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Encoding and Retrieval Biases for Health-Related Scenes in Patients with Severe Health Anxiety

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Author's note

The E-prime file for the paradigm employed in the present study and a data file (containing mean scores and no demographic information in order to avoid information that might disclose participants' identity) can be obtained upon request from the corresponding author.

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Abstract

Severe health anxiety is a disorder characterized by excessive worries about harboring or having a serious illness. The present study examines cognitive biases in evaluation and memory for health-related scenes in severe health anxiety in order to provide insights into the effect of these biases and the formation of illness intrusions in severe health anxiety. Twenty patients with severe health anxiety and 20 healthy participants completed a computerized task consisting of encoding, involuntary retrieval, voluntary retrieval and recognition of health-related, negative and neutral scenes. The results demonstrated that patients with severe health anxiety reported more negative emotional valence and greater physiological arousal to health-related scenes, both during encoding (*p*s <.031, η_p^2 > .09) and retrieval (*p*s <.044, *d*s > 0.18). Furthermore, in contrast to the comparison group, patients with severe health anxiety did not show shorter retrieval time for health-related scenes during involuntary compared with voluntary retrieval (p = .789, d = 0.08), possibly due to greater demands on emotion regulation during involuntary retrieval. The results suggest an important role for negative emotional valence and physiological arousal to health-related stimuli in severe health anxiety, and highlight how cognitive biases in evaluation and memory might be at play in this disorder.

Keywords: Episodic memory; Severe health anxiety; Cognitive bias; Intrusive thoughts

Encoding and Retrieval Biases for Health-Related Scenes in Patients with Severe Health Anxiety

Excessive worries about harboring or having a serious illness and a persistent preoccupation with one's health are characteristic features of severe health anxiety (e.g., Fink et al., 2004; Salkovskis, Rimes, Warwick, & Clark, 2002), also referred to as hypochondriasis (WHO, 1992), illness anxiety disorder or somatic symptom disorder (American Psychiatric Association, 2013; Newby, Hobbs, Mahoney, Wong, & Andrews, 2017). According to the cognitive behavioral model, the maintenance of symptoms of severe health anxiety are driven by a set of processes, such as biases in information processing. This includes an attentional bias towards internal (e.g., somatic sensations) and external (e.g., headlines in the news about cancer) health-related information, which in turn is subject to an interpretation bias, leading to more negative, and sometimes catastrophic, interpretation of this information. The negatively evaluated health-related information might trigger anxiety, which likely increases physiological arousal, and brings normal bodily variations to awareness that would otherwise go unnoticed (Salkovskis & Warwick, 2001; Warwick & Salkovskis, 1990). A recent review (Leonidou & Panayiotou, 2018) assessing the empirical evidence for the maintenance mechanisms proposed by the cognitive behavioral model generally found support for symptoms of health anxiety being associated with an attentional bias towards health-related stimuli and a tendency to evaluate this information more negatively.

The role of a *memory bias* for health-related stimuli is not explicitly addressed in the cognitive behavioral model of health anxiety (Salkovskis & Warwick, 2001; Warwick & Salkovskis, 1990). However, in their review of more recent work, Leonidou and Panayiotou (2018) point out that memory could be an important factor. Studies have demonstrated that health anxiety symptoms are associated with a memory bias for health-related *content* of autobiographical memory and mental imagery (Muse, McManus, Hackmann, Williams, & Williams, 2010; Sansom-Daly,

Bryant, Cohn, & Wakefield, 2014; Wells & Hackmann, 1993; but see Sansom-Daly, Bryant, Cohn, & Wakefield, 2016). Likewise, experimental studies assessing the association between health anxiety symptoms and free recall and/or recognition of health-related stimuli have found evidence of a memory bias (Brown, Kosslyn, Delamater, Fama, & Barsky, 1999; Durso, Reardon, Shore & Delys, 1991; Ferguson Moghaddam, & Bibby, 2007; Hitchcock & Mathews, 1992; Pauli & Alpers, 2002; Witthöft et al., 2016; for negative findings see Gropalis, Bleichhardt, Hiller & Witthöft, 2013; Schmidt, Witthöft, Kornadt, Rist & Bailer, 2013). Specifically, studies have found that higher levels of health anxiety are associated with better recall and recognition of health-related words (Brown et al., 1999; Ferguson et al., 2007; Pauli & Alpers, 2002; Witthöft et al., 2016) and falsely recognizing health-related words that were not presented previously (Ferguson et al., 2007; Pauli & Alpers, 2002; Witthöft et al., 2016). Furthermore, the enhanced recognition of health-related words seems to be influenced by participants with higher levels of health anxiety experiencing stronger negative emotional valence and higher arousal in response to these stimuli (e.g., Ferguson et al., 2007; Witthöft et al., 2016).

These previous studies have advanced our understanding of memory biases in severe health anxiety, but generally share the limitation of examining such biases at only one level of information processing. Cognitive biases are at play at various stages of information processing in psychopathology, for example in attention, evaluation and memory (for reviews see Everaert, Koster, & Derakshan, 2012; Hirsch, Clark, & Mathews, 2006), and the cognitive behavioral model also proposes cognitive biases at different stages of information processing to be at play in health anxiety (Salkovskis & Warwick, 2001; Warwick & Salkovskis, 1990). Examining cognitive biases both during encoding and subsequent memory for the same stimuli would inform the understanding of how these biases interact and together influence the maintenance of the disorder.

A few studies have examined cognitive biases at several stages of information processing in health anxiety. Witthöft et al. (2016) assessed cognitive biases in information processing within the same participants using four experimental paradigms, covering the domains of attention, evaluation, and memory in participants with pathological health anxiety. Across all methods, participants with pathological health anxiety had a stronger attentional bias, more negative explicit evaluations, and biased response behavior towards health-related stimuli. Likewise, Ferguson et al. (2007) examined the interaction of cognitive biases in evaluation and memory. Participants with higher levels of health anxiety were better at recognizing health-related than non-health words, and this was moderated by the remembered health-related words being evaluated as more unpleasant.

None of these studies examined evaluation during encoding and subsequent memory for the *same* material across these different stages of information processing. By examining both the encoding and retrieval of health-related versus other types of material in health anxiety patients versus a healthy comparison group, we here are able to specifically test the hypothesis formulated by Witthöft et al. (2016) that "pathological health anxiety might be characterized by stronger associations of illness-related information and corresponding (negative) emotional evaluations, thereby fostering a greater availability of these concerns in working memory" (Witthöft et al., 2016, p. 465). If so, we should expect health-related scenes to be associated with greater and more intense negative emotional arousal during encoding. This would enhance the encoding of health-related stimuli, which, in turn, would lead to a greater accessibility of this material and its associated emotion during a memory phase (for a review, see Kensinger, 2009). This could result in more frequent memories of, and more negative evaluation and physical reaction in relation to, *memories* of these health-related stimuli in a group of health anxiety patients, relative to a comparison group, when exposed to these cues.

In the present study, we test these possibilities using an experimental paradigm that allows us to measure participants' self-reported reactions to systematically varied pictures of naturalistic scenes during encoding and examine how this same material is remembered after a short delay when participants are cued by associated sounds during a retrieval phase. Our paradigm is designed to simulate real-life situations fostering health-related intrusions. For example, imagine a person with health anxiety seeing a headline in the news about cancer. He or she immediately evaluates this very negatively and experiences a physiological reaction (e.g., beating heart, feeling tense). Later during the same day, the person comes across the same context in which he or she previously noticed the heading. Triggered by the context, the memory of the cancer information pops into the mind of our protagonist with similar negative emotional valence and physiological arousal as when first seeing the headline. This person formed, and involuntarily retrieved, an intrusive memory of the headline about cancer.

