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Emotional responses to illness imagery in young adults: Effects of attention to somatic sensations and levels of illness anxiety

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ABSTRACT

This study investigated the effect of interoceptive attention on emotional responses during illness imagery, and the moderating role of illness anxiety. 101 students (81 female; 18–35 years old) with low, moderate and high levels of illness anxiety had to imagine personally relevant illness scenarios and standardized fearful, joyful and neutral scenarios, after undergoing an attention manipulation to direct their attention towards interoceptive or exteroceptive stimuli. Emotional responses assessed included self-reports of arousal, valence and somatic sensations, and psychophysiological measures of heart rate reactivity and variability, skin conductance level, and facial electromyography. Findings showed increased reports of emotional arousal, negative affect and somatic symptoms, accompanied by negative emotion expressions, but a hypo-arousal physiological response pattern (i.e. low heart rate reactivity) during illness imagery after interoceptive attention, irrespective of illness anxiety levels. Under directed attention, the observed emotional response to illness imagery may increase the risk for developing and perpetuating illness anxiety.

1. Introduction

Illness anxiety (IA) is the preoccupation with having or acquiring a severe medical disease that persists despite appropriate medical reassurance (Rachman, 2012). In addition to individual suffering (Chaturvedi, Desai, & Shaligram, 2006; Sempértegui, Karreman, van Hout, & Bekker, 2017), IA incurs high medical service utilization costs (Burton, 2003; Grabe, Baumeister, John, Freyberger, & Völzke, 2009; Kroenke, 2003). This makes research on understanding the etiological and maintenance mechanisms of IA a priority.

The cognitive-behavioral model supports that IA is developed through dysfunctional schemas about illness, formed during personal and vicarious illness-related, emotionally-laden events (Warwick & Salkovskis, 1990). According to the bio-informational theory of emotion, emotional events, including illness-threats (Leventhal, Diefenbach, & Leventhal, 1992), are encoded in associative networks in memory, which include stimulus, meaning and response representations (Lang, Levin, Miller, & Kozak, 1983; Vrana & Lang, 1990; Weerts & Lang, 1978). Associative networks are activated, and emotional events are retrieved when one is exposed to any sensory cue related to the specific event, e.g. when illness anxious individuals confront threats coming from bodily and environmental sources. This may explain why during stressful periods, illness anxious individuals frequently report intrusive illness-related images (Muse, McManus, Hackmann, Williams, & Williams, 2010; Wells & Hackmann, 1993). Retrieval of such images influences processing of illness-related information in a way that is suggested to increase and maintain IA (Muse et al., 2010; Warwick & Salkovskis, 1990). This study examines the emotional responses elicited by illness imagery and how these are modified by levels of illness anxiety and focus of attention on internal sensations, as described in relevant cognitive behavioral models (Warwick & Salkovskis, 1990).

In anxious individuals, activation of associative networks during aversive mental imagery triggers the defensive-motivational physiological system and negative expressive behaviors (Lang et al., 1983; Vrana & Lang, 1990; Weerts & Lang, 1978). Existing research documents two distinct response patterns to threat imagery between cue and response representations: The first pattern involves increased psychophysiological reactivity accompanied by high distress reports. The second pattern involves a hypo-arousal physiological response, despite high distress reports (Cuthbert et al., 2003; Lang & McTeague, 2009; Panayiotou, Karekla, Georgiou, Constantinou, & Paraskeva-Siamata, 2017). Although such patterns of emotional responses to imagery have been extensively examined in other categories of anxiety symptomatology in an effort to provide tailored interventions to individuals'

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needs (Cuthbert et al., 2003; Lang & McTeague, 2009; Lang et al., 1983; McNeil, Vrana, Melamed, Cuthbert, & Lang, 1993), emotional reactivity in relation to IA symptoms has received limited attention.

The only relevant evidence is derived from two studies that tested the hypothesis that individuals with IA symptoms respond to illness imagery with heightened physiological reactivity. Both were based on the theoretical assumption that increased psychophysiological reactivity in illness anxious individuals results from the effortful evaluation of and, possibly, misinterpretation of the somatic sensations elicited by illness imagery. Brownlee, Leventhal, and Balaban (1992) supported this hypothesis by showing increased heart rate (HR) during illness imagery among individuals with hypochondriacal traits and body vigilance, compared to frequent healthcare users, who did not show hypochondriacal traits and body vigilance, and controls. In contrast, Gramling, Clawson, and McDonald (1996) found no group differences in HR or neck electromyography during illness imagery. The limited and contradictory nature of these findings invites further investigation into the role of emotional responses to illness imagery in IA.

Even more importantly, the mechanisms that underlie the negative emotional responses of illness anxious individuals to illness imagery in such a way as to maintain IA remain poorly addressed in the literature. Three categories of processes that are hypothesized to underlie the emotional responses to illness imagery and contribute to IA were the focus of this study: Interoceptive processes, emotion dysregulation and negativity bias. First, the reactions of illness anxious individuals to illness threats, including imagined ones, have been assumed to entail heightened attention to and, therefore, enhanced perception of somatic sensations (Easterling & Leventhal, 1989), which may amplify their aversiveness. The cognitive-perceptual models (Pennebaker & Watson, 1991; Rief & Barsky, 2005) suggest that interoceptive attention is a central mechanism in biased symptom perception. Previous findings supported that healthy participants reported higher number of somatic symptoms when they focused internally, on their heart and breathing rate, than externally on verbal stimuli (i.e. the competition of cues hypothesis; Fillingim & Fine, 1986). More recent research on IA, showed that perception of somatic sensations is influenced by interoceptive inaccuracy, i.e. the inability to accurately detect and report on somatic sensations, and by somatosensory amplification, the tendency to amplify somatic sensations and interpret them as symptoms, instead of interpreting them as the outcome of normal physiological functioning (e.g. Köteles & Simor, 2014; Krautwurst, Gerlach, Gomille, Hiller, & Witthöft, 2014; Krautwurst, Gerlach, & Witthöft, 2016). Therefore, increased attention to the body does not neccessarily lead to accurate perception of bodily signals but may be associated with misperceptions, as well as increased negative affect and emotional arousal.

Second, it is plausible that the difficulties of illness anxious individuals in regulating emotion (Fergus & Valentiner, 2010; Görgen, Hiller, & Witthöft, 2014) influence emotional responses to illness imagery. Lower resting state HR variability, which has been linked to difficulties in emotion regulation (Williams et al., 2015), was repeatedly found to characterize individuals who meet anxiety disorders diagnostic criteria (Chalmers, Quintana, Abbott, & Kemp, 2014). Emotion regulation ability was previously linked to the perception of interoceptive cues (Kever, Pollatos, Vermeulen, & Grynberg, 2015; Oliveira & Costa, 2014). It can be hypothesized that emotion dysregulation may function in association with interoceptive processes that lead to biased symptom perception and, therefore, to negative emotional responses to illness imagery because somatic sensations are experienced as threatening in IA. This potential mechanism has not yet been tested to our knowledge, creating the need for the present investigation.

