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Ways of encoding somatic information and their effects on retrospective symptom reporting.

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Abstract

Objectives. Retrospective symptom reports tend to overestimate actual symptom intensity. The present study explored how focusing on sensory-perceptual or on affective-motivational aspects of a somatic experience influenced retrospective symptom reports in high and low habitual symptom reporters (HSR). We hypothesized that a focus on affective-motivational aspects of somatic episodes contributes to retrospective overestimation compared to a focus on sensory-perceptual aspects.

Design. Dyspnea (rebreathing) and pain (cold pain) were induced during two experimental sessions in healthy women: 21 high and 24 low HSR, using cut-off scores on a symptom checklist. Within-subject manipulation of sensory and affective processing focus (PF) took place at the encoding phase before symptom induction.

Methods. Dyspnea and pain ratings were collected immediately after the symptom inductions and after 2 weeks. Breathing behavior was recorded during dyspnea trials, while affective state and symptom measures were collected after each trial.

Results. Compared to pain, dyspnea induction was perceived as more unpleasant, arousing, and threatening ($ps < .001$). Affective PF led to higher arousal ($p < .01$) and threat ratings ($p = .01$) than sensory PF. Affective PF also led to an increase in retrospective dyspnea ratings over the course of two weeks ($p = .039$), which was not observed for pain, nor for dyspnea after sensory PF. The effects of PF on symptom ratings were independent of the HSR levels.

Conclusions. The processing focus during symptom encoding may explain previously observed bias in retrospective symptom reporting. The results are relevant to understand the mechanisms underlying symptom overreporting.

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Retrospective symptom reporting is a major source of information for medical doctors during consultations, and symptom questionnaires assessing past symptoms are abundantly used in research to assess the health status of respondents. Inaccurate retrospective symptom memory can adversely affect medical diagnosis, compliance, or outcome evaluation. Previous research has documented various memory biases leading to inaccurate and often overestimated symptom ratings among both patients and healthy individuals (see Van den Bergh & Walentynowicz, 2016, for a review). Those biases start immediately after the actual somatic experience (Walentynowicz, Bogaerts, Van Diest, Raes, & Van den Bergh, 2015) and are related to the duration of the recall period (Broderick et al., 2008; Houtveen & Oei, 2007; Walentynowicz et al., 2015), to characteristics of the somatic experience (Giske, Sandvik, & Røe, 2010; Lefebvre & Keefe, 2002; Sohl & Friedberg, 2008; Walentynowicz et al., 2015), and to individual differences. The latter include negative affectivity (NA), anxiety, catastrophizing, and depression (Larsen, 1992; Lefebvre & Keefe, 2002; Suls & Howren, 2012; Walentynowicz et al., 2015).

Symptom reports are affected by the interplay of sensory-perceptual and affective-motivational aspects of the somatic experience (Craig, 2003; Leventhal, Brown, Shacham, & Engquist, 1979; Price, 2000). While the sensory component refers to distinct sensory characteristics such as quality, intensity, location, and duration, the affective component refers to feelings induced by the experience together with a motivational drive to behaviorally react or adjust to it. Because the relative contribution of both components may impact symptom reports (Leventhal et al., 1979), focusing on the affective aspects of a somatic experience may direct attention towards symptom-related distress and cause more elevated symptom ratings. In line with this argument, it has previously been shown that negative emotional states and appraisals during somatic experiences partially mediate symptom overreporting (Noel, Chambers, McGrath, Klein, & Stewart, 2012; Walentynowicz et al.,

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2015). On the other hand, focusing on the sensory, non-emotional aspects has been shown to result in lower symptom ratings (Ahles, Blanchard, & Leventhal, 1983; Crane & Martin, 2003; Keogh, Hatton, & Ellery, 2000; Leventhal et al., 1979). However, the extent to which sensory focus has a positive effect on symptom ratings seems to be modulated by anxiety-based personality traits, for example health anxiety (Hadjistavropoulos, Hadjistavropoulos, & Quine, 2000), anxiety sensitivity (Hovasapian & Levine, 2016), fear of pain (Roelofs, Peters, van der Zijden, & Vlaeyen, 2004), and habitual symptom reporting (Bogaerts et al., 2008). In particular, previous studies have shown that attending to the sensory rather than affective details as well as symptom reappraisal during the experience lead to reduced symptom ratings, predominantly among individuals with increased anxiety levels.