The paradigm employed in the present study is intended to mimic the way involuntary memories come about in everyday life, and directly compares two types of retrieval: involuntary (spontaneous) and voluntary (deliberate) retrieval (Berntsen, Staugaard & Sørensen, 2013; Staugaard & Berntsen, 2014). Compared to voluntary retrieval, involuntary retrieval appears particularly interesting in relation to health anxiety. First, involuntary retrieval generally involves a greater emotional reaction and impact on mood than voluntary retrieval (e.g., del Palacio-Gonzalez, Berntsen & Watson, 2017; Berntsen & Hall, 2004; Rubin, Boals & Berntsen, 2008; for a review see Berntsen, 2010), thereby placing greater demands on the emotion regulation strategies of the individual (Berntsen, 2010). Dysfunctional emotion regulation strategies are found to be associated with symptoms of health anxiety (e.g., Bardeen & Fergus, 2014; Görgen, Hiller, & Witthöft, 2014), potentially augmenting the emotional impact of involuntary retrieval in patients with severe health anxiety. Furthermore, intrusions are by definition retrieved involuntarily (e.g., Brewin, Gregory,

Lipton, & Burgess, 2010; Horowitz, 1986; Rubin et al., 2008), and even though their role in health anxiety is understudied, intrusive thoughts about disease and illness could be a core feature of the cognitive aspect of severe health anxiety (e.g., Langlois, Ladouceur, Patrick, & Freeston, 2004; Muse et al., 2010; Warwick & Salkovskis, 1990). Intrusions about disease and illness could have major impact on the behavior of patients with severe health anxiety (Warwick & Salkovskis, 1990), and have been found to have great emotional impact and to enforce the urge to act in a non-clinical sample, suggesting a link between illness intrusions and behavior (Pascual-Vera & Belloch, 2018). Therefore, intrusive thoughts about disease and illness could play a crucial role in the maintenance of severe health anxiety. Given the sparse knowledge on intrusions in severe health anxiety, a first step is to examine the role of involuntary retrieval of health-related scenes relative to other scenes. The involuntary retrieval task employed in the present study acts as an experimental parallel to real life situations in which involuntary memories typically come to mind (Berntsen et al., 2013), that is, in situations characterized by less demanding tasks and/or diffuse attention (for a review see Berntsen, 2010). Pictures of natural scenes paired with natural sounds were used to match everyday involuntary memories as much as possible, since they are typically of everyday situations and often triggered by auditory cues (e.g., Berntsen, 2009; Berntsen et al., 2013).

In the present study, we use three types of scenes: Neutral scenes (e.g., scenes with everyday objects), negative scenes (e.g., traffic accidents) and non-aversive health-related scenes, that is, scenes that are benign and emotionally neutral but have a clear reference to health (e.g., neutral hospital scenes).

Hypotheses. The fears in severe health anxiety are specific to illness (American Psychiatric Association, 2013; WHO, 1992), therefore no differences in the encoding, retrieval, or recognition of negative or neutral scenes were expected between patients with severe health anxiety and the comparison group.

For the health-related scenes, patients with severe health anxiety were expected to report higher emotional intensity, a greater physical reaction, and more negative emotional valence in both the encoding and retrieval phases, as well as a higher frequency of remembering such scenes, relatively to the comparison group. Finally, relative to the comparison group, we expected the patients to show greater recognition accuracy for health-related scenes.

Involuntary retrieval is typically found to be faster than voluntary retrieval (e.g., Berntsen et al., 2013; Schlagman & Kvavilashvili, 2008), both for emotional and non-emotional stimuli (e.g., Berntsen & Staugaard, 2014), but this was not expected for health-related scenes in patients with severe health anxiety, based on previous studies finding prolonged reaction time in response to health-related material in health anxiety (e.g., Lee et al., 2013; Witthöft et al., 2016) and involuntary retrieval placing greater demands on emotion regulation strategies than voluntary retrieval (e.g., Berntsen, 2010; del Palacio-Gonzalez et al., 2017).

Method

Participants

Twenty patients with a principal diagnosis of severe health anxiety were recruited while attending a three month treatment program at the Research Clinical for Functional Disorders, Aarhus University Hospital. Before entering treatment, patients underwent a thorough clinical assessment performed by trained clinicians using a modified version of the semi structured psychiatric interview Schedules for Clinical Assessment in Neuropsychiatry (WHO, 1998). All patients fulfilled the diagnostic research criteria for severe health anxiety (Fink et al., 2004). In case of comorbidities, severe health anxiety had to be the primary diagnosis for patients to be included in the study.

A comparison group of twenty healthy participants was recruited through a database of adults interested in participating in research and by word-of-mouth. Exclusion criteria for the comparison group was a current or previous diagnosis of severe health anxiety.

Inclusion criteria for all participants was Danish language proficiency and a minimum age of 18 years. All participants received a gift certificate of 150 DKK (approx. $25).

Participant characteristics are displayed in Table 1.

Procedure

The study was approved by the ethics committee of the Center on Autobiographical Memory Research, Aarhus University, Denmark. Before the study began, participants signed an informed consent form explaining issues relating to confidentiality and withdrawal, as well as information about the occurrence of unpleasant pictures in the study.

The experimental task was a modified version of a design employed in previous studies (e.g., Berntsen et al., 2013; Staugaard & Berntsen, 2014). Participants were tested individually in a session lasting approximately 1.5 hours. The experiment was presented on E-Prime Professional Version 2.0 (Psychology Software Tools, Inc.) on a laptop computer, and consisted of four phases presented in a fixed order: Encoding, involuntary retrieval, voluntary retrieval, and recognition.

Encoding. In the encoding phase, participants were presented with 24 pictures of scenes in randomized order, each picture randomly paired with a unique sound. Participants were instructed that their task was to remember the picture-sound pair. The picture-sound pairs were presented for 4 seconds. Immediately after the presentation, participants rated three characteristics of the scene on five-point scales: how emotionally intense the scene was (1 = not at all intense, 3 = somewhat, 5 = very intense), the emotional valence of the scene (1 = negative, 3 = neutral, 5 = positive) and lastly if the picture of the scene gave rise to any physical reactions, such as beating heart, uneasiness or feeling tense (1 = not at all, 3 = somewhat, 5 = very much). When participants had rated these

aspects of the scene in their individual pace, they were automatically presented with the picture-sound pair again, then a fixation cross appeared for 1.5 seconds before a new scene-sound pair was displayed.

Involuntary retrieval. In the involuntary retrieval phase, participants were instructed to perform a simple star location task. A star was presented either on the left or right side of the computer screen, and participants had to indicate on what side of the screen the star was located. A sound was presented simultaneously with the star. Participants were presented with 36 star-sound pairs, of which 24 sounds were identical to the encoding phase and 12 were unfamiliar to the participant.

If an image entered the participant's mind while performing the star location task, they were instructed to press a different button and describe the image that had entered their mind with keywords. After describing the image, participants rated four aspects of the image on five-point scales: first, if the image referred to a specific scene or whether it was an unspecific mix of elements of different scenes (1 = very unspecific, 5 = very specific), then the same three questions assessing emotional intensity, physical reaction and emotional valence as in the encoding phase. After completing the ratings, participants resumed the star location task.

Voluntary retrieval. In the voluntary retrieval phase, all 24 sounds from the encoding phase were presented one by one in random order. Participants were instructed that their task was to remember the scene that was paired with the sound in the encoding phase. If participants indicated that they could not remember the scene, the next sound was played. If participants were able to remember the scene, they were asked to describe it with keywords. After describing the scene, participants rated the scene they remembered on the four questions assessing specificity, emotional intensity, physical reaction and emotional valence as in the involuntary retrieval phase.

Recognition. In the recognition phase, participants were shown the pictures from the encoding phase along with their mirror image. Participants had to indicate which picture they had previously seen and rate how confident they were in their choice on a five-point scale (1 = very uncertain, 5 = very certain).

Coding of Scenes Reported during Retrieval

The keywords the participants had provided for scenes remembered in the involuntary and voluntary phase were coded for their correspondence to picture categories presented at encoding by two independent coders. If the keywords did not reference a scene presented during encoding, it was coded as 'other'[1] and not included in any analyses. The interrater agreement for picture category (health related, negative, neutral, other) was 97.1%. Disagreements were resolved through discussion.

