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Preliminary communication

Interoceptive awareness, positive affect, and decision making in Major Depressive Disorder

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ABSTRACT

Background: Little work has examined the relation between interoceptive awareness and symptoms of Major Depressive Disorder (MDD). Existing research suggests that depressed individuals exhibit impaired heartbeat perception, though the results of this research have been equivocal. Importantly, depressed participants in these studies have had comorbid anxiety disorders, making it difficult to draw inferences about interoceptive awareness in MDD. The current study addresses this issue by assessing heartbeat perception in depressed women without current anxiety disorders and exploring the relation between interoception and perturbations in both affective intensity and decision making, components of MDD postulated to be related to bodily awareness.
Methods: Depressed women without concurrent anxiety disorders ($n=25$) and never-disordered controls ($n=36$) performed a heartbeat perception task. Participants completed the self-report Affect Intensity Measure (AIM), and decision-making difficulty was assessed in MDD participants using the Structured Clinical Interview for DSM-IV.
Results: Depressed women exhibited poorer heartbeat perception accuracy than did control participants. Impaired accuracy in MDD participants was associated with reduced positive affectivity and difficulty in decision making.
Limitations: Our sample was composed exclusively of females and was heterogeneous with respect to treatment status, thereby limiting our ability to generalize results to depressed males and to exclude the contribution of exogenous factors to the observed group differences.
Conclusions: Results of this study suggest that for depressed individuals without anxiety comorbidities, disrupted perception of bodily responses reduces both the experience of positive arousal and the ability to use interoceptive feedback to inform decision making.

1. Introduction

Since James (1890) proposed that the orientation of our emotional compass follows directly from our awareness, or anticipation, of physiological reactions, the perception of bodily states has figured prominently in theories of emotion generation (e.g., Adelmann and Zajonc, 1989; Damasio, 1994; Schachter, 1964). Indeed, there is mounting evidence that individual differences in interoceptive awareness—the perception of visceral sensations such as cardiac signals and respiratory volume—contributes significantly to variability in a range of affective experiences, including emotional lability (Schandry, 1981), arousal focus (Barrett et al., 2004), emotion regulation (Füstös et al., 2012), and notably, emotion intensity (Füstös et al., 2012; Herbert et al., 2009; Pollatos et al., 2007b, 2007d; Wiens et al., 2000). In general, this research has supported the formulation that interoceptive awareness facilitates the experience of emotional arousal in response to valenced stimuli (but see Blascovich et al., 1992).

Interoception has also been theorized to play a role in maintaining bodily homeostasis and maximizing the experience of pleasure (Paulus and Stein, 2010) by guiding decisions about future behavior. Physiological responses are thought to convey information about the hedonic value of environmental stimuli, thereby biasing our decisions to approach, or to withdraw from, these stimuli. Thus, greater ability to perceive physiological reactions may facilitate more effective choices among multiple plans of action. Damasio (1994) somatic marker hypothesis suggests an additional link between interoception and decision making, positing that bodily responses are encoded in memory together with information about the response-eliciting stimulus or event, such

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that subsequent exposure to predictors of similar events effectively reactivates the initial body state, thereby enabling individuals to experience "gut-level" anticipatory feelings and make quicker decisions. In this view, too, better detection of bodily responses facilitates the biasing of decisions toward one target over another upon encountering choice options, both for the first time and upon subsequent encounters. Indeed, initial evidence supports the association between interoceptive awareness and decision-making ability. Werner et al. (2009), for example, reported that cardiac awareness predicted better performance on the Iowa Gambling Task, a paradigm assessing participants′ ability to learn to maximize gains as they select cards from competing decks with varying payout probabilities.

