential, except as required by law. No individual will be identified in any publication of the results. Access to the data will be restricted to Professor Jones and approved co-investigators.

The findings of this study may be published in a peer-reviewed journal. If you leave us your e-mail address, we will forward you copies of publications arising from the study. Even before data are published (which can take some months), you are welcome to contact Dr Ejova and Professor Jones (anastasia.ejova@mq.edu.au; mike.jones@mq.edu.au) with any questions.

The ethical aspects of this study have been approved by the Macquarie University Human Research Ethics Committee. If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Director, Research Ethics & Integrity (telephone (02) 9850 7854; email ethics@mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome.

Informed consent to Part A through commencement of the survey

By proceeding to the survey, you indicate that you agree to take part in Part A of this study, understanding the information above. Proceeding to the survey also indicates that any questions you might have at this point have been answered to your satisfaction. We remind you that you can withdraw from participation in this research at any time without consequence.

I have read the information above and consent to taking part in Part A of this study:

[redacted]

Yes

No

Demographics

Please enter the following details to ensure that we can match this data to your screener survey and experiment data.

E-mail address	
Name	
Student ID (OneID)	

Have you ever been diagnosed with irritable bowel syndrome (IBS) or functional dyspepsia by a medical practitioner?

No

Yes

DASS

Please read each statement and select the response option that indicates how much the statement applied to you over the past week. The response options are as follows:
N - NEVER - Did not apply to me at all
S - SOMETIMES - Applied to me some of the time
O - OFTEN - Applied to me a considerable degree, or a good part of the time
AA - ALMOST ALWAYS - Applied to me very much, or most of the time

There are no right or wrong answers. Do not spend too much time on any statement.

	N	S	O	AA
I experienced breathing difficulty (e.g., excessively rapid breathing, breathlessness in the absence of physical exertion)	O	O	O	O
I couldn't seem to experience any positive feeling at all	O	O	O	O

	N	S	O	AA
I was unable to become enthusiastic about anything	O	O	O	O
I was intolerant of anything that kept me from getting on with what I was doing	O	O	O	O
I was worried about situations in which I might panic and make a fool of myself	O	O	O	O
I found it hard to wind down	O	O	O	O
	N	S	O	AA
I was aware of dryness in my mouth	O	O	O	O
I found it difficult to relax	O	O	O	O
I felt that I had nothing to look forward to	O	O	O	O
I felt that life was meaningless	O	O	O	O
I felt I wasn't worth much as a person	O	O	O	O
I felt that I was rather touchy	O	O	O	O
	N	S	O	AA
I was aware of teh action of my heart in the absence of physical exertion (e.g., sense of heart rate increase, heart missing a beat)	O	O	O	O
I felt down-hearted and blue	O	O	O	O
I felt scared without any good reason	O	O	O	O
I felt I was close to panic	O	O	O	O
I experienced trembling (e.g., in the hands)	O	O	O	O
I felt that I was using a lot of nervous energy	O	O	O	O
	N	S	O	AA
I tended to over-react to situations	O	O	O	O

	N	S	O	AA
I found it difficult to work up the initiative to do things	O	O	O	O
I found myself getting agitated	O	O	O	O
	N	S	O	AA

PHQ-15

During the past 4 weeks, how much have you been bothered by any of the following problems?

	Not bothered	Bothered a little	Bothered a lot
Constipation, loose bowels, or diarrhea	O	O	O
Headaches	O	O	O
Pain or problems during sexual intercourse	O	O	O
Dizziness	O	O	O
Shortness of breath	O	O	O
Back pain	O	O	O
Menstrual cramps or other problems with your periods	O	O	O
Feeling your heart pound or race	O	O	O
Stomach pain	O	O	O
Pain in your arms, legs, or joints (Knees, hips, etc)	O	O	O
Chest pain	O	O	O
Nausea, gas, or indigestion	O	O	O
Fainting spells	O	O	O

SF- 12

The next few questions ask for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Answer

each question by choosing just one answer. If you are unsure how to answer a question, please give the best answer you can.

In general, would you say your health is:

Excellent

Very good

Good

Fair

Poor

The following questions are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

	YES, limited a lot	YES, limited a little	NO, not limited at all
Moderate activities such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	O	O	O
Climbing several flights of stairs	O	O	O

During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

	Yes	No
Accomplished less than you would like.	O	O
Did work or activities less carefully than usual.	O	O

During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

	Yes	No
Were limited in the kind of work or other activities.	O	O
Accomplished less than you would like.	O	O

During the past 4 weeks, how much did pain interfere with your normal work (including work outside the home and housework)?

Not at all

A little bit

Moderately

Quite a bit

Extremely

These questions are about how you have been feeling during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling.

How much of the time during the past 4 weeks...

	All of the time	Most of the time	A good bit of the time	Some of the time	A little bit of the time	None of the time
Have you felt down-hearted and blue?	O	O	O	O	O	O
Did you have a lot of energy?	O	O	O	O	O	O
Have you felt calm and peaceful?	O	O	O	O	O	O

During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?

All of the time

Most of the time

Some of the time

A little of the time

None of the time

Generalized self-efficacy scale

The following questions ask you about some general thoughts and feelings. Try to answer them quickly, without spending too much time on any one question.
Response options range from 1 = not at all true to 4 = exactly true

Not at all true			Exactly true
1	2	3	4

I can solve most problems if I invest the necessary effort

I am confident that I could deal efficiently with unexpected events

I can remain calm when facing difficulties because I can rely on my coping abilities

Thanks to my resourcefulness, I know how to handle unforeseen situations

If someone opposes me, I can find the means and ways to get what I want

I can always manage to solve difficult problems if I try hard enough

If I am in trouble, I can usually think of a solution

It is easy for me to stick to my aims and accomplish my goals

I can usually handle whatever comes my way

When I am confronted with a problem, I can usually find several solutions

Pain catastrophising

When I'm in pain...

