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Research paper

Emotion Context Insensitivity is generalized in individuals with major depressive disorder but not in those with subclinical depression

Ching-wen Sun [a,b,1], Chao Yan [a,b,*,1], Qin-yu Lv [c], Ya-jing Wang [a], Wen-yi Xiao [a], Yi Wang [d], Zheng-hui Yi [c,**], Ji-kun Wang [a,*]

[a] Key Laboratory of Brain Functional Genomics (MOE&STCSM), Affiliated Mental Health Center (ECNU), School of Psychology and Cognitive Science, East China Normal University, Shanghai, China
[b] Shanghai Changning Mental Health Center, Shanghai, China
[c] Shanghai Mental Health Center, Shanghai Jiao Tong University School of Medicine, Shanghai, China
[d] Neuropsychology and Applied Cognitive Neuroscience Laboratory, CAS Key Laboratory of Mental Health, Institute of Psychology, Chinese Academy of Sciences, Beijing, China

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ABSTRACT

Background: Depressed individuals experience deficits in emotional reactivity. One well-established theory is the Emotion Context Insensitivity (ECI) theory. To better understand impairments in emotional reactivity, we investigated whether the ECI theory is applicable to anticipatory, consummatory, and remembered affect, in both clinical and subclinical depression.

Methods: Participants were divided into four groups: Major Depressive Disorder Group (MDD, $N = 60$), Control Group for MDD ($Control_{MDD}$, $N = 50$), Subclinical Depression Group (SD, $N = 56$), and Control Group for SD ($Control_{SD}$, $N = 56$). The Hamilton Depression Rating Scale and the Beck Depression Inventory were used to assess the severity of depression and anhedonia symptoms. The Monetary Incentive Delay Task evaluated participants' affective responses towards monetary stimuli.

Results: The MDD group was more insensitive to both monetary reward and loss across most types of affect than was the control group. Compared with the controls, the SD group exhibited lower reactivity in anticipatory positive affect but enhanced reactivity in consummatory positive, anticipatory, and remembered negative affect.

Limitations: Emotional affect was evaluated by subjective ratings, which may lack objectivity. Additionally, laboratory settings and monetary rewards used in this study may cause the results less generalized to daily life and to other types of rewards.

Conclusion: The pattern of emotional reactivity in the MDD group was partly consistent with the ECI theory, whereas the SD group showed greater arousal and instability of emotional reactions. These different patterns could facilitate the understanding of emotional reactivity and develop further treatments across the course of depression.

1. Introduction

Major depressive disorder (MDD) is characterized by impaired emotional reactivity (Bylsma, 2020; Rottenberg et al., 2005; Grossberg, 1972), which, in turn, has an aversive effect on quality of life (Cuijpers et al., 2004; Wagner et al., 2000). Although extensive efforts have been devoted to the exploration of emotional impairments (Beck et al., 1979; Rottenberg, 2017), findings remain controversial; some favor blunted reactivity towards both positive and negative stimuli (Kerns et al., 2008; Rottenberg et al., 2005), whereas others support a diminished feeling of positive affect but a heightened negative affect in MDD (Liu et al., 2011; Wu et al., 2017). Thus, clarifying the underpinnings of emotional reactivity impairments would aid precise diagnoses and effective interventions for MDD.

One of the commonly accepted models is the Emotion Context Insensitivity (ECI) theory, which suggests that depressed individuals

* Corresponding authors at: East China Normal University, 3663 North Zhongshan Road, 200062 Shanghai, China.
** Correspondence to: Z.-h. Yi, Shanghai Mental Health Center, 600 South Wanping Road, Shanghai, China.
E-mail addresses: cyan@psy.ecnu.edu.cn (C. Yan), yizhenghui1971@163.com (Z.-h. Yi), jkwang@psy.ecnu.edu.cn (J.-k. Wang).
[1] These authors contributed equally to the study.

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exhibit lower emotional reactivity than do healthy controls (HC; see Rottenberg, 2017 for a review). Specifically, depressed individuals report smaller changes than HCs in response to positive and negative stimuli when responses are compared with neutral conditions. In support of this hypothesis, accumulating evidence has shown that individuals with MDD self-report lower emotional reactivity towards both positive and negative film clips, imagery, and audiotapes of social interactions than do HCs, with moderate to large effect sizes (see Bylsma et al., 2008 for a meta-analysis). In a study comparing depressed participants with HCs, MDD individuals exhibited sadness and amusement towards sad and amusing film clips, respectively, in a flattened and context-insensitive manner (Rottenberg et al., 2002). Moreover, the level of anhedonia symptoms in depressed individuals has been shown to be proportional to the reduced emotional reaction towards positive and negative stimuli (Saxena et al., 2017). Furthermore, evidence from neural responses supports blunted positive emotional reactivity, especially towards rewarding stimuli, although few studies have explored negative emotional reactivity. Both functional magnetic resonance imaging (fMRI) and event-related potential studies have suggested that MDD patients and even individuals with a high risk of depression display attenuated neural reactivity to rewards in terms of striatal reactivity and the late positive potential (Forbes and Dahl, 2012; Gaillard et al., 2020; Klawohn et al., 2021; Webb et al., 2017). In addition, the lack of sensitivity and engagement towards rewards is consistent with the ECI theory. However, it remains unclear whether the ECI concept can be generalized across different aspects of emotional reactivity considering that emotional reactivity is well recognized as a multiple conceptualized framework (Kring and Barch, 2014).

According to the Temporal Experience of Emotion Model (Kring and Barch, 2014; Rizvi et al., 2016), emotional reactivity is a multi-step process that is mainly composed of anticipatory, consummatory, and remembered aspects from the perspective of the time course. Anticipatory affect is defined as an emotional feeling that is experienced while anticipating or predicting future pleasurable or unpleasurable outcomes and consists of two dimensions: feeling and prediction dimensions. The feeling dimension is more closely linked to motivation (e.g., the feeling when a father is waiting for the birth of his baby), whereas the prediction dimension requires the involvement of imagination to evaluate one's future pleasure (e.g., if you are not yet a mother/father, please imagine how you would feel when your first baby is coming). Consummatory affect refers to the "in-the-moment" emotional feeling that is experienced when engaging in positive or negative events/activities (e.g., the feeling of joy when a couple's baby is born). Remembered affect, which is associated with retrieval processing, is defined as an emotional experience towards enjoyable or unenjoyable activities in the past (e.g., a father remembering how he felt when his son was born) (Herbener, 2008).