In sum, this literature provides a framework for understanding the relations among interoceptive awareness, affect intensity, and decision making. Accordingly, there has been interest in the associations between interoceptive awareness and forms of psychopathology characterized by dysfunction in these domains. Researchers have found evidence for enhanced interoceptive awareness across various anxiety disorders (Van der Does et al., 2000), but despite the fact that Major Depressive Disorder (MDD) is characterized by abnormally low positive affect (i.e., anhedonia), and significant decision-making difficulties, few investigators have examined interoceptive awareness in this disorder. Studies of university students have demonstrated inverse correlations between subclinical depressive severity and interoceptive accuracy (Herbert et al., 2011; Pollatos et al., 2009). Other work has illustrated an association in eating-disordered women between diminished awareness of hunger-related interoceptive cues, assessed through self-report, and depression severity (Fassino et al., 2004). In the only study to date to examine interoceptive awareness in clinically-diagnosed MDD, Dunn et al. (2007) similarly found decreased heartbeat perception in depressed persons compared to control participants; the same pattern of results, however, was not identified in a separate sample of hospitalized patients with severe depression. Importantly, over half of this in-patient group had "marked anxiety symptoms," raising the possibility that the preserved interoceptive awareness found in this group was attributable to the presence of anxiety. Thus, the first goal of the present study was to examine interoceptive awareness in diagnosed depressed individuals without anxiety disorders. We hypothesized that these depressed participants would exhibit worse interoceptive awareness than would never-disordered control participants.

The second goal of this study was to examine the relation between interoceptive awareness and two central features of MDD: blunted positive affect and diminished decision-making capacity. In addition to the associations between interoception and affect intensity described above, this goal was motivated by the finding that individual differences in anhedonia moderate the facilitative effect of arousal on interoceptive awareness (Dunn et al., 2010b), suggesting that depressed individuals with greater positive emotional blunting will exhibit more pronounced reductions in the perception of bodily signals. Therefore, we hypothesized that attenuated interoceptive awareness in MDD would be associated with reduced intensity of positive affect. Given the evidence relating interoception to decision-making facility, we also hypothesized that those depressed participants who exhibit the greatest attenuation in interoceptive awareness would exhibit decision-making difficulty.

2. Methods

2.1. Participants

Participants were recruited from local psychiatric outpatient clinics and through website postings. To increase homogeneity, and because gender differences in interoceptive awareness have been reported (Fairclough and Goodwin, 2007), we included only females in our sample. Participants were 18–55 years old, had no history of psychotic ideation, no reported substance abuse within six months, and no indication of impaired mental status. Individuals reporting current cardiovascular complaints, including heart disease, high blood pressure, or chest pain, were excluded. Our final sample included 25 participants diagnosed with MDD without anxiety comorbidity and 36 never-disordered control participants (CTL). Diagnostic evaluations were based on DSM-IV-TR Axis I criteria using the Structured Clinical Interview (SCID; First et al., 2001); participants in the MDD group met criteria for current MDD, but not for any other current Axis-I disorder, and CTL participants did not meet criteria for current or lifetime Axis-I psychopathology. In previous studies, our team of interviewers has demonstrated excellent inter-rater reliability for both MDD (κ=.93) and the non-psychiatric CTL (κ=.92) diagnoses. Depressed participants were classified as having decision-making difficulties on the basis of their responses to the SCID; to meet clinical criteria for this symptom, participants had to have endorsed indecisiveness with respect to everyday matters for at least 10 of the previous 14 days, either by subjective account or as observed by others.

Informed consent was obtained from participants and all aspects of this study complied with the ethical standards for treatment of human participants from the American Psychological Association. Participants were paid $25 per hour.

2.2. Procedure

To compute body mass index (BMI), height and weight were measured at the beginning of the laboratory session. These data were unavailable for one CTL. We used a heartbeat perception procedure described by Schandry (1981). Participants were instructed to count the number of heartbeats that they felt during periods of time signaled by start and end tones without using any alternative methods for detecting the occurrence of a heartbeat, such as feeling pulse points. After each block, lasting 35, 25, and 45 s, participants recorded the number of heartbeats counted.

Participants completed the Beck Depression Inventory-II (BDI), a well-validated self-report measure of depressive symptoms (Beck et al., 1996), and the Beck Anxiety Inventory (BAI), an index of the severity of anxiety symptoms (Beck et al., 1988). In order to assess the intensity with which participants typically experience emotions, we administered the Affect Intensity Measure (AIM), a self-report scale shown to predict affective responses to events of daily life (Larsen et al., 1986). Following previous studies (e.g., Bryant et al., 1996), we computed participants′ scores on three subscales (positive affectivity, negative intensity, and negative reactivity) to examine separately the relation between positive and negative affect intensity and interoceptive awareness.