Third, the presence of negativity bias has been observed when illness anxious individuals process illness-related stimuli, including imagined ones (Leonidou & Panayiotou, 2018). The tendency to negatively evaluate information can be indexed by one's negative expressive response (i.e. bioinformational theory of emotion; Lang, 1979). Responding to illness-related information with exaggerated negativity may contribute to symptom misinterpretation, in combination with increased self-focused attention (i.e. on internal sensations), as supported by studies on medically unexplained symptoms (Mor & Winquist, 2002; Pennebaker, 1982; Rief & Barsky, 2005). One of the objectives of this study was to assess affective responses to health-threatening information using both subjective ratings of valence and objective measures of expressive behavior, i.e. facial electromyography, including zygomatic and corrugator muscles reactivity that index positive and negative emotional valence respectively (Tassinary, Cacioppo, & Vanman, 2009). This is the first study that measures valence based on facial electromyography in relation to illness imagery and IA.

1.1. Current study

This study examined the influence of attentional focus towards somatic sensations on emotional responses during illness imagery, and whether this is modulated by IA levels. We used an experimental manipulation to increase participants' attentional focus on either interoceptive information or innocuous environmental information, as a control condition. We then examined whether the attention manipulation influenced emotional responses during mental imagery of personally relevant illness scenarios vs standardized generally fearful, joyful, and neutral scenarios, and if it affected responses differently depending on level of IA. We expected increased subjective and physiological arousal (HR and skin conductance) during illness imagery following interoceptive attention, compared to the exteroceptive attention condition, supporting the hypothesis that increased focus on internal sensations contributes to IA. We also expected more negative valence, as indicated by self-reports, increased corrugator and decreased zygomatic activity, and more somatic sensation reports at increased levels of IA, verifying the presence of negativity bias. These emotional responses were expected to be more profound during illness imagery, compared to the other imagery conditions, especially in high, vs moderate and low, IA participants. In addition, the effect of IA levels on emotion regulation, based on resting state HR variability recording, was examined. The hypothesis was that the high vs moderate and low, IA group would show lower resting state HR variability as an index of emotion dysregulation.

2. Methods

2.1. Participants

Participants were 101 students (81 female; 18–35 years old) receiving course credit for participation. Exclusion criteria included age below 18 or above 35, presence of vision or hearing disability, prohibitive for participation. Participants were screened through an online questionnaire. Those who provided consent to be contacted for the experimental phase were invited to the laboratory. All interested participants were invited irrespective of IA levels until data were collected for half of the sample; after this point, participants were invited more selectively based on extreme low or high scores on IA, to increase the range of IA scores in the sample. The experimenters were blind to the IA level of each participant. Participants were assigned into groups of low, moderate and high IA based on the suggested clinical cut-offs of the Illness Attitudes Scales (> 47) (Hedman, Ljótsson et al., 2015) and upper and lower tertiles on the Short Health Anxiety Inventory, resulting in 30 participants per group; eleven participants could not be categorized in the three groups in the described way due to high discordance in scores between the two screening measures. The low IA group had scores below the clinical cut-off on IAS and scored in the lower tertile on SHAI (< 9), the high IA group scored above the clinical cut-off on IAS and in the upper tertile on SHAI (> 14), and the moderate IA group scored either below or above but close to the clinical cut-off on IAS and in the middle tertile on SHAI. Thus, the participants in

this study were selected so as to represent a wide range of IA scores, with equal representation of high, low and moderate IA, to circumvent the fact that inviting unselected students to participate might have resulted in a bias towards very low IA scores. This approach was effectively used in a previous study on social anxiety (Dell'Osso et al., 2014) and helps in addressing some of the limitations of the arbitrary extreme groups approach (Preacher, Rucker, MacCallum, & Nicewander, 2005).

Power was calculated using G*Power version 3 (GPower)(Faul, Erdfelder, Lang & Buchner, 2007). The reference effect size was $\eta_p^2 = 0.05$, which is a medium effect size (based on Constantinou, Panayiotou, & Theodorou, 2014). To test a repeated-measures ANOVA within factors interaction hypothesis (1 group (total sample), 8 measurements (4 imagery x 2 attention conditions)), with at least 80 % power and 5 % significance level we needed a total sample size of at least 36 participants. To test a repeated measures ANOVA within-between factors interaction hypothesis (3 IA groups, 8 measurements (4 imagery x 2 attention conditions)), with at least 80 % power and 5 % significance level we needed a total sample size of at least 48 participants. This study had adequate power for the two-way interactions. We could not check the required sample for the three-way interactions (IA group x imagery x attention condition), because the G*Power does not run power analysis for a three-way interaction in a Mixed-model ANOVA. Therefore, we recruited more participants than the sample size suggested by the power analysis results reported above to increase the power of this analysis.

Univariate ANOVAs showed significant group differences in IA levels: the high IA group reported higher IA compared to moderate and low IA groups and the low IA group reported lower IA compared to the moderate IA group. The same pattern of group differences was found with regards to the severity of depression, generalized anxiety, panic, agoraphobia, social anxiety and somatization symptoms. Groups did not differ in age, gender and self-reported medical conditions and baseline measures of interoceptive accuracy, private self-consciousness, resting state HR variability and baseline physiological reactivity (see Table 1).

2.2. Experimental design

The experiment was a mixed 3 × 4 × 2 design with group (low, moderate and high IA) as the between-subjects variable and imagery condition (illness, fearful, joyful, neutral) and attention manipulation (interoceptive or exteroceptive attention) as the within-subject variables. Participants completed 16 trials each consisting of resting, attention manipulation and imagery phases, with an equal number and equally distributed presentation of the four imagery conditions and the attention manipulation task in two counterbalanced orders.

2.2.1. Experimental stimuli

The experimental stimuli were written imagery scripts, which included personally relevant illness scenarios and standardized fearful, joyful and neutral scenarios. The personally relevant scenarios were created based on scene construction forms that guided participants to create scenarios of their worst illness fears (Cuthbert et al., 2003) on the basis of the bio-informational view of affective imagery (Foa & Kozak, 1986; Lang, 1979). Participants who had booked the experiment appointment, received via email the scene construction form to complete with four illness scenarios and return on the day of the experiment. The researcher read the scripts before the experiment to make sure that participants followed the instructions and requested changes in the scripts when needed. Examples of personally relevant illness scenarios were: *"While I am having a bath I find a lump on my breast; I am in panic and I think that I will die.", "I am studying at home when I feel a chest pain; I think that I have a heart attack and I immediately call my doctor", "I have just received an AIDS diagnosis; I worry about how the others will think about me and how my life will be from now on", "I wake up at the hospital severely injured after a car accident; I try to move my body parts as I fear that I am paralyzed and I will never walk again."* (Table 2 presents the categories and frequency of the themes of illness scenarios).

Standardized scenarios were selected from a pool of emotional scripts (Van Oyen Witvliet & Vrana, 1995), which were translated and adapted into Greek by Panayiotou (2008) and describe daily situations that are expected to elicit general fear (e.g. "*A strange man is following me through a bad area of town; Sweat pours down my face as I listen to his footsteps getting closer"*), joy (e.g. "*I jump up with excitement as my dad drives up the road with my Christmas present, a brand new car!"*) and neutral emotions (e.g. "*I lean against the wall, watching people passing by as I wait for a friend before class*.").