Materials

Pictures. Sixteen health-related, 16 negative and 16 neutral pictures of scenes were divided into two sets, each consisting of eight scenes from the three picture categories. Half of the participants in each group were presented with Picture Set 1 and the other half with Picture Set 2. All pictures were adjusted to 840x840 pixels and presented on a black computer screen.

The pictures depicting negative and neutral scenes were from the Nencki Affective Picture System (NAPS; Marchewka, Żurawski, Jednoróg, & Grabowska, 2014). The negative scenes depicted traffic accidents (e.g., car crash, motor cycle accident), and were chosen based on their content and rating in the NAPS (Marchewka et al., 2014) as negative (Picture Set 1: M = 2.58, SD = 0.19; Picture Set 2: M = 2.60, SD = 0.25) rated on a nine-point scale (1 = very negative, 5 = neutral, 9 = very positive) and arousing (Picture Set 1: M = 6.72, SD = 0.36; Picture Set 2: M = 6.83, SD =

[1] For patients with severe health anxiety 8.0% and 2.1% of the reported scenes were coded as "other" in the involuntary and voluntary phase, respectively. For the comparison group this was the case for 35.0% and 3.7% of the reported scenes in the involuntary and voluntary phase, respectively.

0.33) rated on a nine-point scale (1 = relaxed, 5 = neutral/ambivalent, 9 = aroused). The neutral pictures depicted everyday scenes (e.g., a computer keyboard on a table, cleaning supplies on a floor), and were chosen based on their content and rating in the NAPS (Marchewka et al., 2014) as neutral (Picture Set 1: M = 5.03, SD = 0.13; Picture Set 2: M = 5.04, SD = 0.10) rated on a nine-point scale (1 = very negative, 5 = neutral, 9 = very positive) and neutral in arousal (Picture Set 1: M = 4.85, SD = 0.18; Picture Set 2: M = 4.82, SD = 0.15) rated on a nine-point scale (1 = relaxed, 5 = neutral/ambivalent, 9 = aroused).

The pictures depicting health-related scenes were comprised of pictures from the NAPS (Marchewka et al., 2014) and Aarhus University Hospital, and primarily depicted hospital scenes (e.g., hospital room with bed, hospital equipment operated by a nurse). Before the present study was conducted, 32 health-related pictures were validated in a sample of healthy Danish adults (N = 59; 31 females; M_{age} = 44.80, SD = 17.25). The 16 health-related pictures for the present study were chosen based on their content and rating of valence as being neutral (Picture Set 1: M = 5.10, SD = 0.33; Picture Set 2: M = 5.10, SD = 0.30) rated on a nine-point scale (1 = very negative, 9 = very positive) and as low in intensity (Picture Set 1: M = 2.24, SD = 0.20; Picture Set 2: M = 1.62, SD = 0.28) rated on a nine-point scale (1 = not at all intense, 9 = very intense).

ID numbers for all pictures in the present study from the NAPS (Marchewka et al., 2014) are presented in Supplemental material A.

For all pictures in the present study it applies that the focus was on the scene/objects in the picture and not on the people (e.g., no clearly visible faces), for which it is important to control (e.g., Talmi, Schimmack, Paterson, & Moscovitch, 2007). Also, all pictures depicted natural scenes that participants could encounter in their everyday life (hospital scenes, car accidents, everyday objects). Thus, there were no pictures of, for example, war scenes or unfamiliar objects that participants are less likely to have encountered and therefore would associate with low personal

relevance. Furthermore, individuals generally display an attentional bias for negative stimuli (e.g., Talmi et al., 2007; for a review, see Kensinger, 2009). In order to separate the effects of negative emotional valence and health-related content, the present study employed neutral health-related pictures, and negative pictures with no reference to illness or disease. The neutral scenes also had no reference to illness or disease, but were similar to the health-related scenes in terms of emotional valence.

Sounds. Thirty-six emotionally neutral sounds (for ratings of emotional valence, see Staugaard & Berntsen, 2014) from royalty-free sound libraries were presented to participants using headphones. The sounds were normalized and cut short at 4 seconds, and have been used in previous studies (e.g., Berntsen et al., 2013; Staugaard & Berntsen, 2014).

Questionnaires. After all four stages of the experimental task were completed, participants answered the following questionnaires in the order in which they are presented.

To assess executive functioning, participants wrote as many names of animals (category fluency; e.g., cat, elephant) as possible, and then as many words beginning with the letter S (letter fluency; e.g., salt, silver) as possible in one minute (Lezak, Howieson, Bigler, & Tranel, 2012). If participants had written words not related to the task (e.g., nonsense words) or had written the same word twice these were removed before calculating the final word count[2].

Symptoms of severe health anxiety were measured with the Whiteley index consisting of 7 items with a total sum score ranging from 7-35 (WI-7; Conradt, Cavanagh, Franklin, & Rief, 2006; Fink et al., 1999) and the Short Health Anxiety Inventory (SHAI; Salkovskis et al., 2002) which consists of eighteen questions with a total sum ranging from 0-54.

[2] A total of 22 words were removed for the mentioned reasons.

One subscale from the Symptom Check List – revised (Derogatis, 1983) was employed to measure degree of physical symptoms. The scale consists of 12 items with a total sum score ranging from 0-48.

The Generalized Anxiety Disorder scale (GAD-7; Spitzer, Kroenke, Williams, & Löwe, 2006) consists of seven items with a total sum score ranging from 0-21. The GAD-7 was developed as a screening tool for GAD, but has been shown to be reasonable in assessing symptoms of social anxiety, panic disorder and post-traumatic stress disorder (Kroenke, Spitzer, Williams, Monahan, & Löwe, 2007).

Symptoms of depression were assessed with Beck's Depression Inventory (Beck, Steer, & Brown, 1996), which consists of 21 questions with a total sum score ranging from 0-63.

Data Analysis

Data analysis was performed using SPSS (version 24) (IBM Corp., 2016). Differences between the picture sets were assessed with 2 (picture set: one, two) x 3 (picture category: health-related, negative, neutral) repeated measures analysis of variance (ANOVA). The measures at encoding and recognition were analyzed with 2 (group: severe health anxiety, comparison group) x 3 (picture category: health-related, negative, neutral) repeated measures ANOVAs. And the frequency of scenes recalled during the retrieval phases was analyzed with a 2 (group: severe health anxiety, comparison group) x 2 (retrieval type: involuntary, voluntary) x 3 (picture category: health-related, negative, neutral) repeated measures ANOVA based on mean scores calculated for each participant. Main effects and interactions were followed up with simple effects using a Bonferroni correction. Effect sizes are expressed as partial eta squared (η_p^2).

Paired samples t-tests were performed to test specific hypotheses for differences in reaction time between voluntary and involuntary retrieval within groups.

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Data from the retrieval phases was analyzed with multilevel linear models, because cases are not deleted list wise but kept in the analyses, despite of missing data points (e.g., no memories of negative scenes in the voluntary phase). Furthermore, this allowed us to have individual scenes retrieved as the unit of analysis instead of participants. A two-level model was specified (memories nested within individuals), with a random intercept and estimated with the Maximum Likelihood method. Thirty-five separate mixed model analyses were performed. Each retrieval measure (physical reaction, emotional valence, emotional intensity, specificity and retrieval time) were paired with the three predictor variables (1) group (health anxiety, comparison group), (2) picture category (health-related, negative and neutral) and (3) retrieval type (involuntary, voluntary). Effect sizes are reported as Cohen's d calculated based on the *F* statistic as follows, $d = 2 \times \sqrt{(F/ddf)}$ (Verbeke & Molenberghs, 2000).

All p-values are two-tailed and regarded statistically significant at $p < .05$.

Results

Picture Sets

There were no main effects of picture set (Fs < 3.55, ps > .067) or interactions with picture set (Fs < 1.65, ps > .199) for the measures at encoding, the frequency of memories retrieved or confidence and accuracy ratings at recognition, for which reason the two sets will be collapsed in the following analyses.