Taking the abovementioned into account, the manipulation of processing focus towards sensory aspects should be most beneficial for individuals scoring high on trait negative affectivity (NA), who are considered to possess an overreactive affective system (Hariri, Bookheimer, & Mazziotta, 2000; Yiend, 2010) which may increase the relative impact of affective processes compared to sensory-perceptual ones during somatic experiences. Indeed, high trait NA persons tend to be high habitual symptom reporters in daily life (HSR; Bogaerts et al., 2015; Houtveen & Oei, 2007; Walentynowicz et al., 2015; Wan, Stans, Bogaerts, Decramer, & Van den Bergh, 2012), they tend to overreport bodily symptoms (Houtveen & Oei, 2007; Walentynowicz et al., 2015) and they are more likely to develop somatic symptom disorder (SSD; DSM-5, American Psychiatric Association, 2013). Previous research investigating symptom perception and memory in high NA/high HSR groups showed biased processing of bodily information, manifesting as lower correspondence between subjective symptom ratings and relevant physiological responses (Bogaerts et al., 2008; Bogaerts, Van Eylen, et al., 2010), as reduced differentiation between various bodily sensations (Petersen, von Leupoldt, & Van den Bergh, 2015), and as absence of the peak-end

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heuristic for somatic episodes, which impacts retrospective symptom evaluations by assigning disproportional weights to the intensities of the peak episode and of the final moments of an experience, while largely neglecting duration (Bogaerts et al., 2012). While these studies pointed to less detailed sensory processing of bodily information, other studies documented stronger affective responses towards somatic experiences in high HSR and in patients with SSD (Walentynowicz et al., 2015; Wan et al., 2012), and these stronger responses have been shown to mediate symptom overreporting (Walentynowicz et al., 2015). In general, less detailed sensory processing of somatic information along with a stronger influence of negative affective responses may bias retrospective symptom reporting in this group towards overreporting. As a result, shifting focus away from the affective to the sensory aspects of bodily sensations might reduce the impact of negative affective processes, and in return lower symptom ratings.

The purpose of the current study was to examine the mechanisms underlying retrospective symptom overreporting, and more specifically, to investigate the role of processing focus (PF) during symptom episodes. To this end, two types of PF were induced during two somatic symptom inductions, namely pain via a cold stimulus and dyspnea via a rebreathing manipulation in participants high and low on HSR. Participants were instructed to focus either on the sensory features in a neutral way (sensory PF) or on the feelings and emotions induced by the somatic experiences (affective PF). Symptoms and affective responses were measured immediately after the induction of somatic sensations, and after two weeks.

Based on arguments outlined above, we expected the affective PF to result in more emotion-laden/less detailed processing of bodily information, leading to greater distress and higher symptom ratings than the sensory PF. Moreover, as the influence of emotions on memory processes begins to emerge only after a delayed period (Sharot & Phelps, 2004;

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Sharot & Yonelinas, 2008; see Yonelinas & Ritchey, 2015 for a review), the effects of the affective PF condition on retrospective evaluation of symptoms were predicted to be more pronounced over time. Finally, as a sensory PF may be hypothesized to be more beneficial for anxious or oversensitive individuals (Baron, Logan, & Hoppe, 1993; Hadjistavropoulos et al., 2000; Roelofs et al., 2004), the high HSR group was expected to benefit relatively more from this PF manipulation than the low HSR group.

Methods

Participants

The sample consisted of forty-five healthy women ($M_{\text{age}} = 20.07$, $SD_{\text{age}} = 2.10$, range = 17 – 25) selected for a two-part study based on their scores on the Checklist for Symptoms in Daily Life (CSD; based on Wientjes & Grossman, 1994) measuring habitual symptom reporting. Two extreme groups of high (>100 ; $n = 21$) and low (<75 ; $n = 24$) HSR were formed based on the previously used cut-off scores (Bogaerts et al., 2008; Constantinou, Bogaerts, Van Diest, & Van den Bergh, 2013; Walentynowicz et al., 2015). The CSD was re-administered after the first session to confirm the participants' allocation, and only the ones meeting the cut-offs on both measurements were included in the final sample. Participants were excluded if they self-reported a chronic medical condition or psychiatric disorder, current acute illness, recent pain or conditions affecting the dominant arm, or pregnancy. The study protocol was approved by the local Social and Societal and well as the Medical Ethics Committees. Participants received either course credits or 20 euros for their participation.

Self-report measures

Habitual symptom reporting. The Checklist for Symptoms in Daily Life (CSD; based on Wientjes & Grossman, 1994) was used to assess the frequency of 39 symptoms in the past year on a 5-point Likert scale (*never, seldom, sometimes, often, very often*). Cronbach's alpha in the present sample was .94.

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Negative affectivity. Trait and state negative affectivity (NA) were measured with the Positive and Negative Affect Schedule (Engelen, De Peuter, Victoir, Van Diest, & Van den Bergh, 2006; Watson, Clark, & Tellegen, 1988). Participants indicated to which extent 20 positive and negative adjectives apply to their emotions now (state) or in general (trait) on a 5-point Likert scale ranging from *not at all* to *very much*. Cronbach's alphas for both state and trait version ranged from .76 to .87.

State symptom checklist. The occurrence of 14 complaints during the symptom induction trials was assessed on a 5-point rating scale ranging from 1 (*not at all*) to 5 (*very much*). This symptom list included: *chest tightness, pounding of the heart, headache, fatigue, not able to breathe deeply, rapid heartbeat, dizziness, muscular pain, dyspnea, pain, tingling sensation, stinging sensation, cold, burning sensation*. Cronbach's alphas ranged from .76 to .90.