2.2.2. Procedure

Upon arrival at the laboratory, participants were provided with information about the experiment and signed informed consent. They were then guided to a dimly lit room and sat in an armchair in front of a T.V. screen, where instructions for the experiment were displayed. Electrodes for physiological recording were attached and headphones fitted (SONY-MDR-7506). After the physiological recording checks, a 5-minute adjustment period followed, during which resting state HR variability was recorded. The Heartbeat Tracking task to measure baseline interoceptive accuracy (Schandry, 1981; see below) followed and then participants were given instructions for the experiment and went through an example trial to make sure that they understood the instructions. Each experimental trial was preceded by instructions on the screen and a tone, which signalled the beginning and end of each of the three trial phases so that participants could close their eyes without having to keep their attention on the screen. The experiment was controlled using E-Prime 2.

2.2.2.1. Resting phase. The resting phase lasted 20 s and participants were instructed to use the "count 1" method (i.e. please clear your mind and silently repeat the word "one" to yourself) to help them relax (Benson, Greenwood, & Klemchuk, 1975).

2.2.2.2. Attention manipulation phase. Following the resting phase, attention manipulation instructions appeared on the screen, asking the participants to either interoceptively focus or to exteroceptively focus their attention on environmental stimuli for periods of 25/35/45/60 s. During interoceptive attention, participants were asked to count their heartbeats according to the Heartbeat Tracking task of Schandry (1981). This task measures interoceptive accuracy as participants count how many heartbeats, they feel over varying time intervals by concentrating on their heartbeats, without taking their pulse or attempting any other physical manipulations that might facilitate heartbeat detection. Electrocardiography (ECG) was monitored continuously so that the participants' reported heartbeat number was compared with the heartbeats measured by ECG. Interoceptive accuracy was calculated by taking the absolute value of the modulus of the actual value minus the estimated value, dividing this by the actual value: (actual heartbeats–estimated heartbeats) ÷ actual heartbeats; the inverse was the measure of accuracy. Higher score indicated that participants directed their attention to interoceptive cues, as instructed.

For the exteroceptive attention, a similar task to the heartbeat tracking paradigm was developed: Participants were asked to count a tone they heard through headphones that was repeated every 1 s in a very low volume, in a range between 40–60 decibels, for the same time intervals as in the interoceptive focus and to report the number of the tones they heard. A comparison between the reported and the actual number of tones was used to assess participants' compliance to the task.

2.2.2.3. Imagery phase. After participants noted their counted heartbeats or tones, the research assistant read through a microphone a script, drawn among the four conditions and participants were asked to memorize and imagine it during the subsequent imagery phase as

Table 1
Characteristics of the groups based on illness anxiety level.

	Low IA (n = 30) *N*	Moderate IA (n = 30) *N*	High IA (n = 30) *N*	χ^2	*df*	*P*
Gender				2.92	2	> .050
Male	8	7	3			
Female	22	23	27			
Medical condition[1]				2.71	2	> .050
No	28	24	24			
Yes	2	6	6			

	Low IA (n = 30) *M (SD)*	Moderate IA (n = 30) *M (SD)*	High IA (n = 30) *M (SD)*	*F*	*df*	*P*
Age	21.60 (3.86)	21.47 (3.83)	21.68 (3.69)	0.03	2,87	> .050
Private self-consciousness	13.10 (2.35)	13.97 (2.04)	14.80 (2.20)	4.38	2,88	.015
PDSQ Depression	2.03 (2.30)	2.97 (5.67)	5.28 (3.95)	8.75	2,88	< .001
PDSQ Panic Disorder	0.43 (1.10)	0.77 (1.25)	1.97 (2.01)	8.46	2,88	< .001
PDSQ Agoraphobia	0.27 (0.69)	0.53 (1.41)	2.62 (2.60)	16.11	2,88	< .001
PDSQ Social Anxiety	1.50 (2.29)	1.97 (2.41)	4.14 (3.93)	6.63	2,88	.002
PDSQ Generalized Anxiety Disorder	0.93 (1.41)	2.43 (2.42)	5.34 (3.17)	25.05	2,88	< .001
PDSQ Somatization Disorder	0.37 (0.67)	0.83 (1.12)	1.83 (1.44)	13.12	2,88	< .001
Baseline Interoceptive Accuracy	0.62 (0.20)	0.60 (0.18)	0.64 (0.21)	0.22	2,87	> .050
Resting state HR variability: RMSSD	42.25 (19.48)	45.03 (18.98)	50.97 (28.27)	1.14	2,88	> .050
Baseline HR Δ(bpm)	84.09 (7.50)	81.45 (9.01)	81.16 (9.16)	1.00	2,86	> .050
Baseline SCL Δ(μS)	8.72 (4.08)	10.12 (4.01)	7.80 (3.58)	2.66	2,86	> .050
Baseline Corrugator EMG Δ(μV)	4.17 (1.99)	3.85 (1.31)	3.77 (3.58)	.046	2,84	> .050
Baseline Zygomatic EMG Δ(μV)	4.01 (2.90)	5.24 (3.56)	3.66 (2.99)	1.91	2,81	> .050
IAS total	28.67 (8.08)[ab]	37.00 (8.80)[ac]	61.90 (11.32)[bc]	121.63	2,87	< .001
SHAI total	6.10 (2.51)[ab]	12.00 (1.76)[ac]	21.10 (5.73)[bc]	40.33	2,87	< .001

Note. [abc] $p < .001$. IA = illness anxiety; HR = heart rate; SCL = skin conductance level; EMG = electromyography; IAS = Illness Attitudes Scales; SHAI = Short Health Anxiety Inventory.

[1] The self-reported medical conditions included: dyslipidemia, Bechet's disease, nephropathy, orthopedic disorders, tension headache, diabetes type I, rheumatoid arthritis, keratoconus, ulcerative colitis & ankylosing spondylarthritis, prolactinoma in pituitary gland, allergies & arrythmia, lung disease, Crohn's disease. It should be noted that we have tested potential differences in emotional responses between the group of participants who reported that they have a medical diagnosis and the participants who said that they have never received a medical diagnosis and the results did not show significant differences.

Table 2
Thematic categories of the personally relevant illness scenarios and frequency of each theme (total N of scenarios: 404).

Theme	*N*	%
Cancer-related worries	99	24.50
Injury and disability fears	91	22.52
Non-specific illness worries	81	20.05
Intolerance-related worries	21	5.20
Worries about cardiovascular problems	16	3.96
Contamination fear	15	3.71
Worries related to damage in the central nervous system	14	3.47
Fear of medical errors	13	3.22
Worries about disorders in sensory organs	12	2.97
Psychological worries	8	1.98
Worries about gynaecological problems	7	1.73
Autoimmune diseases worries	4	0.99
Diabetes-related worries	2	0.50
Kidney failure-related worries	2	0.50
Worries about the impact of bad health habits	2	0.50
Vicarious illness and suffering worries	2	0.50
Worries about respiratory problems	1	0.25
Thyroid disorders-related worries	1	0.25
Worries about the impact of environmental pollution	1	0.25
Physical threat during generally fearful situations	1	0.25

vividly as possible for 30 s.