Encoding

Means and standard errors for the measures at encoding are displayed in Table 2. A Table displaying correlations between measures at encoding is available in Supplemental material B.

Physical reaction. A main effect of picture category, $F(2,76) = 42.66$, $p < .001$, $\eta_p^2 = .53$, showed that the scenes from the three picture categories differed in their rating of physical reaction

at encoding (negative > health-related > neutral; *p*s < .001). There was also a statistically significant interaction between group and picture category, $F(2,76) = 3.64$, $p = .031$, $\eta_p^2 = .09$, demonstrating that patients with severe health anxiety gave higher ratings of physical reaction for health-related scenes than the comparison group ($p = .022$), but that the two groups did not differ in their rating of neutral ($p = .654$) or negative scenes ($p = .891$) (Figure 1).

Emotional intensity. There was a main effect of picture category for the rating of emotional intensity, $F(2,76) = 134.90$, $p < .001$, $\eta_p^2 = .78$, which reflected that the scenes from the three picture categories differed (negative > health-related > neutral; *p*s < .001). There was also a main effect of group $F(1,38) = 4.35$, $p = .044$, $\eta_p^2 = .10$, which reflected that patients with severe health anxiety gave higher ratings of emotional intensity than the comparison group (Figure 1). No statistically significant interactions were found.

Emotional valence. A main effect of picture category, $F(2,76) = 155.79$, $p < .001$, $\eta_p^2 = .80$, showed that the emotional valence (i.e., pleasantness) of scenes from the three picture categories differed (neutral > health-related > negative; *p*s < .001). There was also a statistically significant interaction between picture category and group, $F(2,76) = 4.35$, $p = .016$, $\eta_p^2 = .10$. This reflected that patients with severe health anxiety differed in their rating of emotional valence for all three picture categories (*p*s < .001), giving neutral pictures the highest rating and negative pictures the lowest rating. In contrast, the comparison group did not differ in their rating of emotional valence for health-related and neutral scenes ($p = .093$), but rated the negative scenes as more negative than the other categories (*p*s < .001) (Figure 1).

Retrieval (Recall)

Means and standard errors for the frequency of scenes remembered and measures at retrieval are displayed in Table 2. Main and interaction effects for the mixed model analyses are presented in

Table 3. A Table displaying correlations between measures at retrieval is available in Supplemental material B.

Frequency. A main effect of retrieval type, $F(1, 38) = 9.47$, $p = .004$, $\eta_p^2 = .20$, demonstrated that the frequency of scenes remembered in the voluntary phase was higher than the frequency of scenes remembered in the involuntary phase (in line with previous studies; Berntsen et al., 2013; Schlagman & Kvavilashvili, 2008; Staugaard & Berntsen, 2014). Furthermore, a main effect of picture category, $F(2, 76) = 10.41$, $p < .001$, $\eta_p^2 = .22$, showed that health related scenes were less frequently remembered than negative and neutral scenes (*p*s < .002), whereas negative and neutral scenes were remembered with equal frequency in the retrieval phases ($p = 1.00$). No statistically significant interactions were found, also not the expected interaction between group and picture category, $F(2, 76) = 0.05$, $p = .954$, $\eta_p^2 = .00$.

Emotional valence. A main effect of picture category (Table 3) showed that memories of scenes from the three picture categories differed in their rating on emotional valence during retrieval (neutral > health-related > negative; *p*s < .001). There was an interaction between picture category and group (Table 3), which reflected that patients with severe health anxiety and the comparison group did not differ in their ratings of the remembered negative ($p = .704$) or neutral scenes ($p = .459$), but patients with severe health anxiety rated the remembered health-related scenes as more negative than the comparison group ($p = .034$) (Figure 1).

Emotional intensity. For emotional intensity there was a main effect of picture category at retrieval (Table 3), demonstrating that memories of scenes from the three picture categories differed (negative > health-related > neutral; *p*s < .005). No statistically significant interactions were found.

Physical reaction. A main effect of picture category at retrieval (Table 3) showed that memories of scenes from the three picture categories differed in their rating of physical reaction (negative > health-related > neutral; *p*s < .001). A two-way interaction between group and picture

category close to the level of statistical significance (p = .053) showed the same pattern as for physical reaction in the encoding phase, that is, patients with severe health anxiety gave higher ratings of physical reaction for health-related scenes than the comparison group (p = .042), but the two groups did not differ in their rating of neutral (p = .124) or negative scenes (p = .770) (Figure 1). However, the tendency for a two-way interaction was qualified by a three-way interaction between group, picture category and retrieval type (Table 3), which reflected that during voluntary – but not involuntary – retrieval, patients with severe health anxiety gave higher ratings of physical reaction for health-related scenes – but not other scenes – than the comparison group (p = .023). There were no group differences for negative (ps > .257) or neutral (ps > .057) scenes during involuntary or voluntary retrieval.

Specificity. A main effect of picture category (Table 3) demonstrated that memories of neutral scenes were rated as more specific than memories of negative scenes (p < .001) (in line with Staugaard & Berntsen, 2014), but that the remembered health-related scenes did not differ from negative or neutral scenes on ratings of specificity at retrieval (ps > .057). There was also an interaction between picture category and group (Table 3), reflecting that patients with severe health anxiety did not differ in their rating of specificity for the remembered scenes across picture categories (ps > .141), but the comparison group remembered the negative scenes as less specific than the health-related (p = .037) and neutral (p < .001) scenes, but did not differ in their rating of the remembered health-related and neutral scenes (p = .189) (Figure 1).

Retrieval time. A main effect of retrieval type showed that scenes were retrieved faster in the involuntary phase than in the voluntary phase (Table 3) (in line with previous studies; Berntsen et al., 2013; Schlagman & Kvavilashvili, 2008; Staugaard & Berntsen, 2014). No statistically significant interactions were found.

Because of specific hypotheses, the retrieval times for involuntary and voluntary retrieval for each picture category were compared within groups. The comparison group was faster at responding to all picture categories during involuntary retrieval than during voluntary retrieval (*t*s > 3.40, *p*s < .009, *d*s > 1.10). Patients with severe health anxiety were also faster at retrieving negative, $t(11) = 2.22$, $p = .048$, $d = 0.64$, and neutral scenes, $t(12) = 2.42$, $p = .033$, $d = 0.67$, during involuntary retrieval compared to voluntary retrieval, but for health-related scenes there was no difference in retrieval time between the two retrieval phases, $t(10) = 0.28$, $p = .789$, $d = 0.08$.

Recognition

Means and standard errors for the measures at recognition are displayed in Table 2.

There were no main effects of group (*F*s < 1.86, *p*s > .181) or interactions with group (*F*s < 1.27, *p*s > .287) for confidence ratings or accuracy at recognition. A main effect of picture category for confidence ratings, $F(2, 76) = 7.84$, $p < .001$, $\eta_p^2 = .17$, showed that neutral scenes had overall lower confidence ratings than negative ($p = .005$) and health-related ($p = .007$) scenes. A main effect of picture category for accuracy, $F(2, 76) = 7.00$, $p = .002$, $\eta_p^2 = .16$, showed that neutral scenes were remembered less accurately than negative scenes ($p = .002$), whereas health-related scenes did not differ in accuracy from the other picture categories (*p*s > .093).

Exploratory Analyses

Given the small sample size, exploratory Bayesian repeated measures ANOVA's using JASP (Wagenmakers et al., 2018) were performed for emotional valence, emotional intensity and physical reaction at encoding and retrieval, and for reaction time and frequency at retrieval. In Supplemental material C, Bayes factors from Bayesian model averaging are reported. The analyses support the interactions between group and picture category for emotional valence ($BF_{10} = 5.72$) and physical reaction ($BF_{10} = 2.71$) at encoding and for emotional valence at retrieval ($BF_{10} = 10.46$).