To the best of our knowledge, few studies to systematically examine anticipatory, consummatory, and remembered aspects of emotional reactivity in individuals with MDD have been conducted. Moran et al. (2012) used the modulated startle paradigm to assess the anticipatory aspect of emotion and discovered that depressed individuals do not exhibit blink magnitudes that vary by valence, either during the viewing of pictures or after the pictures were removed from view, which suggested a potential application of the ECI theory in the anticipatory aspect of emotion. This finding is supported by another fMRI study that reported that depressed participants exhibit attenuated neural responses in the right orbitofrontal cortex during anticipation of positive and negative pictures, respectively (Feeser et al., 2013). Moreover, investigations of remembered pleasure in MDD individuals are scarce. Although research on schizophrenia has explored remembered pleasure, emotional reactivity patterns of remembered pleasure have not been studied directly (Trémeau et al., 2010; Weittenhiller et al., 2020). There is only one study that has applied the chocolate-tasting task to assess all of the above-mentioned aspects of hedonic reactivity; however, significant group differences in anticipated, experienced, or recalled hedonic reactivity prior to, during, or 1 day after the task, were not found (Chentsova-Dutton and Hanley, 2010). Therefore, in the present study, we aimed to examine anticipatory, consummatory, and remembered aspects of emotional reactivity towards monetary reward and punishment in MDD patients, which may offer a generalized interpretation of the ECI model in depression.

In addition, subclinical depression (SD) is widely known as a significant risk factor for experiencing an MDD episode (Cuijpers et al., 2004; Lewinsohn et al., 2000). Furthermore, many antidepressants have been developed to reduce the level of depressive symptoms (DeWilde et al., 2015; Martinotti et al., 2012; Tomarken et al., 2004), thereby affecting emotional processing in individuals with MDD. In such cases, we are also interested in whether the severity of depression and medication affect emotional reactivity, which will facilitate our understanding of the stability of the ECI view across different phases of depression. Results of emotional reactivity studies in subclinical populations to date are heterogeneous. One study assessed emotional reactivity in SD individuals and found that the patterns of self-report data mirror ECI models but not psychophysiological data (Benning and Ait Oumeziane, 2017). Moreover, individuals with depressive symptoms have been shown to exhibit attenuated emotional reactivity towards positive and negative words and images (Hill et al., 2019; Imbault and Kuperman, 2018), whereas another study suggested that individuals with SD experience reduced positive but elevated negative emotional reactivity in response to daily events (Bylsma et al., 2011). Thus, another goal of the present study was to explore whether the ECI model explains the emotional reactions of those with less severe depression.

Accordingly, we tested two hypotheses: 1) MDD patients would exhibit reduced anticipatory, consummatory, and remembered emotional reactivity in response to both pleasurable and unpleasurable stimuli compared with HCs; 2) similar patterns of emotional reactivity impairments will also be observed in individuals with SD symptoms.

2. Methods

2.1. Participants

A total of 222 participants aged 18–40 years were enrolled in this study. Participants were divided into four groups: the MDD group (N = 60, 44 females), the MDD control group (N = 50, 33 females), the SD group (N = 56, 46 females), and the SD control group (N = 56, 33 females) (see the inclusion and exclusion criteria in the Supplementary materials).

All participants were informed of the intention and procedure of the study and provided written informed consent prior to the commencement of the study. The research was approved by the University Committee on Human Research Protection of East China Normal University (HR 472-2019).

2.2. Measurements for depressive symptoms

The Chinese version of each measurement was used, and all had acceptable reliability and validity.

The 17-item Hamilton Depression Rating Scale (HAMD, Hamilton, 1980; Sun et al., 2017) is a semi-structured interview to evaluate the level of depression in the MDD group and encompasses domains such as state of mood, feeling of guilt, insomnia, and interest. A higher score indicates a higher level of depression.

The BDI-IA was used to evaluate the severity of depression and has an acceptable level of reliability (Cronbach's alpha 0.94; Lu et al., 2002). It consists of 21 self-reported items that measure both the physical and mental symptoms of depression. A higher score indicates a greater level of depression.

2.3. Monetary Incentive Delay Task

Before completing the Monetary Incentive Delay (MID) task, participants practiced their tapping responses in a tap controlling task. A white target star flashed briefly, and participants were required to hit the star as fast as possible. The aim of this task was to ensure that the participants were familiar with the target to hit and began the task in a similar motor status.

The MID computer task is typically applied with neuroimaging methods to map individuals' anticipatory and consummatory reward processing (Knutson et al., 2000; Oldham et al., 2018). Because monetary rewards elicit individuals' emotional responses (Kujawa et al., 2015), we used reward processing in the MID task to trigger participants' anticipatory (the feeling dimension) and consummatory affect. Both the valence (positive/negative) and arousal level of these two types of affect were assessed during the MID task. Details of the paradigm are described elsewhere (Yan et al., 2019). The goal of the MID task is to earn or avoid losing money. On each trial, a cue informed the participant about the amount of monetary reward that could be either gained or lost. If participants responded quickly enough to hit the subsequent white star target, they successfully gained or avoided losing money (positive valence); however, if participants failed to hit the target, they did not gain or lose money (negative valence). Feedback showing the money earned or lost was subsequently displayed. During the anticipatory rating trials, valence and arousal ratings were displayed after the cue and before the white star target. During the consummatory rating trials, valence and arousal ratings were displayed after the outcome feedback. The three magnitudes of rewards were none (0 Chinese yuan), low (0.5 Chinese yuan), and high rewards (5 Chinese yuan). The subjects provided a subjective rating on a 9-point Likert scale in terms of valence and arousal, with a score of 1 indicating the least pleasant or lowest arousal level and a score of 9 referring to the most pleasant or highest arousal level.

The prediction dimension of anticipatory affect was assessed using a questionnaire before the computer task, whereby participants imagined and rated their valence and arousal level for each condition. Referring to the study by Nielsen et al. (2008), remembered affect was assessed using the same questionnaire 30 min after the MID task, where participants were asked to recall their valence and arousal levels during the task.

2.4. Data preparation and analysis

A chi-square test was used to detect the differences in sex ratios between the two groups. For the MDD group and its control group, an independent samples *t*-test was used to examine group differences in age and educational level. For the SD group and its control group, these group differences were determined using a univariate analysis of variance (ANOVA) analysis, with sex as a covariate.