Based on our *a priori* hypotheses of diminished interoceptive awareness and positive affectivity, and increased intensity of negative affect, in MDD participants, we used one-tailed statistical tests to examine differences between MDD and CTL participants within these domains. Two-tailed statistical tests were used in all other cases to examine group differences and relations among variables.

2.3. Physiological acquisition and processing

Cardiovascular activity was recorded at a sampling rate of 1 kHz with an integrated system and software package (Biopac MP150, AcqKnowledge; Biopac Systems, Goleta, CA), using an electrocardiogram (ECG) amplifier module and disposable snap ECG electrodes. Following acquisition, raw ECG data were inspected for artifacts and noise. R-peaks were manually counted within each of the three testing intervals and used to calculate estimated heart rate. Consistent with previous work (e.g., Pollatos et al., 2007d), heartbeat perception scores were calculated as mean accuracy across the three perception intervals according to the following transformation:

$$\frac{1}{3}\sum\left(1-\frac{|\text{actual heartbeats}-\text{counted heartbeats}|}{\text{actual heartbeats}}\right)$$

3. Results

3.1. Demographics and clinical characteristics

Demographics, clinical characteristics, and questionnaire statistics are presented in Table 1. There were no group differences in age, $t(59)=.67$, heart rate, $t(59)=.67$, or BMI, $t(58)=1.46$, all $ps>.1$.

Table 1
Means (and Standard Deviations) of sample characteristics by diagnostic group.

	CTL	MDD
N	36	25
Age	36.0(12.5)	38.2(11.9)
Body mass index (BMI)	23.8(3.3)	25.3(4.4)
Heart rate, beats per minute	71.5(9.6)	73.4(12.0)
Beck Depression Inventory-II (BDI)	1.9(3.1)	25.0(9.2)[a]
Beck Anxiety Inventory (BAI)	33.9(23.8)	67.1(28.7)[a]
Affect Intensity Measure (AIM)	3.3(.5)	3.5(.6)
Positive affectivity	3.5(.8)	3.1(.9)[b]
Negative intensity	2.6(.6)	3.6(.9)[b]
Negative reactivity	3.8(.8)	4.4(.6)[b]
Heartbeat perception accuracy	.65(.2)	.55(.21)[b]
With decision-making difficulty		.47(.20)
Without decision-making difficulty		.67(.17)

CTL=control; MDD=Major Depressive Disorder; decision-making difficulty was not assessed in control participants.

[a] Indicates group differences, $p<.05$, two-tailed.
[b] Indicates group differences, $p<.05$, one-tailed.

As expected, the groups differed significantly in BDI score, such that MDDs reported greater severity of depression symptoms than did CTLs, $t(59)=13.972$, $p<0.001$. MDD participants also reported more anxiety symptoms than did CTL participants, $t(59)=6.177$, $p<0.001$. Fifteen MDD participants were taking psychoactive medications. Fifteen of the MDD participants met criteria for impaired decision making.

3.2. Depression and interoceptive awareness

Heartbeat perception accuracy was significantly lower in the MDD than in the CTL group, $t(59)=1.83$, $p=.036$ (Table 1, Fig. 1A). Given previous reports of an association between interoceptive accuracy and depressive symptoms in individuals without clinically-significant depression (Herbert et al., 2011; Pollatos et al., 2009), we examined the relation between BDI score and heartbeat perception in the CTL group and found a trend-level, inverse correlation between these variables ($r=-.321$, $p=.056$), such that higher scores were associated with poorer heartbeat perception. BDI score and interoceptive accuracy were uncorrelated in the MDD group, $r=.112$, $p=.595$. BAI score and interoceptive accuracy were uncorrelated in both CTLs ($r=-.215$, $p=.207$) and MDDs ($r=.009$, $p=.967$). Further clarifying our results, accuracy and heart rate were uncorrelated in CTL ($r=-.067$, $p=.699$) and MDD ($r=-.183$, $p=.380$) groups, and there was no accuracy difference between medicated and unmedicated MDD participants, $t(23)=1.324$, $p=.198$.