Affect and threat ratings. To assess potential differences in the affective responses to experimentally induced symptoms, several self-report scales were administered. Experienced affect was measured after each induction trial via a computerized nine-point version of the Self-Assessment Manikin (SAM; Bradley & Lang, 1994) with the dimensions of valence (1 = *unpleasant*, 9 = *pleasant*), arousal (1 = *very calm*, 9 = *very arousing*), and control (1 = *low control*, 9 = *high control*). The SAM is a pictorial method in which levels of the affective dimensions are represented by human-like pictographs. Together with SAM scales, a single item numerical rating scale (NRS) assessing the threat value of each trial (1 = *not threatening at all*, 9 = *very threatening*) was administered.

Retrospective pain/dyspnea ratings. Symptoms (pain/dyspnea) experienced during each trial were retrospectively evaluated at three moments: immediately after each trial (immediate rating), at the end of the laboratory session (delayed rating) and after 2 weeks (follow-up rating). Three visual analog scales (10cm) ranging from 0 (*no pain/ dyspnea*) to

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100 (*unbearable pain/ dyspnea*) were used to measure (a) average symptom level, (b) symptom level at its most intense moment, and (c) symptom level at the end of the trial.

Apparatuses and Physiological Recordings

Cold pain induction. Painful stimuli were delivered to the ventral surface of the dominant forearm via a 30×30 mm thermode (Medoc, TSA, Ramat Yishau, Israel). This device assures a controllable and precise delivery of thermal stimuli. The baseline temperature was set at 32°C. During pain induction trial, the stimulus temperature decreased to a plateau temperature of 2°C. After a 5-s plateau, the temperature of the thermode returned to the baseline temperature. The rates of decline and rise were equal and set at a constant of 0.5°C/s.

Dyspnea induction. Dyspnea was induced by means of a rebreathing paradigm (Bogaerts et al., 2012; Read, 1967; Walentynowicz et al., 2015). The rebreathing system consisted of an airtight plastic bag containing 5 L of a decompressed air mixture of 5% CO₂ in 95% O₂ fixed to a three-way valve, which allowed to switch between room air and the bag. During the trial, participants wore a noseclip and (re)breathed through the mouthpiece, which was attached to the three-way valve through an antibacterial filter, a pneumotachograph (Fleisch no. 2, Lausanne, Switzerland) measuring airflow and a wide vinyl tube. The exhaled air was sampled via a small tube close to the mouthpiece and sent to an infrared CO₂ monitor (CAPNOGARD ETCO₂ Monitor; Novamatrix Medical Systems Inc; Wallingford, CT) to determine fractional end-tidal concentration of CO₂ (FetCO₂). All data were sampled at 20Hz, stored on a computer and analyzed offline to extract the respiratory parameters: minute ventilation (MV) in L/min, FetCO₂ in %, and respiratory rate (RR) in breaths/min. Due to equipment failure, the FetCO₂ data of 7 participants (5 low HSR/2 high HSR) were not recorded. The data were divided into 3 induction phases (baseline: 0-60s, induction: 60-210s,

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recovery: 210-360s) and the mean values of FetCO_2 , MV, and RR were calculated for each of those phases.

Physiological measures. Heart rate (HR) was measured during both symptom induction trials. Three 8 mm Ag/AgCl electrodes attached to participants' chest, two on left and right shoulders and one below the left lower rib, recorded cardiac activity. The signal was sent to a Coulbourn V75-04 bioamplifier (Allentown, PA) and sampled at 1000 Hz. The signal was manually processed offline and converted to beats per minute (BPM) with the PSPHA software (De Clercq, Verschuere, De Vlieger, & Crombez, 2006). Symptom induction trials were divided into 3 induction phases: baseline, induction, and recovery (pain induction: 0-60s, 60-125s, 125-185s; dyspnea induction: 0-60s, 60-210s, 210-360s), and mean HR was calculated for each of those phases.

Processing focus manipulation

The sensory-perceptual and affective-motivational PF instructions were given to participants prior to each symptom induction. The instructions started with the detailed explanation of the differences between two types of processing focus followed by processing- and trial-specific instructions. In the *sensory PF* condition, participants were asked to: "Focus on all bodily sensations and on how they change during this somatic experience, no matter how weak or strong they are. Observe how they change from moment to moment in the course of time. Try to notice them in a neutral manner like an objective, neutral observer without assessing whether they are good or bad." The *affective PF* condition included the following instructions: "Focus on all emotions and feelings that you experience and on how they change during this somatic experience, no matter how weak or strong they are. Try to notice how this stimulus makes you feel, how you react to these experiences and how they change." The complete instructions are included in the Supporting Information.

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Procedure

Selected participants were invited to a study consisting of two laboratory sessions each followed by retrospective ratings (Figure 1). Both sessions followed the same experimental protocol and differed only in the within-subject manipulation of processing focus during the symptom induction trials (i.e., all individuals did one session with the sensory PF and one with the affective PF manipulation). The time between the two sessions was never shorter than 4 weeks ($M = 7.23$, $SD = 4.21$, range = 4 – 24.14 weeks). The order of PF manipulation and the order of symptom induction trials were fully counterbalanced across all subjects.