Emotional reactivity was calculated as the subtraction of the ratings for none reward/loss from the subjective ratings for high or low reward/loss. Prediction and recall ability were represented by the subtraction of subjective ratings in the MID task from those in the questionnaires (i.e., prediction/recalled ability = ratings in predicting/recalling questionnaire − ratings in MID task). To detect group differences, a 2 (MDD vs $Control_{MDD}$ or SD vs $Control_{SD}$) × 2 (reactivity level: low [ratings of low reward-none reward], high [ratings of high reward-none reward]) mixed ANOVA was conducted separately for reactivity of anticipatory, consummatory, and remembered affect under gain, lose, no-gain, and no-lose conditions (the latter two condition only existed for consummatory affect). A 2 (MDD vs $Control_{MDD}$ or SD vs $Control_{SD}$) × 3 (price: none [¥0], low [¥0.5], high [¥5]) mixed ANOVA was applied to prediction/recalled ability under the gain and lose conditions. In cases where Mauchly's sphericity assumption was violated, Greenhouse-Geisser correction was used to correct the degrees of freedom. Bonferroni correction was used to correct for multiple comparisons.

Correlation analysis was used to investigate the relationship between depression severity and emotional reactivity. In MDD participants, we analyzed the correlation between HAMD scores, duration of illness, and emotional reactivity that showed significant group differences towards high rewards. In SD participants, we analyzed the correlation between BDI scores and emotional reactivity. Bonferroni correction was applied to correct for multiple comparisons.

3. Results

Participants' demographic information, such as sex, age, and years of education, depression scores, and MDD participants' duration of illness and medication are provided in Table 1. No significant differences in sex ratio, age, or education were observed between the MDD group and its control group. There were also no significant differences in age or education between the SD group and its control group. However, the sex ratio between the two groups differed significantly ($\chi^2 = 7.26$, $p = .007$).

3.1. Emotional reactivity in the MDD group

For valence ratings of the MDD group, there were significant interactions between Reactivity Level and Group for the reactivity of the feeling dimension of anticipatory affect ($F(1,108) = 4.19$, $p = .04$, $\eta^2 = 0.04$) and consummatory affect ($F(1,108) = 10.94$, $p = .001$, $\eta^2 = 0.09$) under the gain condition as well as remembered affect under the lose condition ($F(1,108) = 12.69$, $p = .001$, $\eta^2 = 0.11$) (Fig. 1). Further simple effects analysis revealed that compared with HCs, MDD participants had lower reactivity when anticipating a gain of low and high rewards (low: $p < .01$, $d = 0.81$, 95 % confidence interval [CI] [−0.78, −0.29]; high: $p < .01$, $d = 0.74$, 95 % CI [−1.34, −0.44]) and experiencing a gain of a high reward ($p = .005$, $d = 0.55$, 95 % CI [−1.20, −0.22]). Lower reactivity was also observed in MDD participants than in HCs while recalling a high magnitude of monetary loss ($p = .007$, $d = 0.52$, 95 % CI [0.16, 0.97]). Main effects of Group were also observed for the prediction dimensions of anticipatory affect under the gain condition ($F(1,108) = 15.16$, $p < .01$, $\eta^2 = 0.12$; pairwise: $p < .01$, $d = 0.75$, 95 % CI [−0.92, −0.30]), the feeling dimension of anticipatory affect under the lose condition ($F(1,108) = 8.18$, $p = .005$, $\eta^2 = 0.07$; pairwise: $p = .005$, $d = 0.55$, 95 % CI [0.13, 0.73]), consummatory affect under the gain ($F(1,108) = 4.25$, $p = .04$, $\eta^2 = 0.04$; pairwise: $p = .042$, $d = 0.39$, 95 % CI [−0.88, −0.02]) and no-lose conditions ($F(1,108) = 4.51$, $p = .04$, $\eta^2 = 0.04$; pairwise: $p = .036$, $d = 0.41$, 95 % CI [−0.65, −0.02]), and remembered affect under the gain ($F(1,108) = 19.84$, $p < .01$, $\eta^2 = 0.16$; pairwise: $p < .01$, $d = 0.85$, 95 % CI [−1.02, −0.39]) and lose conditions ($F(1,108) = 3.97$, $p = .049$, $\eta^2 = 0.04$; pairwise: $p = .049$, $d = 0.38$, 95 % CI [0.00, 0.67]). Compared with controls, MDD participants showed lower reactivity in positive and negative anticipatory and remembered affect, and in positive consummatory affect.

Regarding arousal ratings of the MDD group, interactions between Reactivity Level and Group were significant for the feeling dimension of anticipatory affect ($F(1,108) = 5.99$, $p = .02$, $\eta^2 = 0.05$) and consummatory affect under the gain condition ($F(1,108) = 6.12$, $p = .01$, $\eta^2 = 0.06$). The simple effects analysis showed that the arousal level of reactivity in MDD participants was lower than that in controls during the anticipation of low and high reward gains (low: $p = .037$, $d = 0.40$, 95 % CI [−0.72, −0.02]; high: $p = .003$, $d = 0.57$, 95 % CI [−1.42, −0.30]; Fig. 2). Although there was no group difference, the arousal level of reactivity was lower when receiving a low reward than when receiving a high reward in both groups (MDD: $p = .001$, $d = 0.31$, 95 % CI [−0.86, −0.25]; HC: $p < .01$, $d = 0.65$, 95 % CI [−1.48, −0.81]). Additionally, arousal reactivity was lower in MDD participants relative to that in HCs in the prediction dimension of anticipatory affect under the gain condition ($F(1,108) = 5.48$, $p = .02$, $\eta^2 = 0.05$; pairwise: $p = .021$, $d = 0.45$, 95 % CI [−0.95, −0.08]) and remembered affect under the gain ($F(1,108) = 8.00$, $p = .006$, $\eta^2 = 0.07$; pairwise: $p = .006$, $d = 0.54$, 95 % CI [−0.95, −0.17]) and lose conditions ($F(1,108) = 5.20$, $p = .03$, $\eta^2 = 0.05$; pairwise: $p = .025$, $d = 0.44$, 95 % CI [−0.85, −0.06]), which was

Table 1
Demographic and disease-relevant information of the participants.

	MDD (N = 60)	HC (N = 50)	t/χ^2	P	Cohen's d	SD (N = 56)	HC (N = 56)	F/χ^2	P	Cohen's d
	Mean (SD)	Mean (SD)				Mean (SD)	Mean (SD)			
Gender (male/female)	16/44	17/33	0.70	0.40		10/46	23/33	7.26	0.007**	
Age	26.98 (7.64)	29.28 (7.71)	−1.56 (108)	0.12	0.30	20.11 (2.16)	20.45 (2.12)	0.70 (1110)	0.404	0.16
Education (year)	15.31 (2.56)	15.18 (3.38)	0.23 (108)	0.82	0.04	14.07 (1.74)	13.80 (1.34)	0.89 (1110)	0.35	0.18
HAMD	20.13 (7.91)									
BDI						22.52 (7.44)	4.50 (4.37)			
DOI (month)	5.83 (10.64)									
Medication (mg)	10.10 (16.25)									

*$p < .05$. **$p < .01$. ***$p < .001$.
Note: MDD = Major Depressive Disorder; HC = Healthy Controls; SD = Subclinical Depression; HAMD = the Hamilton Depression Rating Scale; DOI = Duration of Illness (months); BDI = the Beck Depression Inventory. Only 32 participants provided data for HAMD score and DOI, and 52 participants provided data for medication. All medication was transferred to equivalent fluoxetine dosage per day.