3.3. Affect intensity and interoceptive awareness

MDD and CTL participants did not differ significantly in total AIM score, $t(59)=1.073$, $p=.288$ (Table 1). Multivariate analysis of variance (MANOVA) indicated that the groups differed significantly in their scores on the AIM subscales, $F(3,57)=19.546$, Wilk′s $\lambda=.493$, $p<.001$. Follow-up one-tailed t-tests conducted on each of the subscales revealed higher scores in MDDs than in CTLs in

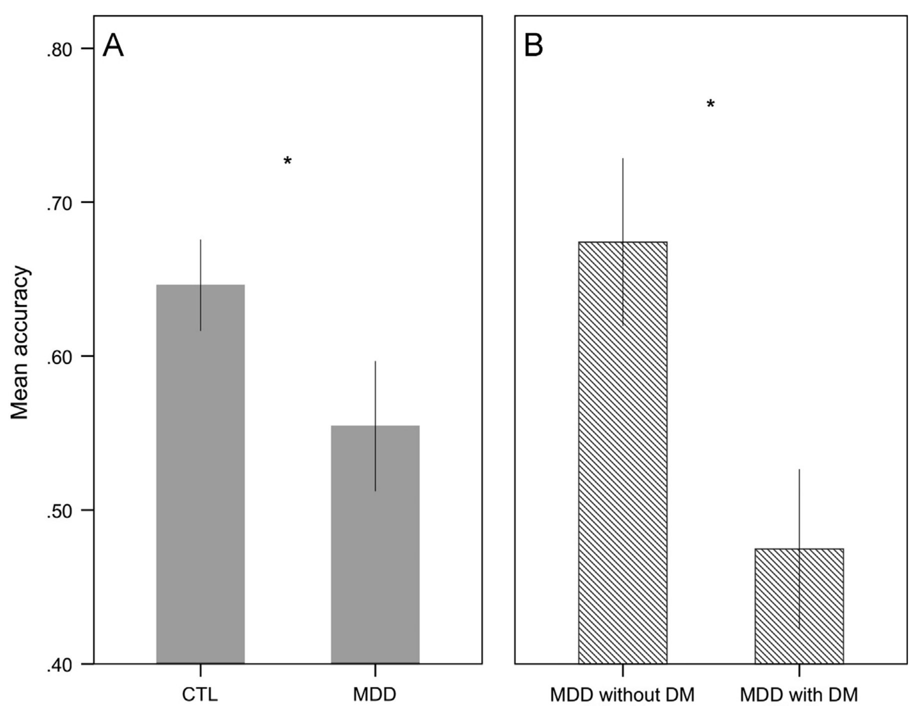

Fig. 1. Heartbeat perception accuracy by diagnostic group. (A) Accuracy as a function of clinical diagnosis. (B) Accuracy in depressed participants as a function of the presence or absence of decision-making difficulties. CTL=control; MDD=Major Depressive Disorder; DM=decision-making; error bars represent standard error of the mean; asterisks (*) indicate group differences, $p<.05$.

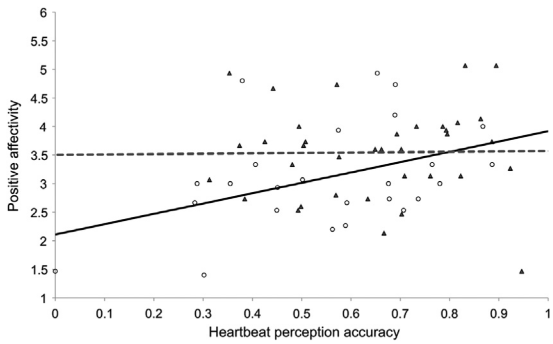

Fig. 2. Correlation between heartbeat perception accuracy and AIM–positive affectivity in control and depressed participants. Controls = triangles, dashed line; depressed = circles, solid line.

negative intensity, $t(59) = 5.211$, and negative reactivity, $t(59) = 3.361$, both $ps < .001$; in contrast, MDDs obtained lower scores than did CTLs in positive affectivity, $t(59) = 1.947$, $p = .028$.