Upon arrival, participants signed an informed consent form and completed the state PANAS. The experimenter explained the procedure and attached the electrodes for HR measurement. Two symptom induction trials were administered in counterbalanced order. In the pain induction trial, cold pain was delivered to the dominant hand via a thermode attached to participants' forearm with a Velcro strap. To assure that the baseline skin temperature was standardized across participants and trials, the trial started with 60-s baseline at the temperature of 32°C, followed by the cold phase (65 s), during which the temperature decreased to a 2°C plateau at the decline rate of 0.5°C/s. After a 5-s plateau, the temperature returned to baseline at the rise rate of 0.5°C/s (60 s). Dyspnea was induced with the rebreathing paradigm, consisting of the baseline phase (60 s of room-air breathing), the rebreathing phase (150 s), during which participants were breathing into the rebreathing bag, and the recovery phase (150 s of room-air breathing). Participants were informed that the trials would start with a baseline phase during which only physiological recording took place, and that the symptom induction would only start once the instructions (*focus on sensations/emotions*) appeared on the screen. Before each symptom induction, participants were instructed to focus on either physical sensations or emotional responses during the trial.

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The PF manipulation instructions were presented on the computer screen and verbally repeated by the experimenter. All subjects were asked to paraphrase the instructions and confirm that they understood them.

After each trial, participants completed retrospective symptom ratings (immediate), state PANAS, SAM, and the threat question. At the end of the laboratory session, retrospective symptom ratings (delayed) for both trials were collected. Participants completed the trait questionnaires (CDS, PANAS) online after the session. Two weeks after the laboratory session, follow-up questionnaires were completed online and participants were invited for the second session.

Statistical Analyses

Physiological responses. Differences in physiological responses (FetCO₂, MV, RR, and HR) between the groups and PF manipulations were analyzed in a series of mixed analyses of variance (ANOVAs) with Phase (baseline/induction/recovery) and PF Manipulation (sensory/affective) as within-subject variables, and Group (high/low HSR) and Order of PF Manipulation (sensory-affective/affective-sensory) as between-subject factors. The analyses were conducted separately for each physiological response. Group and PF manipulation differences in physiological responses were examined with planned contrasts that compared: baseline versus induction phase, baseline versus recovery phase, induction versus recovery phase.

State affect and symptom measures. Group and PF manipulation effects on state variables (symptom, SAM and threat ratings) were investigated with mixed ANOVAs with PF Manipulation and Induction Trial (pain/dyspnea; baseline/pain/dyspnea in state NA analysis) as within-subject factors and Group and Order of PF Manipulation as between-subject factors.

Retrospective symptom ratings. Pain and dyspnea ratings (average, peak and end) were analyzed with mixed ANOVAs, with PF Manipulation and Time (immediate / delayed / follow-up) as within-subject variables and Group and Order of PF Manipulation as between-subject variables. To explore a change in symptom ratings over a 2-weeks period, a planned contrast compared ratings during the experimental session (immediate, delayed) with follow-up ratings.

Greenhouse–Geisser corrections were applied when the sphericity assumption was violated. The reported measure of effect size was partial eta squared (η_p^2). Analyses were conducted with SPSS 23.0.

Results

Sample characteristics

High HSR reported more habitual symptoms (high: $M = 112.81$, $SE = 1.97$; low: $M = 64.63$, $SE = 1.71$; $t(43) = 18.54$, $p < .001$) and higher trait NA levels (high: $M = 27.10$, $SE = 1.64$; low: $M = 16.46$, $SE = 1.04$; $t(43) = 5.61$, $p < .001$) than low HSR.

Physiological responses

The mixed model ANOVAs (Table 1) showed significant Phase effects for all respiratory parameters. While in the induction phase all parameters increased compared to baseline¹, FetCO₂ decreased in the recovery phase to a lower level than during baseline, $F(1, 34) = 40.86$, $p < .00$, MV remained at a similar level as during the induction phase, $F(1, 41) = .01$, $p = .94$, and respiratory rate was higher compared to the induction phase, $F(1, 41) = 20.95$, $p < .001$.² A main effect of the PF manipulation was observed only for RR, with

¹ Contrasts: baseline versus induction phase: FetCO₂, $F(1, 34) = 1831.27$, $p < .001$, $\eta_p^2 = .98$, MV $F(1, 41) = 132.73$, $p < .001$, $\eta_p^2 = .76$, and RR, $F(1, 41) = 26.61$, $p < .001$, $\eta_p^2 = .39$.

² Based on the analyses performed on the data averaged per phase, it may seem that no recovery took place for MV and RR. However, a visual inspection of the respiratory parameters displayed in Figure S1 in the

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the affective PF resulting in higher RR compared with the sensory PF (Table 1). A main effect of group was found for FetCO₂ and MV (Table 1) with lower FetCO₂ and higher MV observed among high HSR compared to low HSR.