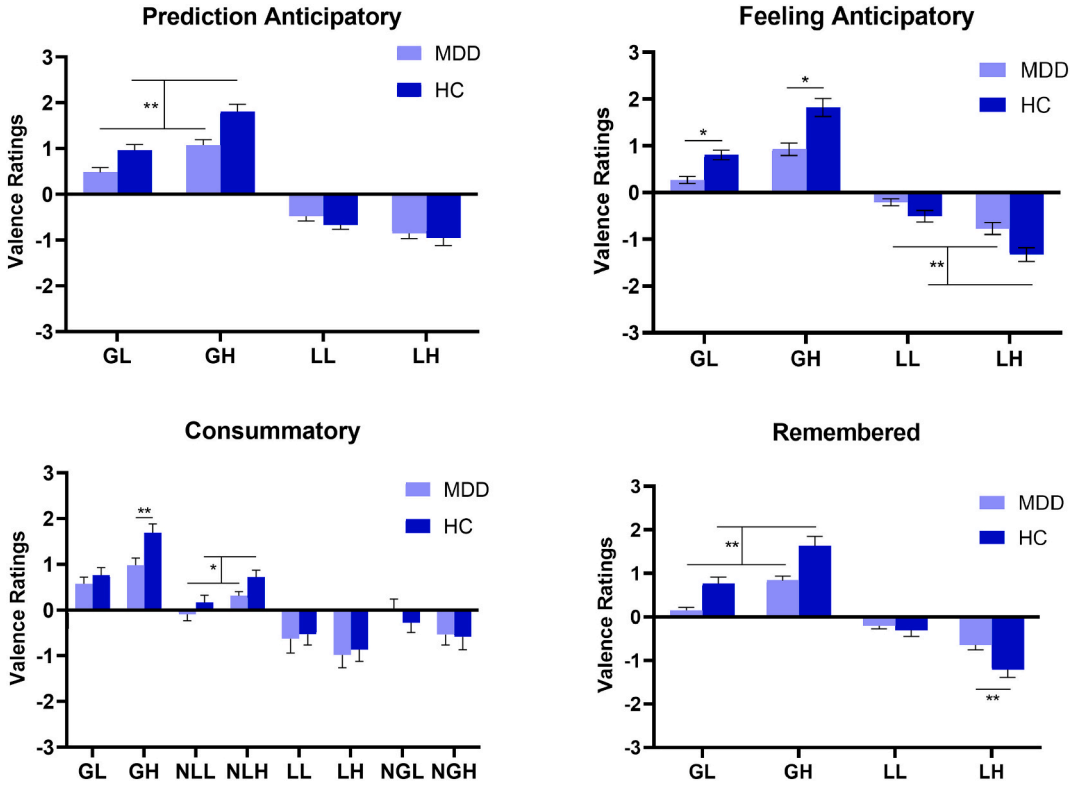

Fig. 1. Valence ratings for emotional reactivity in the MDD group.
Notes: Four graphs represent the valence ratings for emotional reactivity in anticipatory, consummatory, and remembered affect under gain, lose, no-gain, and no-lose condition in the MDD group and its control group. GL/GH: low/high emotional reactivity under gain condition; NGL/NGH: low/high emotional reactivity under no-gain condition; LL/LH: low/high emotional reactivity under lose condition; NLL/NLH: low/high emotional reactivity under no-lose condition.

reflected by the main effects of Group.

3.2. Emotional reactivity in the SD group

In SD participants, as shown in Fig. 3, we found significant interactions between Reactivity Level and Group for the valence ratings for the prediction dimension of anticipatory affect under the gain condition ($F(1,110) = 10.34$, $p = .008$, $\eta^2 = 0.09$) and the prediction ($F(1,110) = 8.59$, $p = .004$, $\eta^2 = 0.07$) and feeling dimension of anticipatory affect ($F(1,110) = 8.84$, $p = .004$, $\eta^2 = 0.08$) and remembered affect under the lose condition ($F(1,110) = 4.80$, $p = .03$, $\eta^2 = 0.04$). Compared with controls, SD participants reported lower reactivity for anticipatory positive affect towards a low reward gain ($p = .031$, $d = 0.41$, 95 % CI [−0.66, −0.033]), whereas their reactivity was higher for the prediction dimension of anticipatory negative affect regarding high loss ($p < .01$, $d = 0.69$, 95 % CI [−1.05, −0.32]), the feeling dimension of anticipatory negative affect regarding low and high loss (low: $p = .037$, $d = 0.40$, 95 % CI [−0.66, −0.02]; high: $p = .002$, $d = 0.61$, 95 % CI [−1.27, −0.31]), and the remembered dimension of negative affect regarding high loss ($p = .012$, $d = 0.49$, 95 % CI [−1.02, −0.13]). There was also a significant main effect of Group for consummatory affect under the gain condition ($F(1,110) = 5.22$, $p = .024$, $\eta^2 = 0.045$). In contrast to what was observed for anticipatory positive affect, SD participants exhibited higher reactivity than controls when experiencing reward gains ($p = .024$, $d = 0.43$, 95 % CI [0.08, 1.18]). After controlling for sex, another significant main effect of Group emerged for remembered affect under the gain condition ($F(1,109) = 4.09$, $p = .046$, $\eta^2 = 0.04$), which also indicated higher reactivity in SD participants relative to controls during the recall of reward gain.