For CTL participants, there were no significant correlations between heartbeat perception accuracy and positive affectivity ($r = .015$), negative intensity ($r = -.216$), or negative reactivity ($r = -.157$), all $ps > .1$. For MDD participants, however, heartbeat perception accuracy was significantly correlated with positive affectivity, $r = .416$, $p = .039$, such that poorer heartbeat perception was associated with diminished intensity of positive emotions (Fig. 2). Negative intensity ($r = -.097$) and negative reactivity ($r = -.033$) were unrelated to accuracy in the MDD group, $ps > .1$. For neither group were scores on any AIM subscale correlated with heart rate, all $ps > .1$.

3.4. Decision-making difficulty and interoceptive awareness

We conducted a binary logistic regression analysis to examine the ability of heartbeat awareness to predict the presence of decision-making difficulty (0 = absent or subthreshold; 1 = present) in participants with MDD. Heartbeat perception score entered alone into the equation significantly predicted presence of indecisiveness, $\beta = -6.491$, Wald $\chi^2(1) = 4.500$, $p = .034$. Heartbeat perception score remained a significant predictor of indecisiveness when BDI and BAI scores were entered simultaneously into the equation, $\beta = -5.947$, Wald $\chi^2(1) = 4.300$, $p = .038$; neither BDI ($\beta = -.021$, Wald $\chi^2(1) = .076$, $p = .783$) nor BAI ($\beta = .128$, Wald $\chi^2(1) = 2.164$, $p = .141$) score predicted symptom presence.

A one-way, three-group (CTL, MDD with decision-making difficulty, MDD without decision-making difficulty), analysis of variance (ANOVA) confirmed a main effect of group on heartbeat perception, $F(2,58) = 5.413$, $p = .007$. Follow-up *t*-tests indicated that MDDs with decision-making difficulty had lower scores than did both MDDs without decision-making difficulty (Fig. 1B), $t[23] = 2.564$, $p = .017$, and CTLs, $t[49] = 3.018$, $p = .004$, who did not differ significantly from each other, $t[44] = .442$, $p = .660$.

4. Discussion

Depressed participants without comorbid anxiety were less able to perceive their heartbeats than were control participants. This result lends support to the formulation that anxiety and depression exert opposing effects on cardiac perception (Pollatos et al., 2009) and may clarify the non-linear relation between interoceptive awareness and depression reported elsewhere (Dunn et al., 2007). Consistent with our hypothesis, we documented an association between interoceptive awareness and positive affect intensity in depressed participants, a relation that was not evident in the control sample. Given the prevalence of anhedonia in depressed individuals, that decreased interoceptive awareness may specifically diminish the experience of everyday positive arousal in MDD is compelling; future research utilizing experience sampling methodology and more fine-grained assessments of anhedonia should address this possibility more explicitly. Perhaps most interesting, we found that greater decrements in interceptive accuracy in depressed individuals predicted the endorsement of clinically-significant decision-making difficulty. Taken together, our pattern of results highlights the possibility that, for a subset of individuals with MDD, difficulty integrating interoceptive feedback from the body is associated with reductions in both the experience (or anticipation) of positive arousal following exposure to previously-enjoyed stimuli, and perhaps also in the ability to retrieve hedonic information about previous experiences to inform current decision making. Indeed, Treadway and Zald (2011) hypothesize that impairment in decision-making ability, particularly under circumstances requiring the estimation of potential reward values, reflects the presence of anhedonic symptoms. While we did not assess impairment within specific decision-making contexts, our results are consistent with this framework and suggest that reduced perception of positive arousal may limit the information (e.g., about potential rewards) available to depressed individuals during decision making.