2.3. Measures

2.3.1. Screening measures

The Short Health Anxiety Inventory (Salkovskis, Rimes, Warwick, & Clark, 2002) total score was used in this study to measure participants' IA levels; in this sample, Cronbach's α = .89. It is an 18-item questionnaire that assesses the features of IA as proposed by the cognitive-behavioral model of IA (Warwick & Salkovskis, 1990). Each item consists of four statements that correspond to a 4-point Likert scale (score range: 0–54). This short version has shown comparable reliability and validity to the 64-item version, which indicated excellent psychometric properties (Hedman, Lekander et al., 2015). In addition to the total score, the questionnaire provides two factors: Health Anxiety and Negative Consequences. The Greek version of the SHAI (Karademas, Christopoulou, Dimostheni, & Pavlu, 2008) showed a good fit of the two-factor model (Leonidou & Panayiotou, 2016).

The Illness Attitudes Scales (IAS; Kellner, 1987) total score was used as an additional measure of IA (Cronbach's α = .85). It is a 27-item scale and assesses fears, attitudes and beliefs associated with hypochondriacal concerns and abnormal illness behaviour on a 5-point Likert scale (score range: 0–108). The IAS shows very good psychometric properties (Hedman, Lekander et al., 2015) and gives both a total score, and scores of nine subscales: Worry about illness, Concerns about pain, Health habits, Hypochondriacal beliefs, Fear of death, Disease phobia, Bodily preoccupations, Treatment experience, Effects of symptoms. It was translated into Greek for the purpose of this study and initial confirmatory factor analysis supported the existing factor structure and model fit (Leonidou & Panayiotou, 2017).

The Private Self-Consciousness subscale (10 items) of the Self Consciousness Scale (SCS; Fenigstein, Scheier, & Buss, 1975; local standardization, Panayiotou & Kokkinos, 2006) was used to measure the tendency to direct attention to covert aspects of the self, such as feelings and beliefs as a trait. In the original standardization study by Fenigstein et al. (1975) all subscales showed good test-retest reliabilities > .73. The SCS has demonstrated good construct validity in

many cultures (Chang, 1998; Nystedt & Smari, 1989), including its local version, which showed acceptable scale reliabilities with α between .63–.84 (Panayiotou, Leonidou, Constantinou, & Michaelides, 2018).

The Psychiatric Diagnostic Screening Questionnaire (Zimmerman & Mattia, 2001b) was used to assess the presence of other psychological disorders, and especially panic or other anxiety disorders that may better explain the variance in the dependent variables. The PDSQ is a self-report instrument that screens for DSM-IV Axis I disorders. Previous standardization efforts showed that the subscales of the PDSQ demonstrated good to excellent psychometric properties, including internal consistency (Cronbach's α = .66–.94), test-retest reliability (r = .61–.92), discriminant, convergent and concurrent validity (Zimmerman & Mattia, 2001a). The Greek version of the PDSQ was validated in a sample of Cypriots (Theodorou, Ioannou, Karekla, & Panayiotou, 2016), and showed similar internal consistencies of the subscales as found in the initial standardization studies (α = .60–.90).

2.3.2. Psychophysiological measures

Psychophysiological reactivity was recorded using the BIOPAC MP150 and the AcqKnowledge Data Acquisition and Analysis Software 3.9. HR reactivity as an index of emotional arousal was measured by ECG recorded at the two inner forearms and filtered by a BIOPAC ECG100C bioamplifier sampled at 1000 Hz, set to record HR between 40 and 140 beats per minute (BPM), and converted to BPM online. The Rate Detector function in AcqKnowledge set to detect peaks between 40 and 140 BPM and reject noise 5 % of peak was used to count the heartbeats. The Root Mean Square of Successive Differences (RMSSD) as a resting state HR variability index was calculated based on HR recording during the 5-minute adjustment period in the beginning of experiment using ARTiiFACT (Kaufmann, Sütterlin, Schulz, & Vögele, 2011). Skin conductance level (SCL) was also used as a measure of arousal, using GSR100C transducer amplifier and electrodes attached on the medial phalanx of the index and middle fingers of the non-dominant hand, sampled at 250 Hz. Facial electromyography as a measure of emotional valence was recorded at the right corrugator supercilii and zygomaticus major muscles, by two electrodes in each muscle, sampled at 1000 Hz, filtered (band pass, 20 Hz high frequency, 500 Hz low frequency), integrated over 20 samples, and rectified.

2.3.3. Self-reported emotion

Following the end of each trial, participants rated the emotional valence, arousal and the vividness they experienced during imagery on a 9-point scale. They also reported any somatic sensations/symptoms they felt by selecting from a list of symptoms chosen from the Patient Health Questionnaire (Kroenke, Spitzer, & Williams, 2001) in a way that at least one symptom per category was represented, e.g. chest pain, dizziness, heart palpitations, stomach ache, backpain, headache, dyspnoea, fatigue or low energy, numbness, weakness.

2.4. Data reduction and analysis

Raw psychophysiological data were reduced by calculating the mean of HR (BPM), SCL (μS) and corrugator and zygomatic activity (μV) during the 20-second resting phases and during the 30-second imagery phases. The SCL data of 14 participants, HR data of four participants, zygomatic activity data of ten participants and corrugator activity data of six participants were not included in analyses due to technical problems. Outliers below or above 2.5 SDs to the mean were removed from the raw data. Change scores of physiological measurements were created by subtracting mean physiology during each resting phase from each subsequent imagery phase, to control for baseline reactivity. The mean of each measurement was calculated for each experimental condition and data were examined for normal distribution and outliers using histograms and boxplots. Few extreme cases were replaced in the corrugator and zygomatic activity variables with the highest value, calculated after the identified outliers had been removed; 2.86 % of values were replaced in total.

To test the effect of experimental manipulation, repeated-measures ANOVAs were conducted on the total sample (n = 101; i.e. without the IA grouping variable) for each psychophysiological and self-report measure separately, using attention and imagery conditions as the within-subjects variables. Greenhouse-Geisser corrections were applied when the assumption of sphericity was not met. To test the main hypotheses, IA was added to the repeated measures ANOVA as a grouping variable. Planned contrasts were corrected with the Holm-Bonferroni method for multiple comparisons (Holm, 1979); corrected alpha levels applied: 1st-rank α = .016, 2nd-rank α = .025, 3rd-rank α = .050). Effects were assumed to have a large effect size if $\eta_p^2 > .25$, medium if $\eta_p^2 > .09$, small if $\eta_p^2 > .01$.