HR increased throughout the dyspnea induction (Table 1). During the pain induction high HSR had a higher HR than low HSR.

State symptoms and affective responses

As presented in Table 2, group-related differences were observed for a number of variables. High HSR reported higher state NA and state symptoms (checklist) than low HSR and they also tended to perceive the symptom induction trials as more threatening. However, no group differences were found with respect to valence, arousal and control ratings of the induction trials.

Furthermore, compared to pain induction, dyspnea induction trials were evaluated as more unpleasant, arousing, and threatening (Table 2). During those trials, participants experienced also higher state NA, more symptoms, and lower sense of control.

With regard to the processing focus manipulation, affective PF was more arousing and threatening for the participants than the sensory PF. It also resulted in higher state NA during the symptom induction trials.

Retrospective average symptom ratings. Groups did not differ in their average retrospective symptom reports, neither for pain, $F(1, 41) = 1.37, p = .25, \eta_p^2 = .03$, nor for dyspnea ratings, $F(1, 41) = 1.61, p = .21, \eta_p^2 = .04$ (Figure S2 in the Supporting Information). Also no group differences were found for symptom intensity at the peak and the end (Figure S2). In general, no main effects of PF manipulations for pain and dyspnea ratings were found. However, an interaction between PF Manipulation and Time emerged for average dyspnea

Supporting Information shows that these averages represent a gradual decrease in MV and RR during the recovery phase (which emerges significantly when including repeated measures during recovery).

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ratings, $F(2, 69.99) = 3.15, p = .057, \eta_p^2 = .07$ (Figure 2, right panel). This showed that the average dyspnea ratings during the experiment increased over the course of two weeks in the affective PF as compared to the sensory PF condition, planned contrast: $F(1, 41) = 4.56, p = .039, \eta_p^2 = .10$. Such interaction was not observed for the retrospective average pain ratings (Figure 2, left panel), which in contrast showed a weak tendency to decrease over time, $F(1.50, 61.35) = 2.53, p = .10, \eta_p^2 = .06$. Detailed results concerning the retrospective peak and end ratings are provided in the Supporting Information.

Discussion

The current study examined whether focusing on affective compared to sensory aspects of a somatic experience could be a mechanism explaining previously reported distortions in retrospective symptom reporting. To this end, participants high and low on habitual symptom reporting were instructed to focus on either the sensory-perceptual aspects (sensory PF) or on feelings and emotions (affective PF) evoked by experimentally induced pain and dyspnea. The type of PF was manipulated within subject, and its effect on symptom ratings and affective responses was measured during the experiment and after 2 weeks. Our study showed that an affective PF resulted in stronger affective responses during the somatic episode followed by an increase in retrospective symptom reporting over time. However, this effect was only observed for the dyspnea episode, which was perceived as more unpleasant than the pain induction. This shows that the impact of PF manipulation depends on the initial aversiveness of the stimulus.

The manipulation checks confirmed our predictions regarding symptom induction and experimental group differences. First, not only was the dyspnea induction perceived as more unpleasant, arousing, and threatening, it also resulted in a lower sense of control and higher state NA than the pain induction. This supported previous findings showing that experimentally induced dyspnea is overall more anxiogenic than pain induced by a cold

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stimulus (Walentynowicz et al., 2015). Second, high HSR reported higher state NA and symptoms ratings than low HSR in response to the symptom inductions, confirming that high HSR respond more strongly to experimentally induced symptoms and experience them as more aversive (Bogaerts et al., 2008; Walentynowicz et al., 2015). As in a previous study (Walentynowicz et al., 2015), the groups did not differ in intensity of their physiological responses to the symptom induction. However, the high HSR group differed from the low HSR with regard to the overall levels of FetCO_2 , minute ventilation, and heart rate, possibly related to the general distress caused by the experimental context. In general, these findings are consistent with other research showing that NA predisposes individuals to experience somatic stimuli as more threatening (Stegen, Van Diest, Van de Woestijne, & Van den Bergh, 2000).

Interestingly, whereas in studies that do not manipulate the processing style it is typically found that high HSR report more symptoms and higher state NA than low HSR groups (Bogaerts, Janssens, De Peuter, Van Diest, & Van den Bergh, 2010; Constantinou et al., 2013; Walentynowicz et al., 2015), such overall difference in retrospective symptom ratings and affective responses (as measured by SAM) was not found in the present study. As the focus of participants' attention was manipulated by the PF instructions, this finding suggests that the participants may not have used their "default processing focus", resulting in no overall differences between the groups in symptom ratings.