	Not at all	Slightly	Moderately	Greatly	All the time
I anxiously want the pain to go away	O	O	O	O	O
I become afraid that the pain will get worse	O	O	O	O	O
I can't seem to keep it out of my mind	O	O	O	O	O
I feel I can't stand it anymore	O	O	O	O	O
I keep thinking about how badly I want the pain to stop	O	O	O	O	O
I keep thinking of other painful events	O	O	O	O	O
I keep thinking about how much it hurts	O	O	O	O	O
There's nothing I can do to reduce the intensity of the pain	O	O	O	O	O
I wonder whether something serious may happen	O	O	O	O	O
I worry all the time about whether the pain will end	O	O	O	O	O
It's awful and I feel that it overwhelms me	O	O	O	O	O
I feel that I can't go on	O	O	O	O	O
It's terrible and I think it's never going to get any better	O	O	O	O	O

Neuroticism

Please indicate how much you feel each statement applies to you. Describe yourself as you generally are now, not as you wish to be in the future.

Indicate whether each statement whether it is:
1. Very Inaccurate, 2. Moderately Inaccurate, 3. Neither Accurate Nor Inaccurate, 4. Moderately Accurate, or 5. Very Accurate as a description of you.

1	2	3	4	5

I am very pleased with myself
I am not easily bothered by things
I feel comfortable with myself
I am often down in the dumps
I often feel blue
I rarely get irritated
I panic easily
I dislike myself
I seldom feel blue
I have frequent mood swings

Brief Cope

We are interested in how people respond when they confront difficult or stressful events in their lives. There are lots of ways to try to deal with stress. This part of the questionnaire asks you to indicate what you generally do and feel when you experience stressful events. Obviously, different events bring out somewhat different responses, but think about what you usually do when you are under a lot of stress.

	I haven't been doing this at all	I've been doing this a little bit	I've been doing this sometimes	I've been doing this a lot
I've been getting emotional support from others.	O	O	O	O
I've been trying to get advice or help from other people about what to do.	O	O	O	O
I've been refusing to believe that it has happened.	O	O	O	O
I've been trying to find comfort in my religion or spiritual beliefs.	O	O	O	O

	I haven't been doing this at all	I've been doing this a little bit	I've been doing this sometimes	I've been doing this a lot
I've been giving up trying to deal with it.	O	O	O	O
I've been trying to come up with a strategy about what to do.	O	O	O	O
I've been concentrating my efforts on doing something about the situation I'm in.	O	O	O	O
	I haven't been doing this at all	I've been doing this a little bit	I've been doing this sometimes	I've been doing this a lot
I've been making fun of the situation.	O	O	O	O
I've been blaming myself for things that happen.	O	O	O	O
I've been accepting the reality of the fact that it has happened.	O	O	O	O
I've been saying to myself "this isn't real."	O	O	O	O
I've been looking for something good in what is happening.	O	O	O	O
I've been giving up the attempt to cope.	O	O	O	O
I've been thinking hard about the steps to take.	O	O	O	O
	I haven't been doing this at all	I've been doing this a little bit	I've been doing this sometimes	I've been doing this a lot
I've been expressing my negative feelings.	O	O	O	O
I've been using alcohol or other drugs to make myself feel better.	O	O	O	O
I've been turning to work or others activities to take my mind off things.	O	O	O	O
I've been using alcohol or other drugs to help me get through it.	O	O	O	O
I've been criticising myself.	O	O	O	O
I've been learning to live with it.	O	O	O	O
I've been praying or meditating.	O	O	O	O

	I haven't been doing this at all	I've been doing this a little bit	I've been doing this sometimes	I've been doing this a lot
	I haven't been doing this at all	I've been doing this a little bit	I've been doing this sometimes	I've been doing this a lot
I've been trying to see it in a different light, to make it see more positive.				
I've been getting help and advice from other people.				
I've been taking action to try to make the situation better.				
I've been saying things to let my unpleasant feelings escape.				
I've been getting comfort and understanding form someone.				
I've been doing something to think about it less such as going to movies, watching TV, reading, daydreaming, sleeping, or shopping.				
I've been making jokes about it.				

Hypochondriasis scale

Below is a list of questions about your health. For each one please select either 'Yes' or 'No'.

	Yes	No
Do you often worry about the possibility that you have got a serious illness?		
Are you bothered by many aches and pains?		
Do you find that you are often aware of various things happening in your body?		
Do you worry a lot about your health?		

	Yes	No
Do you often have the symptoms of very serious illnesses?	O	O
	Yes	No
If a disease is brought to your attention (through the radio, television, newspapers or someone you know) do you worry about getting it yourself?	O	O
If you feel ill and someone tells you that you are looking better, do you become annoyed?	O	O
Do you find that you are bothered by many different symptoms?	O	O
Is it easy for you to forget about yourself and think about all sorts of other things?	O	O
Is it hard for you to believe the doctor when he tells you there is nothing for you to worry about?	O	O
	Yes	No
Do you get the feeling that people are not taking your illness seriously enough?	O	O
Do you think that you worry about your health more than most people?	O	O
Do you think there is something seriously wrong with your body?	O	O
Are you afraid of illness?	O	O

Dissemination of results

Would you like to be e-mailed a copy of any publications arising from this study?

Yes

No

The publication of results can take 6 months to 2 years, so if there is an e-mail address other than your university one that you would prefer us to use for disseminating publications, please write it below.

End and password

Thank you for completing this second part of the study. You are now ready to sign up for a recording session time using the invitation code (eegle) provided in an earlier e-mail.

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