3. Results

3.1. Manipulation checks

3.1.1. Imagery manipulation

The mean score on reported vividness of imagery across all conditions (M = 6.92, SD = 1.19) was high, suggesting vivid imagery was achieved. Imagery condition had a significant main effect on arousal reports, $F(3,96) = 248.82$, $p < .001$, $\eta_p^2 = .72$ ($\varepsilon = .81$). Planned contrasts showed higher arousal reports after illness imagery compared to joyful, $F(1,98) = 27.42$, $p < .001$, $\eta_p^2 = .22$, and neutral imagery, $F(1,98) = 517.44$, $p < .001$, $\eta_p^2 = .84$; arousal reported after illness imagery was, however, lower compared to fearful imagery, $F(1,98) = 18.55$, $p < .001$, $\eta_p^2 = .16$. Imagery condition had a significant main effect on self-reported emotional valence, $F(3,96) = 681.99$, $p < .001$, $\eta_p^2 = .87$, ($\varepsilon = .69$): more negative valence was reported after illness imagery compared to fearful, $F(1,98) = 9.02$, $p < .01$, $\eta_p^2 = .08$; joyful, $F(1,98) = 1307.61$, $p < .001$, $\eta_p^2 = .93$; and neutral imagery, $F(1,98) = 591.54$, $p < .001$, $\eta_p^2 = .86$. In addition, imagery condition had a main effect on somatic sensation reports, $F(3,98) = 78.88$, $p < .001$, $\eta_p^2 = .44$ ($\varepsilon = .50$): higher reports in the illness compared to the fearful, $F(1,100) = 24.12$, $p < .001$, $\eta_p^2 = .19$, joyful, $F(1,100) = 88.57$, $p < .001$, $\eta_p^2 = .47$) and neutral conditions, $F(1,100) = 102.51$, $p < .001$, $\eta_p^2 = .51$. Results suggest that emotion was effectively manipulated, with illness imagery being perceived as more negative even though less arousing than standardized fear imagery.

Imagery condition had no main effects on HR, $F(3,94) = 1.49$, $p > .05$ ($\varepsilon = .89$). However, the main effect of imagery condition on SCL was significant, $F(3,84) = 3.75$, $p = .015$, $\eta_p^2 = .04$ ($\varepsilon = .94$). Planned contrasts showed higher SCL during illness imagery, compared to neutral; $F(1,86) = 8.87$, $p < .01$, $\eta_p^2 = .08$; but not compared to fearful, $F(1,86) = 3.47$, $p > .05$, and joyful imagery, $F(1,86) = 3.89$, $p > .025$, which was expected due to the nature of these conditions that elicit high emotional arousal.

In examining the effects of experimental manipulation on corrugator activity, there was a main effect of imagery condition, $F(3,91) = 27.27$, $p < .001$, $\eta_p^2 = .23$ ($\varepsilon = .84$). As expected, illness imagery triggered significantly greater corrugator activity compared to joyful, $F(1,93) = 45.17$, $p < .001$, $\eta_p^2 = .33$; but not compared to neutral, $F(1,93) = 4.99$, $p > .025$; and fearful imagery during which corrugator activity was similar, $F(1,93) = 0.17$, $p > .05$. A main effect of imagery condition on zygomatic activity was also indicated, $F(3,85) = 26.27$, $p < .001$, $\eta_p^2 = .23$ ($\varepsilon = .56$), and as expected, planned contrasts showed a significant difference between illness and joyful imagery, $F(1,87) = 33.25$, $p < .001$, $\eta_p^2 = .28$, but not fearful, $F(1,87) = 3.89$, $p = .052$, and neutral imagery, $F(1,87) = 0.07$, $p > .05$. Thus, physiological measures as well verify the effectiveness of emotion manipulation, with illness imagery being equally arousing and eliciting equivalent negative valence to fear imagery.

3.1.2. Attention manipulation

Participants reported that the interoceptive attention was more difficult ($M = 7.11$, $SD = 2.49$) than the exteroceptive attention ($M = 2.54$, $SD = 2.00$), $F(1,98) = 198.34$, $p < .001$, $\eta_p^2 = .67$. This was also reflected in participants' mean accuracy on the counting task, which was significantly lower during interoceptive attention ($M = 69.91$, $SD = 16.20$), compared to exteroceptive attention ($M = 95.62$, $SD = 4.63$), $F(1,96) = 231.33$, $p < .001$, $\eta_p^2 = .71$.

The attention condition had a significant main effect on arousal reports, $F(1,98) = 16.79$, $p < .001$, $\eta_p^2 = .15$; on valence reports, $F(1,98) = 10.40$, $p < .01$, $\eta_p^2 = .10$, and on somatic symptom reports, $F(3,100) = 20.17$, $p < .001$, $\eta_p^2 = .17$. Participants rated imagery as more arousing and less negative and they reported more somatic symptoms after interoceptive compared to exteroceptive attention.

Attention condition had no main effects on HR, $F(1,96) = 0.38$, $p > .05$, however, it had a main effect on SCL, $F(1,86) = 10.45$, $p < .01$, $\eta_p^2 = .11$, i.e. decreased SCL after interoceptive attention. The main effect of attention condition on corrugator activity was not significant, $F(1,93) = 0.21$, $p > .05$. There was a main effect of attention condition on zygomatic activity, $F(1,87) = 4.85$, $p = .030$, $\eta_p^2 = .05$, i.e. less zygomatic activity after interoceptive attention in all imagery conditions.

3.2. Imagery x attention manipulation interaction

Table 3 presents means and standard deviations of emotional response measures per imagery x attention condition. The imagery x attention interaction effect on arousal reports was significant, $F(3,96) = 16.18$, $p < .001$, $\eta_p^2 = .14$ ($\varepsilon = .92$), suggesting different effects of attention condition depending on the imagery condition. Planned contrasts showed that for illness imagery, higher arousal was reported after interoceptive compared to exteroceptive attention, while for neutral imagery, lower arousal was reported after interoceptive compared to exteroceptive attention, $F(1,98) = 26.56$, $p < .001$, $\eta_p^2 = .21$. The contrasts between illness and fearful or joyful imagery were not significant, i.e. similar reported arousal after interoceptive and exteroceptive attention (see Fig. 1).

Another imagery x attention significant interaction, $F(3,96) = 21.43$, $p < .001$, $\eta_p^2 = .18$ ($\varepsilon = .86$), suggested that the effect of attention condition on valence ratings also depended on imagery condition. Planned contrasts showed a significant difference between the illness and neutral imagery, depending on attention condition, $F(1,98) = 81.43$, $p < .001$, $\eta_p^2 = .45$: while for illness imagery valence was more negative after interoceptive compared to exteroceptive attention, for neutral imagery valence was less negative after interoceptive compared to exteroceptive attention. The contrasts between illness and fearful or joyful imagery were not significant, i.e. similar reported valence after interoceptive and exteroceptive attention (see Fig. 1). The imagery x attention interaction on somatic symptom reports was not significant, $F(3,98) = 2.21$, $p > .05$ ($\varepsilon = .86$).

A significant imagery x attention interaction was observed on HR, $F(3,94) = 8.63$, $p < .001$, $\eta_p^2 = .22$. Planned contrasts showed a significant difference between illness and fearful, $F(1,96) = 16.92$, $p < .001$, $\eta_p^2 = .15$, and joyful, $F(1,96) = 13.77$, $p < .001$, $\eta_p^2 = .13$; but not neutral conditions, $F(1,96) = 1.34$, $p > .05$, so that in illness and neutral conditions there was more HR deceleration from baseline (lower HR) under interoceptive than the same comparison in exteroceptive attention. In contrast, for the fearful and joyful conditions, interoceptive attention was associated with less HR deceleration (higher HR), compared to exteroceptive attention (see Fig. 2).