Even though the impact of a different processing focus on retrospective ratings did not appear immediately on the day of the laboratory session, it did show up after two weeks, and only for the dyspnea induction. While ratings in the sensory PF remained stable over time, the affective PF resulted in the expected increase in symptom ratings after two weeks. However, this effect was only present in retrospective dyspnea ratings, whereas the pain ratings did not change. Several mechanisms may play a role in this selective and delayed

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effect of PF on somatic memory. First, the effect of emotion on memory processes has been shown to be time-dependent, such that an enhancement for emotional memories was observed after a delay, but not immediately after encoding (e.g., Sharot & Phelps, 2004; Sharot & Yonelinas, 2008). Second, the rates of forgetting differ for emotional and nonemotional material, with central emotional elements being remembered better than peripheral nonemotional aspects (e.g., Kensinger, Garoff-Eaton, & Schacter, 2007). Third, the relative influence of affective dimension of somatic experience on symptom memory was reported to increase over time (Gedney & Logan, 2004; Gedney, Logan, & Baron, 2003; Kent, 1985). This suggests that the affective responses to symptoms and anxiety-related psychological characteristics of individuals influence long-term symptom memory more than the sensory-perceptual details of somatic experience. In addition, sensory details tend to decay at a faster rate (Reyna & Brainerd, 1998), again giving more room for the influence of the affective features. In the present study, focusing on the affective component of experience enhanced the subjective and physiological responses to the stimuli, as indicated by higher arousal and threat ratings, as well as higher respiratory rate in dyspnea trials. Thus, it seems that attending to emotions evoked by unpleasant and arousing dyspnea induction led to better perception and to encoding of negative emotional memory traces at the expense of sensory details (Leventhal et al., 1979). This, together with a delayed effects of emotions on memory processes and a greater impact of the affective component on long-term symptom memory, has likely caused elevated retrospective dyspnea ratings.

The present study makes several noteworthy contributions to the growing symptom memory research. The inclusion of both immediate and retrospective reports allowed us to investigate how manipulating the processing focus during encoding influences not only symptom perception, but also symptom recall, which is relatively understudied. Moreover, results of this study corroborate recent findings demonstrating that modulation of the

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affective evaluation of the experience can alter retrospective symptom reporting (Hovasapian & Levine, 2016), which may have important clinical implications for the development of the techniques that counteract reporting bias. This study was limited by the absence of a measure assessing the amount of actual focus on sensory or affective aspects of experience, which was not possible due to a within-subject study design. Nevertheless, the reported effects of affective PF on emotional responses suggest that participants followed the instructions. The lack of a control no-instruction condition could be regarded as another limiting factor. However, the decision to not include such a group was based on previous research in the field (Cioffi & Holloway, 1993; Keogh & Herdenfeldt, 2002) suggesting that instead of remaining ‘neutral’, participants might have chosen one of the processing foci. Finally, our participant sample was limited to healthy women. Female gender is a well-established factor associated with elevated symptom reporting and with a higher probability to present with medically unexplained symptoms (e.g., Gijbbers van Wijk, Huisman, & Kolk, 1999; Van Diest et al., 2005). To improve the generalizability of our findings, future studies should include clinical groups.

To conclude, this work extends our knowledge of cognitive and affective processes influencing symptom reporting by showing that attention to different components of an aversive somatic experience affects not only emotional distress but also increasingly biases retrospective symptom memory with longer delays. This may explain why individuals with overreactive affective response system, such as habitual symptom reporters or patients with SSD, overreport experienced symptoms when retrospectively assessed.

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Figure Captions

Figure 1. Study procedure.

Figure 2. Mean retrospective average pain ratings (0-100, left) and dyspnea ratings (0-100, right) for sensory and affective processing focus manipulation. Whiskers denote standard errors.

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Fig 1

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Fig 2

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Table 1. Means (SDs) for physiological responses to dyspnea and pain inductions in each group during sensory and affective processing focus sessions and significant effects of mixed model ANOVAs.

Response	PF	HSR group	Baseline phase	Induction phase	Recovery phase	Significant effects	<i>F</i> -test(<i>df</i>)	<i>p</i>	η_p^2
<i>Dyspnea induction</i>									
FetCO ₂ (%)	Sensory	Low	5.07 (.49)	6.31 (.53)	4.84 (.49)	Phase	892.06 (1.70, 57.74)	<.001	.96
		High	4.67 (.46)	6.00 (.45)	4.37 (.47)	Group	7.79 (1, 34)	.008	.19
	Affective	Low	5.03 (.52)	6.33 (.47)	4.81 (.51)				
		High	4.71 (.38)	6.11 (.39)	4.34 (.51)				
MV (l/min)	Sensory	Low	8.88 (1.88)	15.41 (5.83)	16.07 (6.58)	Phase	86.72 (2, 82)	<.001	.68
		High	11.91 (3.15)	18.45 (3.97)	17.84 (3.50)	Group	4.91 (1, 41)	.032	.11
	Affective	Low	10.11 (2.27)	16.63 (5.40)	16.38 (6.25)				
		High	11.62 (2.34)	18.34 (3.48)	18.37 (3.20)				
RR (breaths /min)	Sensory	Low	12.06 (3.21)	13.09 (3.63)	15.68 (5.59)	Phase	31.12 (1.30, 53.44)	<.001	.43
		High	14.44 (4.60)	15.44 (4.01)	17.00 (4.76)	PF	4.22 (1, 41)	.046	.09
	Affective	Low	12.98 (3.24)	13.94 (3.35)	15.94 (5.46)				
		High	14.52 (5.04)	15.96 (4.51)	18.06 (5.14)				
HR (beats /min)	Sensory	Low	76.90 (12.84)	79.63 (11.14)	82.62 (13.48)	Phase	23.05 (1.43, 58.48)	<.001	.36
		High	84.96 (14.38)	86.33 (12.24)	91.49 (14.82)				
	Affective	Low	77.55 (11.01)	80.47 (11.21)	81.99 (11.47)				
		High	83.11 (13.19)	85.78 (12.19)	87.80 (10.31)				
<i>Pain induction</i>									
HR (beats /min)	Sensory	Low	72.73 (10.06)	71.24 (11.39)	73.19 (11.29)	Group	6.16 (1, 41)	.017	.13
		High	82.55 (12.15)	80.87 (12.02)	80.80 (10.33)				
	Affective	Low	72.98 (10.59)	71.28 (10.61)	72.56 (9.83)				
		High	77.96 (12.15)	78.43 (12.46)	78.08 (12.16)				