Discussion

The present study examined cognitive biases in evaluation and memory across encoding, involuntary and voluntary retrieval and recognition of negative, neutral and health-related scenes in patients with severe health anxiety and a comparison group. Patients with severe health anxiety encoded and subsequently remembered health-related scenes as more negative and self-reported a greater physical reaction to the health-related scenes than the comparison group. Also, contrary to the comparison group, patients with severe health anxiety did not have shorter retrieval times to health-related scenes at involuntary retrieval compared with voluntary retrieval.

In line with previous studies (e.g., Ferguson et al., 2007; Pauli & Alpers, 2002), the present findings suggest that information processing biases in health anxiety (relative to healthy cognition) are specific to health-related stimuli, and do not generalize to other emotional material, consistent with the disorder being conceptualized in terms of the object of the fear (American Psychiatric Association, 2013; WHO, 1992), although some studies have not found a bias specific to only health-related stimuli (e.g., Gropalis et al., 2013; Schmidt et al., 2013).

One exception to the specificity towards health-related stimuli in the present study was the finding that patients with severe health anxiety overall reported higher emotional intensity than the comparison group for all picture categories at encoding, but not at retrieval. One of the components of emotion dysfunction potentially involved in psychopathology is heightened intensity of emotions, which includes having emotional reactions occurring easily and intensely (Menin, Holaway, Fresco, Moore, & Heimberg, 2007). Therefore, one reason for this finding could be that the random presentation of scenes during encoding sparked a generally heightened emotional intensity in patients that persisted throughout the encoding phase, maybe due to poorer emotion

regulation (e.g., Bardeen & Fergus, 2014; Görgen et al., 2014). Possibly, this effect was not maintained at retrieval because no stimuli were presented.

We did not find the predicted interaction between group and picture category for emotional intensity at encoding or retrieval. Thus, patients with health anxiety did not rate health-related scenes as more emotionally intense than did the comparison group. This aspect of emotion is not explicitly covered in the cognitive behavioral model (Salkovskis & Warwick, 2001; Warwick & Salkovskis, 1990), and it might be secondary to the feeling of physiological arousal in severe health anxiety, given the importance of body vigilance and physical sensations in this disorder (e.g., Leonidou & Panayiotou, 2018; WHO, 1992).

In line with this, we consistently found that patients with severe health anxiety reported higher physiological arousal as well as more negative emotional valence in response to health-related scenes across encoding and retrieval, suggesting an important role for an evaluation bias in health anxiety, but also that this evaluation bias might contribute to a subsequent memory bias for the same health-related stimuli. Consistent with Ferguson et al. (2007) and Witthöft et al. (2016), it could be suggested that a strong connection between feelings of emotional arousal and health-related stimuli in working memory during encoding in health anxiety patients could increase the salience of health-related stimuli in long-term memory. Emotional arousal enhances memory (e.g., Hall & Berntsen, 2008; Talmi et al., 2007; see Kensinger, 2009 for a review), especially for stimuli that capture attention (for a review, see Kensinger, 2009), such as health-related stimuli do in health anxiety (e.g., Salkovskis & Warwick, 2001; Witthöft et al., 2016), making them more likely to be remembered later.

Previous studies have found that higher levels of health anxiety are associated with recalling more health-related stimuli (Brown et al., 1999; Pauli & Alpers, 2002). In the present study, the mean frequency of remembering health-related scenes was numerically higher for patients with

severe health anxiety than for the comparison group, especially during voluntary retrieval. However, the expected interaction between group and picture category was statistically non-significant. Nonetheless, the present findings may still contribute to new insights about the mechanisms underlying intrusions in health anxiety. The finding that health-related scenes were interpreted as more negative and as more physiologically arousing at retrieval by patients with severe health anxiety could suggest that the frequency with which material is remembered is less crucial for intrusions in severe health anxiety, compared with the emotional evaluation and arousal associated with this material during retrieval. In other words, the crucial factor might not be how often health-related memories and images occur in consciousness, but how they are reacted to when they come to mind. These findings lend support to the idea that a combined effect of interpretation and memory biases might be more important for understanding illness intrusions in health anxiety than each of these cognitive biases in isolation, consistent with the hypothesis that combined effects of cognitive biases impact the maintenance of a disorder to the greatest extent (for reviews see Everaert et al., 2012; Hirsch et al., 2006). Future studies could aim at testing this hypothesis by employing other approaches than the present study, such as cross lagged models examining the association between measures over time. Future studies could also include negative health-related scenes alongside neutral health-related scenes to more fully disentangle the effects of negative emotional valence and health-related content.

Slower reaction times for health-related stimuli at *exposure* have been associated with health anxiety symptoms (e.g., Lee et al., 2013; Witthöft et al., 2016). In the present study, reaction times were measured at *retrieval*, and no statistically significant group differences emerged, but the means were in the direction that patients with severe health anxiety had longer retrieval times for health-related scenes than the comparison group, especially during involuntary retrieval. Involuntary retrieval generally involves substantially shorter retrieval time than voluntary retrieval

(e.g., Berntsen et al., 2013; Schlagman & Kvavilashvili, 2008). In the present study, this was found across all scene categories in the comparison group. However, in the health anxiety group, it was found only for negative and neutral scenes, whereas retrieval times for health-related scenes were the same for involuntary and voluntary retrieval. When events come to mind spontaneously, emotion regulation strategies might be less efficient (e.g., Berntsen, 2010; del Palacio-Gonzalez et al., 2017). This finding, combined with the association between health anxiety and dysfunctional emotion regulation strategies (Görgen et al., 2014) could result in more time needed to regulate emotions when retrieving health-related scenes involuntarily, which could explain the effect.

Previous studies have found that health anxiety is associated with better recognition of health-related stimuli (Ferguson et al., 2007; Witthöft et al., 2016), as well as greater confusion of previously presented and novel health-related stimuli (Durso et al., 1991; Ferguson et al., 2007; Pauli & Alpers, 2002; Witthöft et al., 2016). In the present study, no statistically significant group differences in recognition were found, but the means were in the direction that patients with severe health anxiety were more accurate at identifying the health-related scenes than the comparison group. It is important to note that the recognition task in the present study was not designed to replicate previous studies. The task primarily served as a manipulation check, that is, it served to make sure that participants actually had encoded the scenes and were capable of remembering them, which was supported by participants having high scores of accuracy and confidence, reflecting the fact that the task was easily accomplished. It was only a subordinate goal to examine group differences, given the findings of previous studies (e.g., Durso et al., 1991; Witthöft et al., 2016), as the recognition task differed greatly from the ones used in earlier work, for example, by using mirror images as foils (as opposed to new scenes, not previously presented).

Lastly, we found that patients with severe health anxiety rated scenes from all picture categories as equally specific during retrieval, in contrast to the comparison group, who rated the

negative scenes as less specific than the health-related and neutral scenes, in line with previous studies (e.g., Staugaard & Berntsen, 2014). Few studies have examined specificity in health anxiety, but Sansom-Daly et al. (2014) found that symptoms of health anxiety were associated with more specific illness-related future imaginings, in contrast to other psychopathologies where reduced memory specificity is typically found (Williams & Broadbent, 1986; Williams et al., 2007). Future studies should explore the role of memory specificity in health anxiety.

The present study holds several limitations. First, although the sample size is in the range of other experimental studies with samples of patients diagnosed with severe health anxiety (e.g., Brown et al., 1999; Pauli & Alpers, 2002), it is still relatively small. Therefore, the present study is only powered to detect large effects, but when comparing clinically severe samples with healthy comparison groups at least some large effects are expected (in line with previous studies, e.g., Brown et al., 1999; Witthöft et al., 2016).

Second, patients with severe health anxiety had higher levels of symptoms of depression and anxiety than the comparison group, bringing to question whether the observed findings are specific for health anxiety or reflect elevated levels of depression and anxiety. However, heightened symptoms of depression and anxiety are typically found in patients with severe health anxiety relative to control participants (e.g., Pauli & Alpers, 2002; Witthöft et al., 2016), and might be hard, if not impossible, to avoid in clinical treatment seeking samples.