The imagery x attention interaction on corrugator activity was significant, $F(3,91) = 3.41$, $p = .023$, $\eta_p^2 = .04$ ($\varepsilon = .92$). Planned contrasts showed that illness and neutral conditions differed in corrugator responses, $F(1,93) = 8.99$, $p < .01$, $\eta_p^2 = .09$; such that interoceptive attention triggers higher corrugator activity than exteroceptive attention during illness imagery, but lower corrugator activity than exteroceptive attention during neutral imagery (see Fig. 3). For fear and joy imagery ($F(1,93) = 3.50$, $p > .05$; and $F(1,93) = 1.88$, $p > .05$ respectively) the interaction was not significant, suggesting that corrugator responses were similar irrespective of attention condition. The imagery x attention interaction effect on zygomatic activity was not significant, $F(3,85) = 1.49$, $p < 05$ ($\varepsilon = .88$).

3.3. Effect of IA group on emotional responses

Mixed-model ANOVAs showed that the two-way interaction effects of IA group x imagery condition and of IA group x attention condition and the three-way interaction effects of IA group x imagery condition x attention condition on emotional responses were not significant. All mixed-model ANOVAs were repeated controlling for depression, generalized anxiety, panic, agoraphobia, social anxiety and somatization symptoms (all PDSQ variables added as covariates in the same analysis) and the results remained the same, i.e. non-significant. The means, standard deviations per IA group and the interaction effects with IA group from the mixed-model ANOVAs results are presented as supplementary material.

4. Discussion

The current study investigated the effect of interoceptive vs exteroceptive attention on emotional responses during illness imagery and how this is modulated by IA levels. The overall results are consistent with the expectation that illness imagery, irrespective of attention manipulation, triggers negative emotional reactions evident in both self-reports and physiological reactivity. The results are in line with the study of Brownlee et al. (1992), who reported increased emotional arousal, negative affect and physiological activation (HR, SCL, respiratory rate) during illness compared to neutral imagery. In our study, the distressing and unpleasant nature of illness imagery was further supported by higher negative valence and somatic sensation reports, compared not only to neutral but also to generally fearful imagery. In addition, illness imagery was rated as more intense, and

Table 3
Means and standard deviations (in parentheses) for self-reported and physiological measurements in the total sample (N = 101).

	Interoceptive Attention Task				Exteroceptive Attention Task			
	Illness	Fearful	Joyful	Neutral	Illness	Fearful	Joyful	Neutral
Arousal (1-9)	6.98 (1.31)	7.42 (1.18)	6.04 (2.07)	2.50 (1.31)	6.51 (1.44)	7.09 (1.34)	5.22 (1.87)	3.02 (1.35)
Valence (1-9)	1.92 (1.21)	2.30 (1.21)	8.18 (1.34)	6.84 (1.32)	2.18 (1.10)	2.45 (1.41)	8.01 (1.22)	5.76 (1.19)
Somatic Sensations (n)	2.06 (1.82)	1.62 (1.60)	0.66 (0.99)	0.40 (0.72)	1.79 (1.71)	1.38 (1.48)	0.45 (0.65)	0.39 (0.72)
HR Δ(bpm)	−5.79 (5.86)	−4.58 (5.73)	−5.09 (5.60)	−6.11 (6.17)	−3.58 (4.16)	−6.02 (5.43)	−6.14 (5.78)	−5.08 (5.65)
SCL Δ(μS)	−0.28 (0.67)	−0.37 (0.57)	−0.30 (0.71)	−0.50 (0.71)	−0.13 (0.66)	−0.25 (0.66)	−0.31 (0.74)	−0.28 (0.56)
Corrugator EMG Δ(μV)	0.88 (1.88)	0.70 (1.53)	−0.55 (1.32)	0.20 (1.14)	0.55 (1.55)	0.84 (2.22)	−0.57 (1.78)	0.57 (1.51)
Zygomatic EMG Δ(μV)	−0.61 (2.04)	−0.02 (1.57)	1.30 (3.17)	−0.44 (1.33)	−0.04 (1.23)	−0.03 (1.42)	1.76 (3.49)	−0.29 (1.79)

Note. HR = heart rate; SCL = skin conductance; EMG = electromyography; Δ = difference score; bpm = beats per minute.

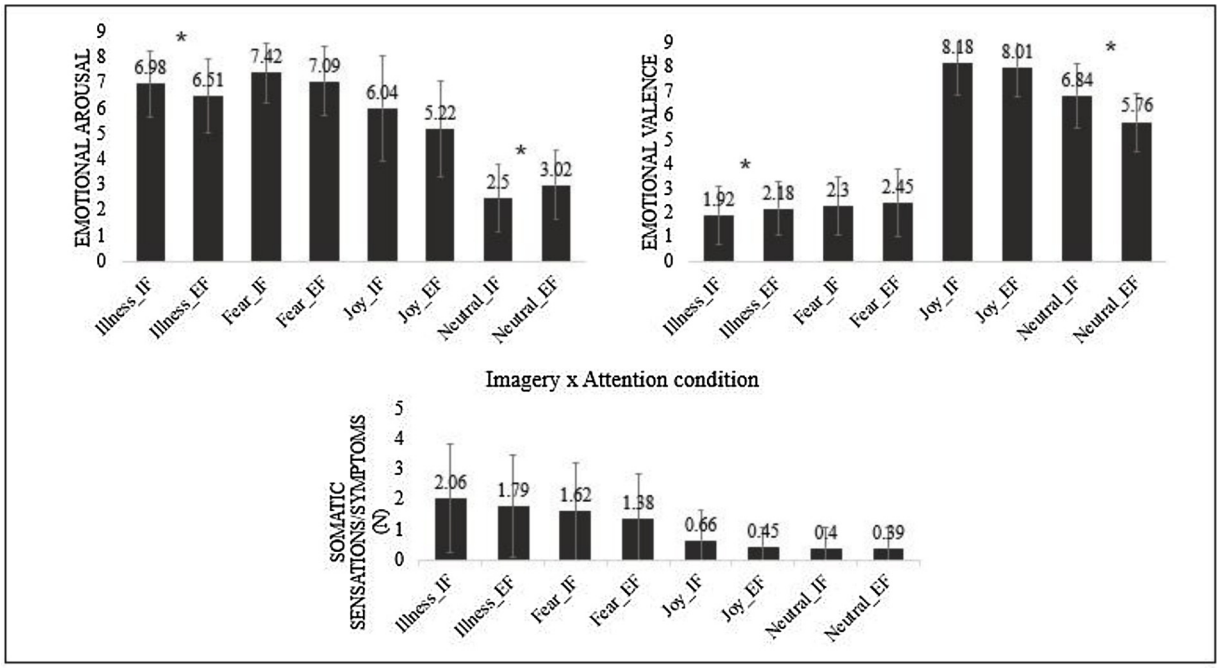

Fig. 1. Self-reported emotional arousal (1 = not intense at all, 9 = extremely intense emotion) and valence (1 = extremely unpleasant, 9 = extremely pleasant) and somatic sensations/symptoms (number) during imagery for the total sample. IF = Interoceptive Focus of attention; EF = Exteroceptive Focus of attention.