Note: PF = processing focus; HSR = habitual symptom reporting; FetCO₂ = fractional end-tidal concentration of CO₂, MV = minute ventilation, RR = respiratory rate, HR = heart rate.

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Table 2. Means (SDs) for state negative affect (NA), symptoms, SAM (valence, arousal, and control) and threat ratings for each processing focus and significant effects of mixed model ANOVAs.

Measure	HSR group	Sensory PF			Affective PF			Significant effects	<i>F</i> -test (<i>df</i>)	<i>p</i>	η_p^2
		BL	Pain	Dyspnea	BL	Pain	Dyspnea				
State NA	Low	13.54 (4.44)	14.46 (4.32)	17.38 (5.58)	12.38 (1.93)	18.50 (6.06)	22.13 (6.87)	PF	11.70 (1,41)	.001	.22
								PF×Order	7.75 (1,41)	.008	.16
	High	17.48 (4.92)	17.76 (5.77)	22.05 (5.85)	16.67 (5.89)	19.19 (5.47)	25.24 (8.00)	IND	57.58 (2,82)	<.001	.58
								PF×IND	12.49 (2,82)	<.001	.23
								PF×IND×Order	4.14 (2,82)	.019	.09
State symptoms	Low		26.79 (5.63)	28.79 (8.80)		26.21 (7.71)	30.58 (8.54)	Group	8.16 (1,41)	.007	.17
								IND	19.38 (1,41)	<.001	.32
	High		32.10 (6.88)	35.67 (8.69)		29.95 (7.61)	35.38 (7.72)	PF×IND×Order	6.40 (1,41)	.015	.14
								Group	9.02 (1,41)	.005	.18
								Group×Order	4.63 (1,41)	.037	.10
Valence (1-9)	Low		4.63 (1.61)	3.50 (1.22)		4.63 (1.84)	3.17 (1.17)	IND	21.79 (1,41)	<.001	.35
	High		4.81 (1.63)	3.76 (1.84)		4.48 (1.75)	3.29 (1.15)				
Arousal (1-9)	Low		3.58 (1.86)	5.54 (1.79)		4.58 (1.86)	6.25 (1.36)	PF	9.21 (1,41)	.004	.18
	High		4.38 (2.11)	6.05 (1.60)		5.19 (1.72)	6.14 (1.96)	IND	37.20 (1,41)	<.001	.48
Control (1-9)	Low		4.71 (2.29)	3.33 (1.95)		4.08 (1.84)	3.04 (1.90)	IND	29.51 (1,41)	<.001	.42
	High		4.67 (2.39)	2.86 (2.03)		4.29 (2.22)	2.81 (1.50)				
Threat (1-9)	Low		2.75 (1.62)	4.88 (2.42)		3.54 (1.98)	5.42 (2.08)	PF	7.22 (1,41)	.01	.15
								IND	59.85 (1,41)	<.001	.59
	High		3.76 (1.95)	5.62 (1.47)		3.95 (1.99)	6.43 (1.50)	Group	3.89 (1,41)	.055	.09

Note: BL = baseline; HSR = habitual symptom reporting; IND = induction trial; PF = processing focus.

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Supporting Information

Processing focus manipulation instructions

In everyday life we constantly experience all sorts of bodily sensations. They can vary in type (such as hunger, butterflies in the stomach, fatigue or a stiff knee) and can differ in unpleasantness (pleasant, neutral or unpleasant) and intensity (barely noticeable to attention demanding). Our attention is often externally directed and we do not notice many sensations from within our body, but we can also pay attention to our body and then the feelings such as butterflies in the stomach or being fatigued become more pronounced. We can also focus on the sensations in our body in various ways. We can focus, for example like a doctor, on the different sensations to know what they exactly are, where we can locate them, how intense they are, if they change, and so on. Or we can also focus on the emotional experience related to the sensations, for example how pleasant, annoying or bothersome they are, whether you become frightened or cheerful, in short, how do they make you feel.