Third, the order of the involuntary and voluntary retrieval tasks were fixed in the present study, potentially making scenes retrieved in the involuntary phase more likely to also be retrieved in the voluntary phase. Previous studies using the same paradigm employed a between-subjects design to avoid this issue. They showed results similar to the present study for retrieval time and frequency during retrieval (Berntsen et al., 2013; Staugaard & Berntsen, 2014), which supports the validity of the present findings. Importantly, participants did not know that the involuntary task was

about memory, whereas this was explicit in the voluntary retrieval phase. Therefore, placing the voluntary retrieval task before the involuntary retrieval task would likely introduce demand characteristics in the involuntary phase, thereby strongly limiting its utility as a task to study involuntary retrieval processes. Furthermore, participants only remembered some of the presented scenes during retrieval, but this did not lead to enhanced memory for these scenes (or decreased memory for the non-remembered scenes), as both groups had high levels of accuracy during the recognition phase and all categories of scenes were recognized equally well, despite differences in frequency during the retrieval phases.

Fourth, the pictures in the present study were generic and not idiosyncratic (i.e., they were not individually tailored to participants). Using idiosyncratic pictures might have yielded larger effects, but also introduces issues, such as adapting pictures to the comparison group and to the sometimes fluctuating concerns of patients with severe health anxiety. Having a serious illness will likely result in visits to the hospital or hospitalization, therefore pictures with hospital scenes should be relevant to many different kinds of illness fears. Previous studies have found an *attentional bias* in health anxiety both when using idiosyncratic (e.g., Lee et al., 2013; Lee, Goetz, Turkel, & Siwiec, 2015) and generic (e.g., Pauli & Alpers, 2002; Witthöft et al., 2016) stimuli.

In summary, the findings suggest an important role for negative emotional evaluation and physiological arousal to health-related stimuli in health anxiety, consistent with the cognitive behavioral model proposing that a central component in generating anxiety in health anxiety is the misinterpretation of neutral or ambiguous health-related information as being threatening (Salkovskis & Warwick, 2001). This enhanced negative emotional arousal might in turn augment memory for these stimuli (e.g., Hall & Berntsen, 2008; Talmi et al., 2007; see Kensinger, 2009 for a review). The present findings suggest that cognitive biases during both stimuli exposure and

memory are at play in severe health anxiety, and that these biases, as well as their interplay during everyday life, are likely to contribute to the maintenance of severe health anxiety.

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Disclosure of Interest

All authors declare no conflicts of interest.

References

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders* (5th. ed.). Washington, DC: American Psychiatric Association.

Bardeen, J. R. & Fergus, T. A. (2014). An examination of the incremental contribution of emotion regulation difficulties to health anxiety beyond specific emotion regulation strategies. *Journal of Anxiety Disorders, 28*, 394-401.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio, TX: Psychological Corporation.

Berntsen, D. (2009). Involuntary Autobiographical Memories: An introduction to the unbidden past. Cambridge: Cambridge University Press.

Berntsen, D. (2010). The unbidden past: Involuntary autobiographical memories as a basic mode of remembering. *Current Directions in Psychological Science, 19*, 138-142.

Berntsen, D. & Hall, N. M. (2004). The episodic nature of involuntary autobiographical memories. *Memory & Cognition, 32*, 789-803.

Berntsen, D., Staugaard, S. R., & Sørensen, L. M. T. (2013). Why am I remembering this now? Predicting the occurrence of involuntary spontaneous episodic memories. *Journal of Experimental Psychology: General, 142*, 426-444.

Brewin, C. R., Gregory, J. D., Lipton, M., & Burgess, N. (2010). Intrusive images in psychological disorders: Characteristics, neural mechanisms, and treatment implications. *Psychological Review, 117*, 210-232.

Brown, H. D., Kosslyn, S. M., Delamater, B., Fama, J., Barsky, A. J. (1999). Perceptual and memory biases for health-related information in hypochondriacal individuals. *Journal of Psychosomatic Research, 47*, 67-78.

Conradt, M., Cavanagh, M., Franklin, J., & Rief, W. (2006). Dimensionality of the Whiteley index: Assessment of hypochondriasis in an Australian sample of primary care patients. *Journal of Psychosomatic Research, 60*, 137-143.

del Palacio-Gonzalez, A., Berntsen, D., & Watson, L. A. (2017). Emotional intensity and emotion regulation in response to autobiographical memories during dysphoria. *Cognitive Therapy and Research, 41*, 530-542.

Derogatis L. R. (1983). *SCL-90-R. Administration, scoring, and procedures. MANUAL-II*. Towson, MD: Clinical Psychometric Research.

Durso, F. T., Reardon, R., Shore, W. J., & Delys, S. M. (1991). Memory processes and hypochondriacal tendencies. *The Journal of Nervous and Mental Disease, 179*, 279-283.

Everaert, J., Koster, E. H. W., Derakshan, N. (2012). The combined cognitive bias hypothesis in depression. *Clinical Psychology Review, 32*, 413-424.

Ferguson, E., Moghaddam, N. G., & Bibby, P. A. (2007). Memory bias in health anxiety is related to the emotional valence of health-related words. *Journal of Psychosomatic Research, 62*, 263–274.

Fink, P., Ewald, H., Jensen, J., Sørensen, L., Engberg, M., Holm, M., & Munk-Jørgensen, P. (1999). Screening for somatization and hypochondriasis in primary care and neurological in-patients: A seven-item scale for hypochondriasis and somatization. *Journal of Psychosomatic Research, 46*, 261–273.

Fink, P., Ørnbøl, E., Toft, T., Sparle, K. C., Frostholm, L., & Olsen, F. (2004). A New, empirically established hypochondriasis diagnosis. *The American journal of psychiatry, 161*, 1680-1691.

Görgen, S. M., Hiller, W., & Witthöft, M. (2014). Health anxiety, cognitive coping, and emotion regulation: A latent variable approach. *International Journal of Behavioral Medicine, 21*, 364-374.

Gropalis, M., Bleichhardt, G., Hiller, W., & Witthöft, M. (2013). Specificity and Modifiability of Cognitive Biases in Hypochondriasis. *Journal of Consulting and Clinical Psychology, 81*, 558-565.

Hall, N. M. & Berntsen, D. (2008). The effect of emotional stress on involuntary and voluntary conscious memories. *Memory, 16*, 48-57.

Hirsch, C. R., Clark, D. M., & Mathews, A. (2006). Imagery and interpretations in social phobia: Support for the combined cognitive biases hypothesis. *Behavior Therapy, 37*, 223-236.

Hitchcock, P. B. & Mathews, A. (1992). Interpretation of bodily symptoms in hypochondriasis. *Behavior Research and Therapy, 30*, 223-234.

Horowitz, M. J. (1986). Stress-response syndromes: A review of posttraumatic and adjustment disorders. *Hospital and Community Psychiatry, 37*, 241-249.

IBM Corp. (2016). *IBM SPSS Statistics for Windows, Version 24.0*. Armonk, NY: IBM Corp.

Kensinger, E. A. (2009). Remembering the Details: Effects of Emotion. *Emotion Review, 1*, 99-113.

Kroenke, K., Spitzer, R. L., Williams, J. B. W., Monahan, P. O., & Löwe, B. (2007). Anxiety disorders in primary care: Prevalence, impairment, comorbidity, and detection. *Annals of internal medicine, 146*, 317-325.

Langlois, F., Ladouceur, R., Patrick, G., & Freeston, M. H. (2004). Characteristics of illness intrusions in a non-clinical sample. *Behavior Research and Therapy, 42*, 683-696.

Lee, H.-J., Goetz, A. R., Turkel, J. E., & Siwiec, S. G. (2015). Computerized attention retraining for individuals with elevated health anxiety. *Anxiety, Stress, and Coping, 28*, 226-237.

Lee, H., Turkel, J. E., Cotter, S. P., Milliken, J. M., Cougle, J., Goetz, A. R., & Lesnick, A. M. (2013). Attentional bias toward personally relevant health-threat words. *Anxiety, Stress, & Coping, 26*, 493-507.