In regard to arousal ratings (Fig. 4), there were significant

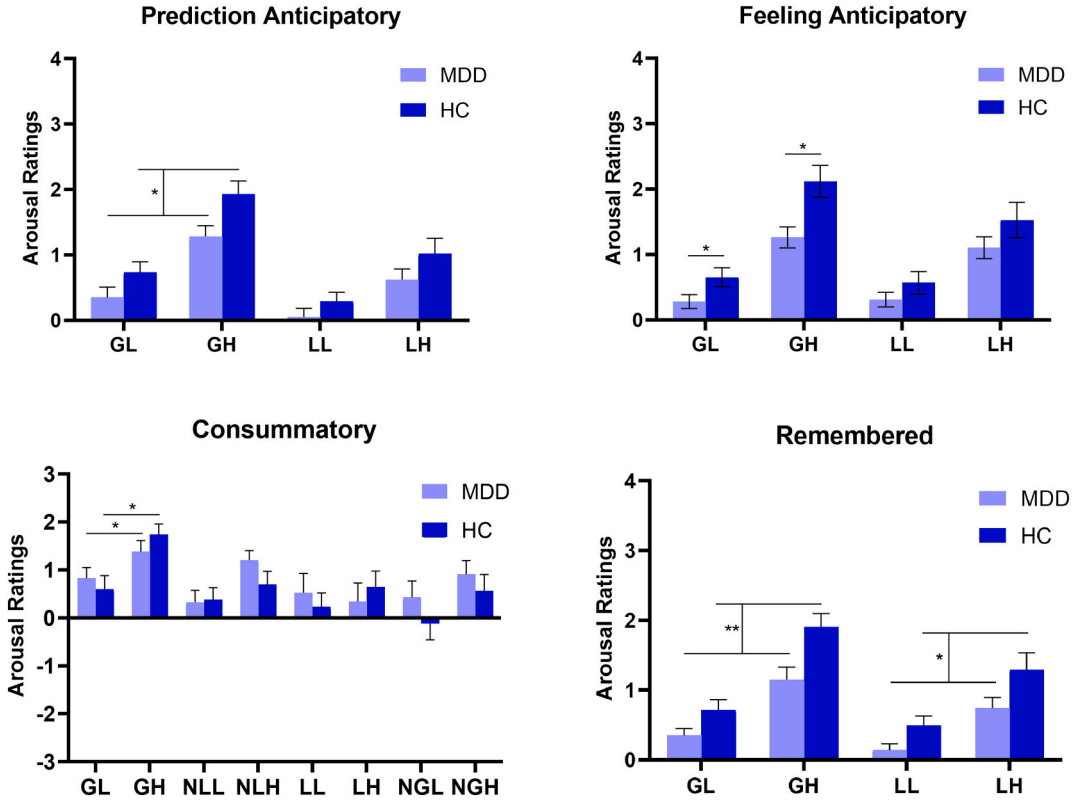

Fig. 2. Arousal ratings for emotional reactivity in the MDD group.
Notes: Four graphs represent the arousal ratings for emotional reactivity in anticipatory, consummatory, and remembered affect under gain, lose, no-gain, and no-lose condition in the MDD group and its control group. GL/GH: low/high emotional reactivity under gain condition; NGL/NGH: low/high emotional reactivity under no-gain condition; LL/LH: low/high emotional reactivity under lose condition; NLL/NLH: low/high emotional reactivity under no-lose condition.

interactions between Reactivity Level and Group for the prediction ($F(1,110) = 11.90$, $p = .001$, $\eta^2 = 0.098$) and feeling dimension of anticipatory affect ($F(1,110) = 3.98$, $p = .048$, $\eta^2 = 0.04$), consummatory affect under the gain condition ($F(1,110) = 5.89$, $p = .017$, $\eta^2 = 0.05$), as well as remembered affect under the lose condition ($F(1,110) = 10.90$, $p = .001$, $\eta^2 = 0.09$). As indicated by the simple effects analysis, SD participants showed a higher arousal level of reactivity than that of controls when anticipating gains of high reward (prediction dimension: $p < .01$, $d = 0.68$, 95 % CI [0.45, 1.54]; feeling dimension: $p = .012$, $d = 0.48$, 95 % CI [0.21, 1.65]), experiencing gain of low and high rewards (low: $p = .013$, $d = 0.48$, 95 % CI [0.17, 1.41]; high: $p < .01$, $d = 0.74$, 95 % CI [0.64, 1.94]), and recalling the loss of low and high magnitudes of money (low: $p < .01$, $d = 0.73$, 95 % CI [0.48, 1.48]; high: $p < .01$, $d = 0.88$, 95 % CI [0.87, 2.15]). After controlling for sex, results remained unchanged except that the interaction for the feeling dimension of anticipatory affect under the gain condition became non-significant ($F(1,109) = 2.43$, $p = .122$, $\eta^2 = 0.02$). The analysis also revealed main effects of Group for the prediction ($F(1,110) = 15.71$, $p < .01$, $\eta^2 = 0.13$; pairwise: $p < .01$, $d = 0.75$, 95 % CI [0.46, 138]) and feeling dimension of anticipatory affect under the lose condition ($F(1,110) = 16.22$, $p < .01$, $\eta^2 = 0.13$; pairwise: $p < .01$, $d = 0.76$, 95 % CI [0.60, 1.76]), consummatory affect under the lose ($F(1,110) = 5.11$, $p = .026$, $\eta^2 = 0.04$; pairwise: $p = .026$, $d = 0.42$, 95 % CI [0.12, 1.77]) and no-gain conditions ($F(1,110) = 4.10$, $p = .045$, $\eta^2 = 0.04$; pairwise: $p = .045$, $d = 0.38$, 95 % CI [0.015, 1.37]), and remembered affect under the gain condition ($F(1,110) = 9.13$, $p = .003$, $\eta^2 = 0.08$; pairwise: $p = .003$, $d = 0.57$, 95 % CI [0.27, 1.31]). The arousal level of reactivity was higher in SD participants than in controls regardless of type of affect or gain/lose condition. After controlling for sex, the results remained the same except that the main effect of Group for arousal ratings for consummatory affect under the lose and no-gain conditions became non-significant (lose: $F(1,109) = 0.04$, $p = .849$, $\eta^2 = 0.00$, no gain: $F(1,109) = 3.45$, $p = .984$, $\eta^2 = 0.32$).

3.3. Prediction and recall ability

To investigate whether cognitive function contributes to the impairment in emotional reactivity, we also examined how accurately the depressed groups predicted or recalled emotion compared with their control groups.

For MDD participants, there was only one significant main effect of Group for the arousal level of prediction ability towards monetary gain ($F(1,108) = 3.96$, $p = .049$, $\eta^2 = 0.04$). MDD participants overestimated their arousal level when expecting a gain of rewards compared with HCs.