A comparable example is a piece of music on the radio. You can focus, for example like an expert or researcher, on the different instruments that you can distinguish, how intense the sounds are, which rhythm the music has, etc. But you can also get carried away emotionally with the music, immerse yourself in it and become aware of the emotions and feelings that music evokes in you, such as sadness or joy. Another example is how you can feel after a feast when you have eaten too much. You can focus, like an objective, neutral observer, on the expansion of and sensations in your stomach, or on possible hot flushes. But you can also focus on the annoying and unpleasant feeling in your body, maybe even with some guilt over that big belly, or on the lazy and satisfied feeling, enjoying the memory of a good meal.

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Sensory-perceptual processing focus. Hopefully it is clear that you can focus on the sensations in your body in various ways. In the next trial you will experience some physical sensations. We ask you to pay attention (like an objective, neutral observer) to the different sensations that occur when *the cold stimulus is delivered to the inside of your arm with the thermode/ you are breathing through the mouthpiece*. In particular, concentrate on the *changes in temperature and on the sensations that you experience on your skin/in the intensity of your breathing or in the breathing effort, or on the changes in sensations in your mouth, throat, airways or lungs*. But maybe you also feel different kinds of sensations elsewhere in your body or changes in your position and muscles. Focus on all bodily sensations and how they change during this somatic experience, no matter how weak or strong they are. Observe how they change from moment to moment in the course of time. Try to notice them in a neutral manner (like an objective, neutral observer) without assessing whether they are good or bad. Also, try to remember all of the sensations, because after this trial we will ask you to describe all of them in detail.

Affective-motivational processing focus. Hopefully it is clear that you can focus on the sensations in your body in various ways. In the next trial you will experience some physical sensations. We ask you to pay attention to the different feelings that occur when *the cold stimulus is delivered to the inside of your arm with the thermode/ you are breathing through the mouthpiece*. We ask you to completely give in and immerse yourself in these feelings. Notice how pleasant or unpleasant they are, how intense they are, or if they make you feel relaxed, calm, scared or angry, etc. But you may also feel some surprise, sadness, joy, cheerfulness or indifference during this trial. Focus on all emotions and feelings that you experience and how they change during this somatic experience, no matter how weak or strong they are. Try to notice how *this cold stimulus/ the breathing through the mouthpiece* makes you feel, how you react to these experiences and how they change. Try to remember

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all of the emotional experiences, because after this trial we will ask you to describe all of them in detail.

Results

Retrospective peak symptom ratings. Retrospective peak pain ratings decreased over the course of two weeks in both groups, $C4$ for Time, $F(1, 41) = 9.71, p = .003, \eta_p^2 = .19$; Time, $F(1.55, 63.61) = 8.28, p = .002, \eta_p^2 = .17$ (Figure S2). Peak dyspnea ratings remained at the same level throughout this time. However, peak dyspnea was retrospectively rated higher for the first session compared to the second session. This habituation effect was expressed by the interaction between the PF Manipulation and Order, $F(1, 41) = 8.50, p = .006, \eta_p^2 = .17$.

Retrospective end symptom ratings. The change in retrospective end pain ratings over time was influenced by both order of PF manipulations and group, Time $\times$ Group $\times$ Order, $F(1.63, 66.81) = 16.13, p < .001, \eta_p^2 = .28$ (Figure S3). This interaction revealed that a session order, in which the first experimental session included the affective PF manipulation, resulted in the largest discrepancy in immediate and delayed end pain ratings between high and low HSR. However, after 2 weeks the ratings of the two groups did not differ. With regard to the end dyspnea evaluations, the ratings increased over time to the same extent in both groups, $F(2, 82) = 11.89, p < .001, \eta_p^2 = .23$. Also, an interaction effect between Group and PF manipulation at a trend level showed that while in the affective PF condition the groups did not differ from each other, in the sensory PF high HSR retrospectively rated end dyspnea higher than low HSR, $F(1, 41) = 3.68, p = .062, \eta_p^2 = .08$.

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Figure S1. Mean values and standard errors of fractional end-tidal concentration of CO₂ (FetCO₂, %), minute ventilation (l/min), and respiratory rate (breaths/min) for high and low habitual symptom reporters (HSR) during dyspnea induction. Data from two sessions are aggregated. To obtain a detailed picture of change over time, data are displayed per 30s intervals: baseline phase: 0-60s, induction phase: 60-210s; recovery phase: 210-360s.

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Figure S2. Mean retrospective pain ratings (0-100, left) and dyspnea ratings (0-100, right) for high and low habitual symptom reporters (HSR) in sensory and affective processing focus conditions. Top panels represent average ratings, middle panels – peak ratings, and bottom panels – end ratings. Whiskers denote standard errors.

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Figure S3. Mean retrospective end pain ratings (0-100) for high and low habitual symptom reporters (HSR) as a function of processing focus manipulation order (sensory-affective/affective-sensory). Whiskers denote standard errors.