Why the perception of physiological activity is disrupted in MDD is still unknown. It is possible that physiological reactions are themselves blunted in depression, thereby limiting the intensity or variability of interoceptive input available to depressed individuals on a daily basis. That the quality or intensity of interoceptive input shapes our ability to become aware of these cues is suggested by work demonstrating considerable correspondence between cardiac awareness and physiological reactivity to valenced stimuli (Herbert et al., 2009; Pollatos et al., 2007a, 2007b; Pollatos and Schandry, 2007) though the evidence is mixed (Dunn et al., 2010a; Wiens et al., 2000). And indeed, researchers have identified associations between depressive symptoms and blunted physiological reactivity to positive stimuli (Sloan and Sandt, 2010), and results of a meta-analysis suggest a trend toward reduced autonomic reactivity to positive stimuli in MDD (Bylsma et al., 2008). Thus, decreases in autonomic reactivity to positive information (or to cues predicting future rewards) in MDD may decrease interoceptive awareness—even in the absence of immediate stimulation—by limiting exposure to, and thus the development of sensitivity for, such signals.

It is also possible that bodily responses to salient environmental cues are intact in MDD, but these changes are simply not consciously detected. Dunn et al. (2010a) hint at the dissociability of bodily reactivity and interoception, arguing that physiological reactivity alone does not have as great an impact on decision making as does a combination of physiological reactivity and interoceptive sensitivity. Further, although interoceptive awareness is often construed as a stable individual difference, there is evidence to suggest that the ability to perceive visceral signals varies as a function of cognitive and emotional context. For example, acute stress has been shown to reduce interoceptive sensitivity in healthy female participants (Fairclough and Goodwin, 2007), suggesting that interoceptive awareness is compromised by the presence of competing cognitive or emotional states. Similarly, after observing that chronic pain patients exhibit impaired decision making, Apkarian et al. (2004) proposed that optimal decision making requires input from a *limited-capacity* interoceptive channel, and that the presence of a competing emotional or cognitive state compromises the ability to process interoceptive information and to utilize this information to make the best choices. Paulus and Stein (2010) further theorize that, as a result of a reduced signal-to-noise ratio of interoceptive afferents, individuals at risk for depression may attempt to cognitively amplify signals that are predictive of future states, thereby increasing the production of thoughts and associated beliefs. Interoceptive awareness in MDD may thus suffer as a result of increased thought volume and sustained negative affect, both of which can divert attentional and other resources from incoming interoceptive information.

The current findings have implications for the study of the neurobiology of MDD. Neuroimaging studies have consistently implicated the anterior insula in interoceptive awareness (Critchley et al., 2004; Pollatos et al., 2007c). Naqvi and Bechara (2010) have proposed that, through its connections with the ventral striatum, the insula acts as a "gate" through which memories for the interoceptive effects of experiences can motivate future experience-seeking behaviors. Indeed, insula activation is seen not only with the elicitation of primary emotions (Phan et al., 2002), but also with appetitive feeling states (Craig, 2010) and during financial decision making (Knutson et al., 2007). While abnormalities of the insula have been reported in depression (Hamilton et al., 2012), insula activation has not been found to be aberrant in depressed individuals during interoception (Wiebking et al., 2010). The present results suggest that only a subsample of this population would be expected to exhibit interoceptive difficulties and, consequently, observable perturbations in neural activation. Thus, although blunting of positive affect and decision-making difficulty in depression may reflect abnormalities in the structural integrity of the insula and its connections, researchers should exercise caution when studying heterogeneous samples of depressed persons given that relevant neural phenotypes may be specific to those individuals exhibiting particular symptoms.

4.1. Limitations

We note a few limitations of this study. First, our samples were exclusively female. While we recruited only women in order to increase homogeneity of the sample, it will be important to determine whether the pattern of results obtained in this study generalizes to depressed males. Second, our participants were heterogeneous with respect to medication status. We did not find differences in interoceptive perception as a function of medication status, though Dunn et al. (2007) reported a restorative effect of antidepressant treatment on interoceptive awareness. This suggests that the current result may be a conservative estimate of group differences in interoceptive awareness. Finally, our measure of decision-making difficulty in MDD consisted of a single item; therefore, we cannot determine which components of decision making are compromised in individuals with poorer interoceptive awareness. Despite these limitations, however, the results of this study indicate that access to interoceptive information is disturbed for a subset of depressed individuals, and that this anomalous functioning may contribute to the blunting of positive affect and the experience of indecisiveness that frequently characterize MDD.

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The sponsors were not involved in the design of the study, the collection, analysis, or interpretation of the data, or the preparation of the manuscript.

Conflict of interest

None.

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