For SD participants, the interactions between Price and Group were significant for valence ratings of prediction ability under both gain and lose conditions (gain: $F(2,220) = 4.02$, $p = .019$, $\eta^2 = 0.035$, lose: $F(2,220) = 4.24$, $p = .02$, $\eta^2 = 0.04$). When imagining feelings of anticipating a gain, SD participants and controls reported similar patterns of valence levels. When predicting feelings of loss of a reward, SD participants overestimated valence levels for a low reward more than the control group did ($p = .008$, $d = 0.51$, 95 % CI [0.12, 0.78]). There were no other significant group-relevant effects observed for arousal ratings. SD participants did not differ from controls in the ability to predict or recall emotion. After controlling for sex, most results remained unchanged; however, there was an additional significant main effect of Group for recall ability of valence level under the gain condition ($F(1,109) = 3.98$, $p = .049$, $\eta^2 = 0.04$). SD participants were more likely to overrate their valence than were controls for the recall of monetary gain.

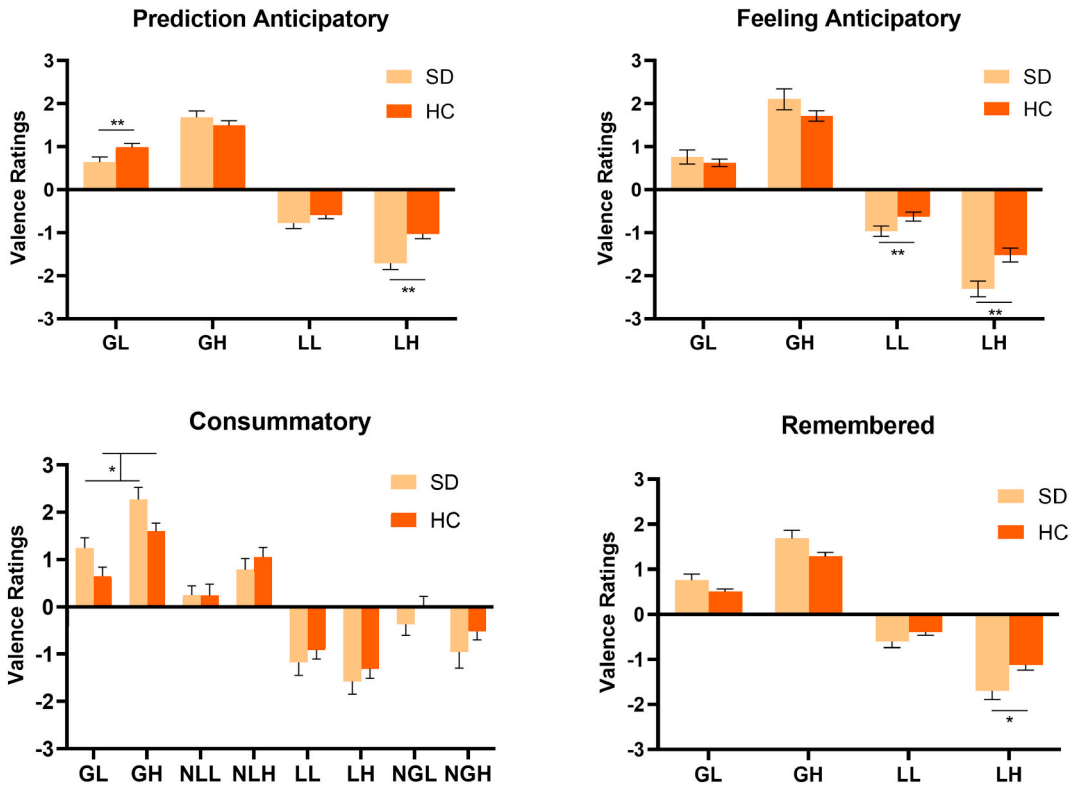

Fig. 3. Valence ratings for emotional reactivity in the SD group.
Notes: Four graphs represent the valence ratings for emotional reactivity in anticipatory, consummatory, and remembered affect under gain, lose, no-gain, and no-lose condition in the SD group and its control group. GL/GH: low/high emotional reactivity under gain condition; NGL/NGH: low/high emotional reactivity under no-gain condition; LL/LH: low/high emotional reactivity under lose condition; NLL/NLH: low/high emotional reactivity under no-lose condition.

3.4. Correlation between depression and emotional reactivity

MDD participants' HAMD scores were significantly negatively associated with valence ratings of reactivity in the prediction ($r = -0.47$, $p < .01$) and feeling dimension of anticipatory ($r = -0.44$, $p = .01$) and consummatory positive affect ($r = -0.55$, $p < .01$), and arousal ratings of reactivity for remembered positive affect ($r = -0.49$, $p < .01$) (Fig. 5). No significant correlations were found between duration of illness or emotional reactivity ($ps > 0.05$). After Bonferroni correction, results remained the same except for the correlation for the feeling dimension of anticipatory affect.

There were no significant correlations between SD participants' BDI scores and emotional reactivity.

4. Discussion

This study examined the generalization of the ECI theory across reactivity of anticipatory, consummatory, and remembered affect in clinically and subclinically depressed participants. MDD participants showed blunted reactivity for anticipatory, consummatory, and remembered positive affect; however, their reactivity was only blunted in the feeling dimension of anticipatory and remembered negative affect. In contrast, SD participants were highly aroused and showed fluctuating patterns of reactivity towards monetary rewards and elevated reactivity towards monetary loss for all three types of affect.

MDD participants experienced blunted emotional reactivity for anticipatory, consummatory, and remembered positive affect compared with controls, which generally corresponds to the ECI theory. Previous research has reported that clinically depressed individuals are insensitive to emotional stimuli (Jin et al., 2015; McIvor et al., 2020; Rottenberg et al., 2005). Current study further generalized the insensitivity to the anticipation, experience and recall of positive affect and the finding is consolidated by abundant neuroimaging evidence implicating blunted reduced reward positivity and reduced activity in the mesolimbic reward circuitry (Klawohn et al., 2021; Wang et al., 2021). However, MDD participants exhibited blunted emotional reactivity on recall but not prediction or experience of the loss or non-gaining of a reward, which is inconsistent with the ECI theory. Similarly, several studies failed to observe blunted responsiveness towards negative stimuli in depressed populations. Both studies used money as a reward and found that individuals with depression and healthy individuals did not differ in emotional reactivity towards punishment or no reward, which was reflected in the affect rating feedback negativity (Liu et al., 2014; McFarland and Klein, 2009). Moreover, other research has revealed that individuals with depression are more biased towards negative stimuli (Fossati, 2008; Watters and Williams, 2011). Thus, it appears that negative emotional reactivity in the clinically depressed population may be either normal or more intense than in healthy individuals, rather than weaker. Furthermore, a monetary incentive may contribute to the maintenance of a negative reaction in the clinically depressed population. Studies have found that in those with MDD, negative self-relevant stimuli are more likely to trigger affective responses and biases than are general and positive stimuli (Benau et al., 2019; Gaddy and Ingram, 2014; Guhn et al., 2018). Compared with faces, daily events and other affective stimuli (e.g., money used in this study) may be more motivationally salient stimuli for participants because their participation fee depended on the amount of money they gained or lost in the task. Although prediction and recalled ability of affect appeared to be intact in MDD participants in this study, their blunted recalled emotional reactivity may serve as an adaptive emotion regulation strategy that disengages clinically depressed individuals from distressing events (Benning and Ait Oumeziane, 2017; Nesse, 2000). That said, despite the cognitive bias towards negative stimuli, individuals with clinical depression may be prone to suppressing negative memories when