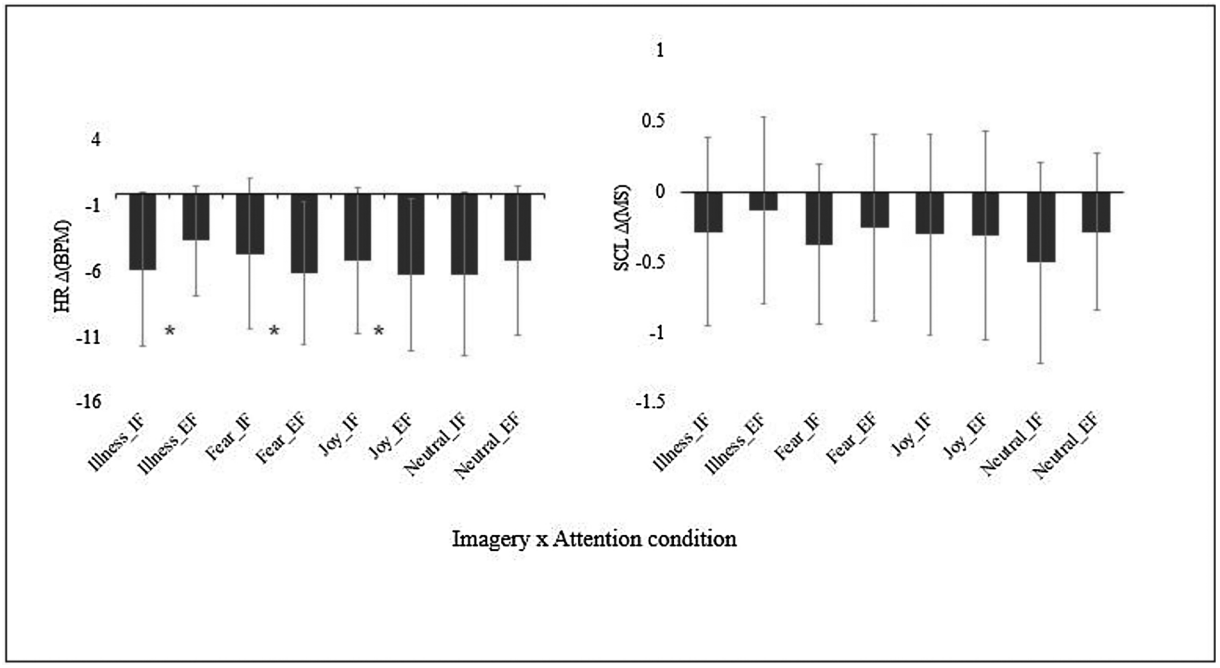

Fig. 2. Psychophysiological measures of arousal: HR reactivity Δ(BPM) and skin conductance level Δ(μS) during imagery for the total sample. IF = Interoceptive Focus of attention; EF = Exteroceptive Focus of attention.

was linked to greater corrugator and less zygomatic activity, compared to joyful imagery (a highly arousing condition with a positive valence), and similarly intense compared to generally fearful imagery. SCL was similarly increased during illness, fearful and joyful as compared to neutral imagery, suggesting that all three conditions elicit high levels of bodily arousal.

The major novel contribution of this study pertains to findings which showed that some of the emotional reactions of participants to illness imagery depended on the type of attention manipulation, supporting our initial hypothesis. For illness imagery and apparently for other intense emotional conditions, aversive and positive (fearful and joyful imagery), prior interoceptive attention led to higher self-reported emotional arousal and negative valence, as compared to exteroceptive attention. In contrast, in neutral imagery, when a less extreme subjective and physiological response is expected, interoceptive attention was associated with decreased subjective arousal and increased positive emotions. These results were further supported by the facial electromyography indices, i.e. corrugator activity, indicative of negative emotion, was higher during the high arousal imagery conditions (including illness imagery), while zygomatic activity was lower in all conditions after interoceptive attention. Our findings provide preliminary evidence of higher perceived aversiveness of intense emotional

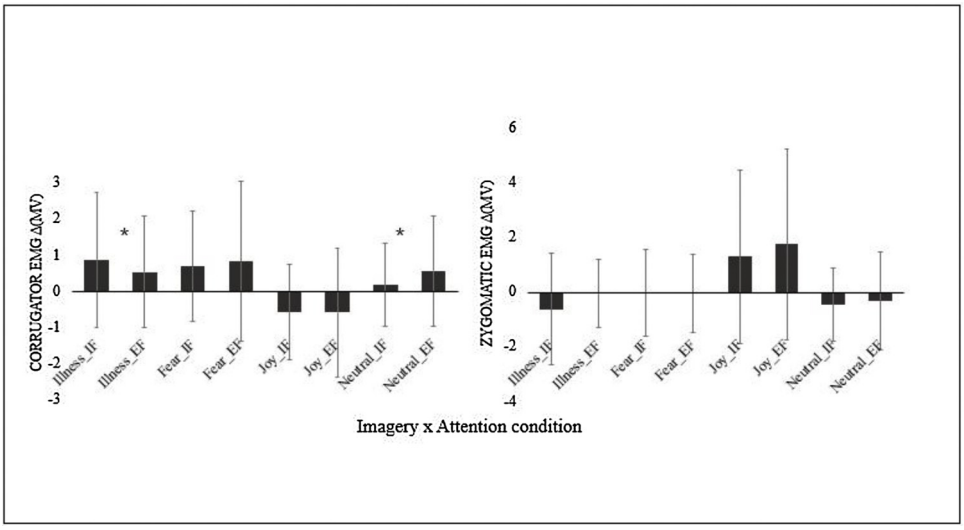

Fig. 3. Facial electromyography: Corrugator activity Δ(μV) and zygomatic activity Δ(μV) during imagery for the total sample. IF = Interoceptive Focus of attention; EF = Exteroceptive Focus of attention.

conditions after increasing interoceptive attention. Considering illness imagery more specifically, this finding may explain the increased anxiety about somatic symptoms that seems to result when one focuses on and ruminates about such symptoms. Even though this effect seemed to hold equally for all IA groups in our sample, since interactions with IA level were not observed, according to the cognitive-behavioral model of IA, such exaggerated emotional responses may play a part in the reassurance and healthcare seeking behavioral responses of illness anxious individuals, which further contribute to the development and maintenance of IA (Warwick & Salkovskis, 1990).