Leonidou, C. & Panayiotou, G. (2018). How do illness-anxious individuals process health-threatening information? A systematic review of evidence for the cognitive-behavioral model. *Journal of Psychosomatic Research, 111*, 100-115.

Lezak, M. D., Howieson, D. B., Bigler, E. D., & Tranel, D. (2012). *Neuropsychological Assessment* (5th ed.). New York: Oxford University Press.

Marchewka, A., Żurawski, Ł., Jednoróg, K., & Grabowska, A. (2014). The Nencki Affective Picture System (NAPS): Introduction to a novel, standardized, wide-range, high-quality, realistic picture database. *Behavior Research Methods, 46*, 596-610.

Menin, D. S., Holaway, R. M., Fresco, D. M., Moore, M. T., & Heimberg, R. G. (2007). Delineating components of emotion and its dysregulation in anxiety and mood psychopathology. *Behavior Therapy, 38*, 284-302.

Muse, K., McManus, F., Hackmann, A., Williams, M., & Williams, M. (2010). Intrusive imagery in severe health anxiety: Prevalence, nature and links with memories and maintenance cycles. *Behaviour Research and Therapy*, *48*, 792-798.

Newby, J. M., Hobbs, M. J., Mahoney, A. E. J., Wong, S., & Andrews, G. (2017). DSM-5 illness anxiety disorder and somatic symptom disorder: Comorbidity, correlates, and overlap with DSM-IV hypochondriasis. *Journal of Psychosomatic Research, 101*, 31-37.

Pascual-Vera, B. & Belloch, A. (2018). Functional links of obsessive, dysmorphic, hypochondriac, and eating-disorders related mental intrusions. *International Journal of Clinical and Health Psychology, 18*, 43-51.

Pauli, P. & Alpers, G. W. (2002). Memory bias in patients with hypochondriasis and somatoform pain disorder. *Journal of Psychosomatic Research, 52*, 45-53.

Rubin, D. C., Boals, A., & Berntsen, D. (2008). Memory in posttraumatic stress disorder: Properties of voluntary and involuntary, traumatic and non-traumatic autobiographical memories in

people with and without PTSD symptoms. *Journal of Experimental Psychology: General, 137*, 591-614.

Salkovskis, P. M., Rimes, K. A., Warwick, H. M. C., & Clark, D. M. (2002). The Health Anxiety Inventory: Development and validation of scales for the measurement of health anxiety and hypochondriasis. *Psychological Medicine, 32*, 843-853.

Salkovskis, P. M., & Warwick, H. M. C. (2001). Meaning, misinterpretations, and medicine: a cognitive-behavioral approach to understanding health anxiety and hypochondriasis. In: V. Starcevic, & D. R. Lipsitt (Eds.), *Hypochondriasis: modern perspectives on an ancient malady* (pp. 202–222). Oxford: University Press.

Sansom-Daly, U. M., Bryant, R. A., Cohn, R. J., & Wakefield, C. E. (2014). Imagining the future in health anxiety: The impact of rumination on the specificity of illness-related memory and future thinking. *Anxiety, Stress, & Coping*, *27*, 587-600.

Sansom-Daly, U. M., Bryant, R. A., Cohn, R. J., & Wakefield, C. E. (2016). Rumination and self-defining memories in the context of health concerns. *Memory*, *24*, 939-948.

Schlagman, S. & Kvavilashvili, L. (2008). Involuntary autobiographical memories in and outside of the laboratory: How different are they from voluntary autobiographical memories? *Memory & Cognition, 36*, 920-932.

Schmidt, E.,Witthöft, M., Kornadt, A., Rist, F., & Bailer, J. (2013). Negative automatic evaluation and better recognition of bodily symptom words in college students with elevated health anxiety. *Cognitive Therapy and Research, 37*, 1027-1040.

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine, 166*, 1092-1097.

Staugaard, S. R. & Berntsen, D. (2014). Involuntary memories of emotional scenes: The effects of cue discriminability and emotion over time. *Journal of Experimental Psychology: General, 143*, 1939-1957.

Talmi, D., Schimmack, U., Paterson, T., & Moscovitch, M. (2007). The role of attention and relatedness in emotionally enhanced memory. *Emotion, 7*, 89-102.

Verbeke, G., & Molenberghs, G. (2000). *Linear Mixed Models for Longitudinal Data*. New York: Springer-Verlag.

Wagenmakers, E.-J., Love, J., Marsman, M., Jamil, T., Ly, A., Verhagen, J. … Morey, R. D. (2018). Bayesian inference for psychology. Part II: Example applications with JASP. *Psychonomic Bulletin & Review, 25*, 58-76.

Warwick, H. M. C., & Salkovskis, P. M. (1990). Hypochondriasis. *Behavior Research and Therapy, 28*, 105-117.

Wells, A., & Hackmann, A. (1993). Imagery and core beliefs in health anxiety: content and origins. *Behavioural and Cognitive Psychotherapy, 21*, 265-273.

Williams, J. M. G., Barnhofer, T., Crane, C., Herman, D., Raes, F., Watkins, E., & Dalgleish, T. (2007). Autobiographical memory specificity and emotional disorder. *Psychological Bulletin, 133*, 122-148.

Williams J. M. G. & Broadbent K. (1986). Autobiographical memory in suicide attempters. *Journal of Abnormal Psychology, 95*, 144-149.

Witthöft, M., Kerstner, T., Ofer, J., Mier, D., Rist, F., Diener, C., & Bailer, J. (2016). Cognitive biases in pathological health anxiety: The contribution of attention, memory and evaluation processes. *Clinical Psychological Science, 4*, 464-479.

World Health Organization (WHO) (1992). *The ICD-10 classification of mental and behavioural disorders: clinical descriptions and diagnostic guidelines*. Geneva: WHO.

World Health Organization (WHO) (1998). *SCAN. Schedules for Clinical Assessment in Neuropsychiatry*. Geneva: WHO.

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Table 1

Sample Characteristics and Mean Scores on Symptom Measures presented According to Group.

	α	Severe health anxiety	Comparison group	*t*(38)	*p*	*d*
N (females)		20 (10)	20 (10)			
Age (*SD*)		45.00 (9.89)	44.85 (10.21)	0.05	.963	0.02
Years of education (*SD*)		16.38 (2.69)	16.18 (3.31)	0.21	.835	0.07
Education (%)						
Basic school		10.00	10.00			
High school or skilled worker		20.00	30.00			
Higher education < 3 years		10.00	5.00			
Higher education > 3 years		60.00	55.00			
Employment (%)						
Full or part time employment		60.00	85.00			
Unemployed		10.00	10.00			
On leave (e.g., child birth, illness)		20.00	0.00			
Regular and early retirement		10.00	5.00			
Symptom measures (*SD*)						
Health anxiety (WI-7)	.95	28.00 (5.71)	13.95 (6.07)	7.54	> .001	2.38
Health anxiety (SHAI)	.97	32.70 (10.89)	10.45 (7.35)	7.57	> .001	2.40
Physical symptoms	.88	18.30 (9.37)	7.15 (4.55)	4.79	> .001	1.51
Symptoms of anxiety	.94	10.40 (6.48)	3.00 (2.38)	4.80	> .001	1.52
Symptoms of depression	.90	19.45 (10.35)	6.95 (6.08)	4.66	> .001	1.47
Executive functioning						
Category fluency		17.00 (4.13)	16.74 (4.52)	0.19	.850	0.06
Letter fluency		15.45 (4.95)	14.58 (3.95)	0.61	.548	0.19

Note. SD = Standard deviation; *α* = Cronbach's alfa; *p* = p-value; *d* = Cohen's d; WI-7 = Whiteley index 7 items; SHAI = short health anxiety inventory

Table 2

Means and Standard Errors of Measures at Encoding, Retrieval, Recognition, and Retrieval Frequency.