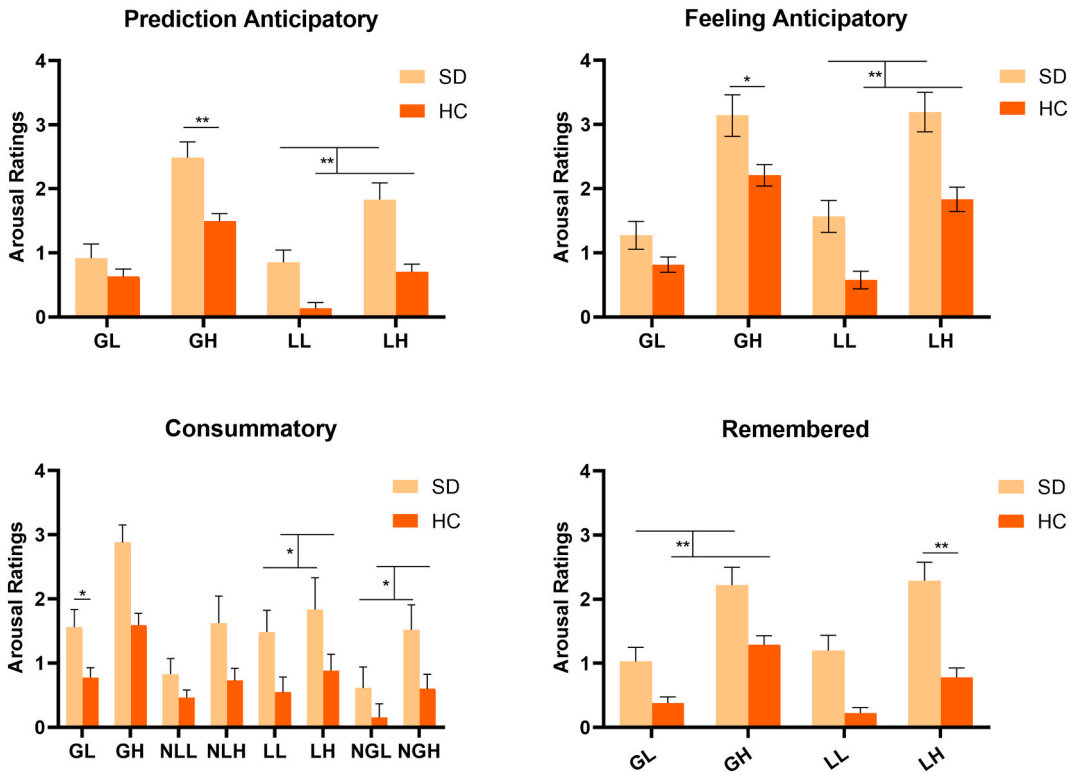

Fig. 4. Arousal ratings for emotional reactivity in the SD group.
Notes: Four graphs represent the arousal ratings for emotional reactivity in anticipatory, consummatory, and remembered affect under gain, lose, no-gain, and no-lose condition in the SD group and its control group. GL/GH: low/high emotional reactivity under gain condition; NGL/NGH: low/high emotional reactivity under no-gain condition; LL/LH: low/high emotional reactivity under lose condition; NLL/NLH: low/high emotional reactivity under no-lose condition.

emotions accumulate during the late emotion process, which likely reduces responses towards various environmental contexts (Gross and John, 2003). Similarly, evidence in healthy individuals has revealed that the suppression of negative affect may also hinder the processing of positive information (Dunn, 2012; Taylor and Brown, 1988). Clinically depressed individuals may exert considerable effort to suppress negative emotions triggered during the anticipatory and consummatory period and use up mental resources for positive emotions, which eventually leads to blunted responses towards both positive and negative information during recall. Alternatively, blunted recalled emotional reactivity may be associated with rumination. Depressed individuals experiencing one-time rumination could have more overgeneral autobiographical memories (Raes et al., 2005; Watkins and Teasdale, 2004). Their overgeneral memories may be loaded with summaries of numerous emotionally-laden situations that lack details, which may induce a lower level of affective reactivity.

In contrast, the results of the SD group revealed a mixed pattern of emotional reactivity. Reduced reactivity was only observed when SD participants were expecting a monetary reward, which, to some extent, may reflect the feature of the ECI theory. Inconsistent with the ECI theory, SD participants showed increased reactivity for consummatory positive affect and anticipatory and remembered negative affect and an enhanced arousal level of reactivity for all three types of affect. Thus, SD participants appeared to be characterized by a more unstable and oversensitive emotional reactivity than were MDD participants. This instability may develop into a more severe depression that reaches clinical criteria or may result in recovery from depression symptoms. The tendency of hyperarousal in the SD group may be due to the comorbidity of subclinical depression and anxiety. Individuals with high BDI scores are usually exposed to a high level of anxiety (Werner-Seidler et al., 2013), which provokes high physiological arousal and tension (Dunn et al., 2010). Another possible explanation for the hyperarousal is that subclinically depressed individuals show higher sensitivity towards rewards than clinically depressed individuals (Takagaki et al., 2014). Moreover, subclinically depressed and clinically depressed individuals with comorbid anxiety are sensitive towards signs of punishment, in contrast to the clinically depressed population without comorbid anxiety (Brinkmann et al., 2009; Henriques et al., 1994; Henriques and Davidson, 2000). Therefore, individuals who are at a subclinical stage of depression may have a higher level of arousal, which is opposite to the pattern of those who are clinically depressed. On this basis, emotional arousal may be a turning point between subclinical and clinical depression, although several studies have reported a pattern of ECI in individuals with subclinical depression (Benning and Ait Oumeziane, 2017; Moran et al., 2012), which suggests that the presentation of ECI may not be affected by depression severity.