In contrast to the above finding, and contrary to our hypothesis, HR was lower (more deceleration from baseline) after interoceptive compared to exteroceptive attention, for illness but also neutral imagery; instead in joyful and fearful imagery HR was higher (less deceleration from baseline). To interpret this finding we need to draw from previous work: HR deceleration during processing affective pictorial stimuli was previously found to be associated with higher interoceptive awareness (Pollatos, Herbert, Matthias, & Schandry, 2007) and was more profound among individuals with better interoceptive awareness in the heartbeat tracking task (Pollatos & Schandry, 2008). In addition, inward attention meditation, a technique similar to the interoceptive attention in this study, was previously linked to increased parasympathetic activity (Wu & Lo, 2008), which calms the heart. In the current study, HR deceleration could therefore reflect a greater focus on and stronger intake of affective stimuli triggered by the interoceptive focus manipulation. In turn interoceptive attention may trigger more parasympathetic activity (which reduced autonomic arousal, as evident in both HR and SCL after interoceptive attention) during personally relevant illness and neutral imagery; the latter may have been perceived as an ambivalent condition by individuals who interpreted it in more personalized ways. Another plausible explanation about the decreased HR in illness and neutral imagery following interoceptive attention may be that these imagery conditions involve low salience of the expected emotional response (i.e. it is unclear what action needs to be taken), compared to scripts for joyful and fearful imagery (Lang, 1979). In sum, attentional focus on somatic sensations triggers a hypo-arousal pattern of emotional response in conditions that may be perceived as highly aversive, but ambivalent in the action tendency required. Hypo-arousal may then reflect efforts to regulate emotion by reducing autonomic arousal parameters.

Moreover, the discordance between subjective and physiological indices of arousal (HR), especially observed during illness imagery should be noted here. Although after interoceptive attention participants showed less HR, they reported more subjective arousal during illness imagery. These findings may reflect tendencies for a ruminative or worrisome approach to the emotions and somatic sensations elicited during illness imagery, i.e. more reminiscent of the emotional responses of people with non-focal, broad negative affect and generalized anxiety rather than focal, specific fears (Cuthbert et al., 2003; Lang & McTeague, 2009; Panayiotou et al., 2017). The hypo-arousal physiological response (HR deceleration) observed during interoceptive attention and potentially increased parasympathetic activity (seen in the reduced autonomic indices) may be therefore explained by the temporary stress reducing effect of rumination and worrying (i.e. high subjective negative affect), which are, however, characterized by high reports of distress (Borkovec & Hu, 1990; Delgado et al., 2009; Fisher & Newman, 2013; Kirschner, Hilbert, Hoyer, Lueken, & Beesdo-Baum, 2016), i.e. high emotional arousal, negative reported affect, more somatic sensations, and negative facial expressive behavior. This discordance in emotional response systems needs to be further investigated in relation to specific emotion regulation strategies, like rumination, to understand its function and maintenance role in IA.

Findings regarding IA levels did not support our hypothesis that they would modulate affective responses to illness imagery. Although the high, compared to moderate and low, IA group, presented higher self-reported emotional arousal, somatic sensations and negative valence, as well as increased corrugator and lower zygomatic activity but a trend for lower HR and SCL after the interoceptive attention during illness imagery, these effects did not reach statistical significance. Resting state HR variability was also in similar levels across groups indicating no differences in autonomic regulation. The absence of effects of IA levels may be attributed to two main reasons: First, although the high IA group presented relatively high levels of IA, the sample was a non-clinical sample of young and healthy students and, therefore, illness imagery, which was personally relevant may not be significantly more distressing among this sample of high, compared to moderate and low, IA. Second, the interoceptive attention was perceived as equally difficult and may have elicited high distress in all groups, and therefore, more somatic sensation reports, irrespective of IA levels, as was found in previous studies (Mirams, Poliakoff, Brown, & Lloyd, 2012). It should be also acknowledged that participants rated the heartbeat tracking task as more difficult than the tone tracking task, which may have influenced the distress experienced in the following imagery conditions. However, it should be underscored that to prevent effects of such difference in attentional task difficulty, the emotional response measures

were recorded during and after the imagery phase and not during the attention manipulation phase. Although the current study provides important findings about the influence of attentional focus on somatic sensations on emotional reactions to illness imagery among young, healthy in their majority, individuals with a range of IA levels, replication studies are needed in samples with more severe and dysfunctional IA. Replication studies may also need to recruit more participants to have a greater power in testing the three-way interactions (IA group x imagery x attention condition). The sample size in this study provided adequate power to test the two-way interactions.

Another limitation may have been the focus of the interoceptive focus task on HR, as heart-related sensations may not be fearful to all individuals, especially in younger ages. The heartbeat tracking task provided the advantages of a previously-tested paradigm and it was easy to control in an experimental setting; its validity as a manipulation is verified by the fact that it had effects on emotional reactions during imagery. Future studies should consider a body scan task with broader focus, targeting more categories of somatic sensations.

In spite of some limitations, this study has noteworthy strengths. The inclusion of both subjective and objective measures of emotion made possible a thorough investigation of emotional responses to illness imagery and has been proved essential to observe the discordance between different aspects of emotional response during illness imagery. Personally relevant illness scenarios tailored to participants' worst illness-related fears precluded absence of effects due to irrelevance of stimuli, as there is a variability in this population regarding the fear of specific symptoms and diseases, which may change from time to time (Newby, Hobbs, Mahoney, Wong, & Andrews, 2017). Other imagery conditions in addition to neutral imagery provided the opportunity to test the specificity of emotional responses to illness imagery compared to other intense emotional conditions.

More importantly, this study design can be thought as an experimental analog in assessing emotional reactions to intrusive illness imagery under the influence of attention to somatic sensations. Therefore, findings may inform the conceptualization of illness-related information processing in a range of IA levels, and have implications in prevention and therapeutic interventions. Focusing on somatic sensations may increase processing of motor and visceral response aspects of the associative network, which was also supported by participants' emotional reactions in this study, and is suggested to produce greater effects on reduction of phobic behavior (Lang, 1979). This study may provide support for the utilization of interoceptive attentional focus techniques, e.g. a simple heartbeat tracking task, in therapeutic interventions for IA. Mindful body scan exercises and interoceptive exposure techniques are already being used as part of therapy for IA and in most cases have been effective in introducing a changed and more adaptive way to confront somatic sensations and intrusive images (McManus, Muse, Surawy, Hackmann, & Williams, 2015; Walker & Furer, 2008; Weck, Neng, & Stangier, 2013; Williams, McManus, Muse, & Williams, 2011). Such techniques may also be useful for young healthy populations, as this study's sample, with the purpose to prevent development of symptomatology in those with high risk of IA. Similar experimental paradigms examining the effects of attentional focus on somatic sensations over time in a longitudinal design may inform the field about the effectiveness of such techniques in processing illness-threats in a more adaptive way.

In sum, our findings extend prior knowledge about illness imagery by presenting evidence which supports that the emotional experience in response to imagery about personally relevant health-threats is influenced by heightened focus of attention on somatic sensations, an important component of the cognitive-behavioral model of IA.

Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964.

Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval for this study was obtained by the Cyprus National Bioethics Committee (Protocol Number: ΕΕΒΚ/ΕΠ/2017/12).

This article does not contain any studies with animals performed by any of the authors.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Declaration of Competing Interest

Authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.biopsycho.2019.107812.

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