	Severe health anxiety						Comparison group					
	Health related		Negative		Neutral		Health related		Negative		Neutral	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Encoding												
Emotional valence	2.35	0.07	1.51	0.06	3.19	0.06	2.62	0.07	1.34	0.05	2.94	0.06
Emotional intensity	2.88	0.09	3.93	0.08	1.66	0.08	2.27	0.09	3.61	0.10	1.49	0.07
Physical reaction	2.25	0.10	2.51	0.10	1.36	0.06	1.61	0.07	2.46	0.11	1.31	0.06
Involuntary retrieval												
Emotional valence	2.30	0.18	1.55	0.14	3.13	0.14	2.59	0.20	1.46	0.15	2.96	0.16
Emotional intensity	2.52	0.30	3.09	0.26	2.04	0.27	2.75	0.32	2.97	0.28	1.97	0.29
Physical reaction	2.24	0.26	2.44	0.22	1.73	0.23	1.76	0.28	2.57	0.23	1.03	0.25
Specificity	3.61	0.30	3.50	0.24	3.77	0.25	3.37	0.32	3.04	0.26	4.50	0.28
Reaction time (in seconds)	6.19	0.96	4.01	0.73	3.79	0.77	3.82	1.05	4.35	0.78	3.95	0.86
Voluntary retrieval												
Emotional valence	2.16	0.13	1.51	0.11	2.99	0.12	2.55	0.17	1.46	0.13	2.92	0.12
Emotional intensity	2.72	0.24	3.08	0.23	1.88	0.23	2.14	0.29	2.71	0.25	1.77	0.24
Physical reaction	2.14	0.21	2.47	0.19	1.52	0.20	1.40	0.25	2.15	0.21	1.33	0.21
Specificity	3.68	0.24	3.43	0.23	3.79	0.23	4.09	0.30	3.31	0.25	4.00	0.24
Reaction time (in seconds)	6.61	0.67	6.82	0.60	6.26	0.61	6.35	0.85	6.75	0.68	6.28	0.65
Recognition												
Confidence	4.19	0.09	4.28	0.09	3.96	0.11	4.16	0.09	4.13	0.10	3.79	0.11
Accuracy	0.89	0.02	0.89	0.02	0.81	0.03	0.81	0.03	0.89	0.03	0.79	0.03
Frequency												
Involuntary retrieval	0.95	0.28	1.95	0.39	1.70	0.34	0.80	0.19	1.75	0.45	1.35	0.34
Voluntary retrieval	1.80	0.19	2.60	0.43	2.45	0.33	1.05	0.20	1.95	0.39	2.15	0.34

Note. M = Mean; SE = Standard error.

Table 3

Main and Interaction Effects from Mixed Model Analyses of Measures at Retrieval.

	Measures at retrieval									
	Emotional valence		Emotional intensity		Physical reaction		Specificity		Reaction time	
	F	*d*	*F*	*d*	*F*	*d*	*F*	*d*	*F*	*d*
Group	0.06	0.08	0.75	0.28	1.89	0.43	0.03	0.05	0.65	0.26
Picture Category	153.61***	1.24	46.45***	0.70	50.04***	0.72	12.64***	0.36	0.84	0.09
Retrieval type	0.03	0.02	1.17	0.11	1.02	0.10	0.00	0.00	29.18***	0.54
Group x Picture Category	3.23*	0.18	0.28	0.05	2.97[a]	0.18	3.45*	0.19	1.07	0.10
Group x Retrieval type	0.59	0.08	2.08	0.15	1.00	0.10	0.92	0.10	0.96	0.10
Picture Category x Retrieval type	0.20	0.05	0.02	0.01	0.74	0.09	2.45	0.16	0.96	0.10
Group x Picture Category x Retrieval type	0.01	0.01	1.24	0.12	3.23*	0.19	1.76	0.14	1.01	0.10

Note. * p <.05; *** p <.001, d = Cohen's d

[a] significance level p = .053

Notice: This is the author's version of a work that was accepted for publication in *Memory*. A definitive version was subsequently published in *Memory, 27 (8), 1110-1121*. DOI: 10.1080/09658211.2019.1626437

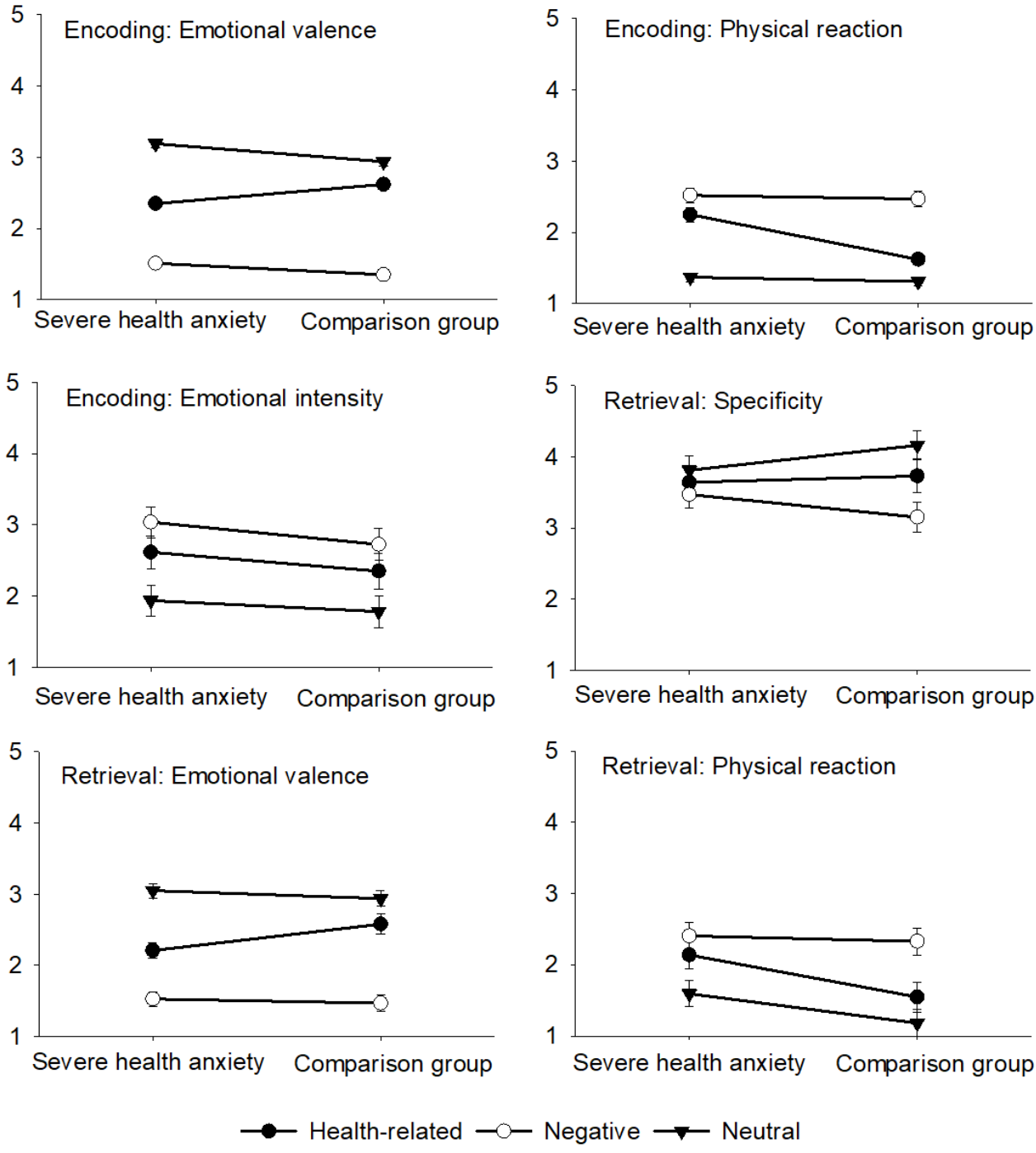

Figure 1. Variables showing main effects of group or two-way interactions between group and picture category at encoding (top and middle panel) or retrieval[3] (middle and bottom panel). Error bars indicate the standard errors of the means.

[3] For the interaction between group and picture category for physical reaction at retrieval $p = .053$.