The discrepant pattern of emotional reactivity between MDD and SD participants was also reflected in the differing relationship between depression severity and reactivity. The level of depression in MDD participants was negatively related to diminished reactivity towards monetary rewards, whereas the severity of subclinical depression in SD participants showed no correlation with emotional reactivity. In line with this finding, greater severity of depression is correlated to diminished reactivity towards positive videos (Reichenberger et al., 2017), and positive reactivity decrease more than negative reactivity in MDD individuals (Bylsma et al., 2008). Clinically depressed individuals are typically characterized by low reactivity for positive affect, which corresponds with two cardinal diagnosis criteria of MDD: low mood and loss of pleasure (American Psychiatric Association, 2013). On the other hand, the null correlation results may strengthen the finding that emotional reactivity in SD participants is unstable. We speculate that impairments in emotional reactivity develop in parallel with the course of depression and eventually result in a pattern of decreased positive emotional reactivity.

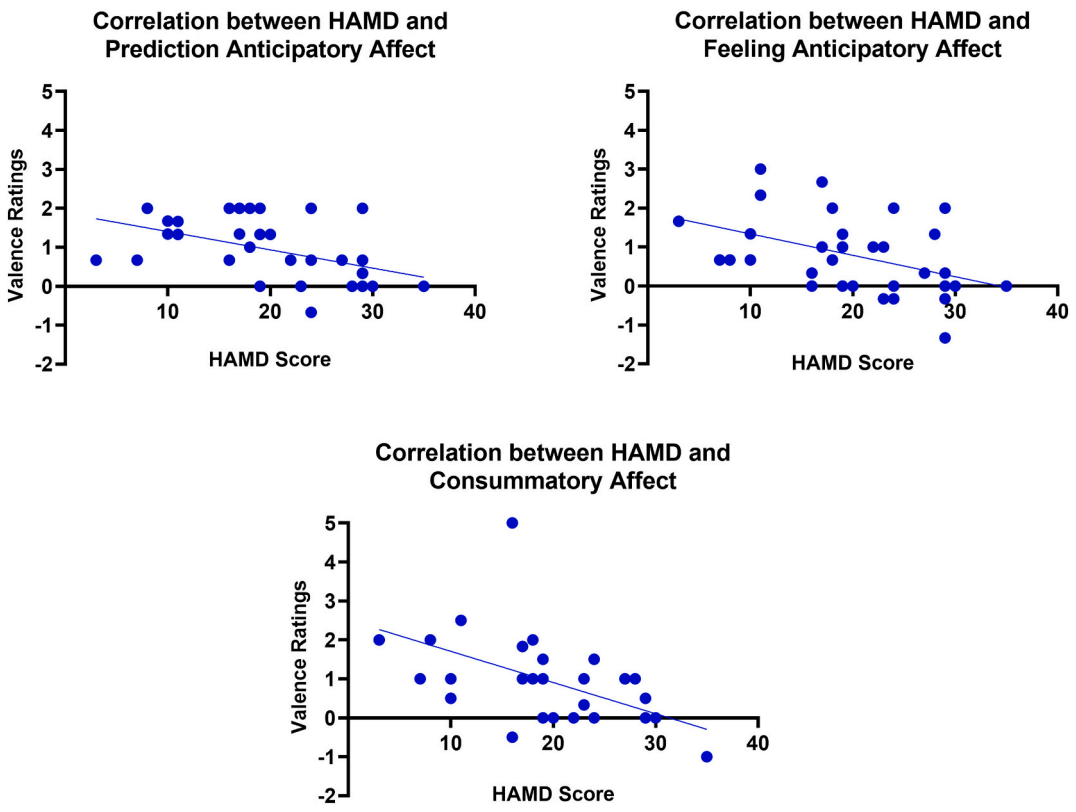

Fig. 5. Correlations between HAMD score and valence ratings of emotional reactivity in the MDD group.
Notes: Three graphs present negative correlations between HAMD score and valence ratings of emotional reactivity in prediction and feeling dimension of anticipatory affect and consummatory affect. Data of 32 participants were included in total.

To the best of our knowledge, the current study is the first to address the reactivity of anticipatory, consummatory, and remembered affect towards positive and negative stimuli and provides a comprehensive picture of the emotional features of depressed individuals. In addition, both self-reported and laboratory methods were applied to evaluate the severity of hedonic capacity. The current study contributes significantly to existing knowledge: we revealed similarities and discrepancies in hedonic responses between clinical and subclinical depression populations. Our findings may provide further insight into the early detection or prevention of severe depression and facilitate personalized treatments for individuals with different levels of depression.

The current study has several limitations that deserve mentioning. Firstly, emotional affect was assessed via subjective ratings. Thus, participants may rate the reward rather than their affect as pleasurable or arousing, which would lower the reliability of the measurement. Future studies are needed to employ physiological (e.g., physiological data acquisition system) and neurobiological methods (e.g., functional magnetic resonance imaging) to unfold the nature of emotional affect in depressed individuals. Secondly, the current study was embedded into a laboratory setting; therefore, the results may not be generalizable to daily life. Indeed, individuals with depression are more reactive towards daily events than towards laboratory materials (Khazanov et al., 2019). Because individuals may have different thresholds for pleasantness, identical laboratory stimuli are unlikely to provoke the target emotional reaction in all participants. Furthermore, monetary stimuli in laboratory settings are not representative of all rewards in social contexts. It has been suggested that individuals respond differently towards monetary and social rewards (Spreckelmeyer et al., 2009). Alternatively, experience sampling methodology (ESM), is considered a fine-grained approach that evaluates emotional experience and symptoms in the real-world context (Myin-Germeys et al., 2018). Future studies regarding major depressive disorder are in need to carefully elaborate the feature of anhedonia in real-life settings. Finally, we recruited more female than male participants since the proportion of females is higher than males in depressed population. Our findings may be less applicable for male population.

5. Conclusion

The ECI theory was partly supported by the emotional reactivity of clinically depressed individuals with an exception in anticipatory and consummatory negative affect. However, the ECI theory was not supported by the emotional reactivity of those with subclinical depression. Insensitive reactivity in clinical depression may be due to a psychopathological process rather than the severity of depression, and the arousal level of reactivity may serve as a turning point between subclinical and clinical depression.

CRediT authorship contribution statement

CY and JKW collaboratively generated the idea and conceptualized the aims and hypotheses of the study. QYL, JWK and ZHY conducted clinical assessments and transferred patients to our study. CY ensured appropriate application of analysis methods and drafted part of the manuscript. CWS recruited participants and collected data with the assistance of YJW. CWS conducted final data analysis and completed the manuscript. WYX helped with reference management and both CY and YW provided feedback on the concept and the text of the manuscript.

Conflict of interest

No authors reported any conflicts of interest with this work.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2022.06.069.

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