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Blunted Cardiovascular Reactivity in Dysphoria during Reward and Punishment Anticipation

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Abstract

Hyposensitivity to reward in depression and dysphoria has been found in behavioral and neuroimaging studies. For punishment responsiveness, some studies showed hyposensitivity to punishment while other studies demonstrated hypersensitivity. Only few studies have addressed the motivational question as to whether depressed individuals mobilize less effort in anticipation of a positive or a negative consequence.

The present study aimed at investigating reward and punishment responsiveness in subclinical depression from an effort mobilization perspective. Working on a recognition memory task, one third of the participants could earn small amounts of money, one third could lose small amounts of money, and one third could neither earn nor lose money. Effort mobilization was operationalized as participants' cardiovascular reactivity during task performance.

As expected, reactivity of cardiac pre-ejection period and heart rate was higher in both incentive conditions compared to the neutral condition for nondysphorics, while it was blunted across conditions for dysphorics. Moreover, the present study found that dysphorics show an altered behavioral response to punishment. These findings thus show that dysphorics present a reduced motivation to obtain a reward or to avoid a punishment in terms of reduced effort-related cardiac reactivity.

1. Introduction

Depression is one of the most frequent psychiatric disorders (Diagnostic and Statistical Manual of Mental Disorders [DSM-IV-TR], American Psychiatric Association, 2000). One of its core symptoms is anhedonia, defined as the loss of pleasure and interest (see Dichter, 2010, for a review) and related to insensitivity to hedonic consequences.

In the present study, we focus on one specific aspect of this anhedonic symptom, which is reward and punishment responsiveness. Using cardiovascular and behavioral measures, this study aims at investigating anticipatory motivation for obtaining a monetary reward and for avoiding a monetary punishment in dysphoria (i.e., subclinical depression). Our main hypothesis suggests that nondysphoric individuals would mobilize more effort in the incentive conditions than in the neutral condition, while effort mobilization would be blunted across all conditions for dysphoric individuals.

1.1. Reward and punishment anticipation in depression

Regarding reward responsiveness, depression has been associated with a deficit in the motivational approach system. Behavioral theories suggest that depressed individuals experience a lack of positive reinforcement. As a consequence, the behavior leading to positive consequences is given up (Beck, 1979; Jacobson et al., 2001). Depression is also characterized by a deficit in the behavioral facilitation system (Depue and Iacono, 1989) and in the behavioral activation system (Fowles, 1994). Finally, several authors affirm that depressed individuals do not experience rewards as reinforcing (Costello, 1972; Meehl, 1975; Strauman, 2002). Nowadays, reward is considered as a complex construct involving several psychological components, including reward learning, reward wanting, and reward liking (Berridge and Kringelbach, 2008). In the present study, we focus on reward wanting, which is defined as the anticipatory motivated behavior to obtain a reward (Berridge and Robinson, 2003). Most of the behavioral and neuroimaging studies revealed that depressed (Olino et al., 2011) and dysphoric individuals (Chentsova-Dutton and Hanley, 2010) showed a reduced motivation to obtain a reward.

Contrary to reward, punishment responsiveness has been less studied and the literature is less consistent (see Eshel and Roiser, 2010, for a review). However, the emotion context insensitivity hypothesis (Rottenberg et al., 2005), considers depression as characterized by disengagement, and suggests that depressed individuals show diminished emotional reactivity to both positive and negative stimuli. Moreover, following an error feedback, depressed persons are at an enhanced risk of making a subsequent error (e.g., Elliott et al., 1997). An interpretation of this phenomenon suggests a hyposensitivity to negative consequences, in the sense that depressed individuals have difficulties using negative feedback to improve future performance (Eshel and Roiser, 2010). There are a couple of studies that have investigated punishment anticipation with tasks involving monetary gains and losses. Some of them found that high risk girls (Gotlib et al., 2010) and remitted depressed (Schiller et al., 2013) showed a neural hyposensitivity during punishment anticipation. However, other studies (Knutson et al., 2008; Olino et al., 2011) did not find these neural differences between depressed and non depressed individuals during punishment anticipation.

In sum, the literature consistently shows reduced reward sensitivity in depression and dysphoria during reward anticipation (i.e., wanting). The literature also demonstrates hyposensitivity to punishment, even though this evidence is less consistent. From a motivational perspective the important question remains open as to whether clinically and subclinically depressed individuals indeed mobilize less effort in anticipation of a positive or a negative consequence.

1.2. Effort mobilization and cardiovascular reactivity

Effort mobilization is defined as the mobilization of resources for attaining goals (Gendolla and Wright, 2009) and represents the intensity of motivation. Brehm's motivational intensity theory (Brehm and Self, 1989) postulates that task difficulty and success importance determine effort mobilization in goal pursuit. Reward and punishment are variables that determine success importance: The higher the positive consequence to be obtained or the higher the negative consequence to be avoided, the higher is success importance. In motivational intensity theory, success importance is expected to have a direct impact on effort mobilization when task difficulty is unclear or unfixed (i.e., when the performance standard is unknown or when the performance standard can be chosen by the individual; Brehm and Self, 1989; Richter, 2012; Wright, 1996). Accordingly, unclear or unfixed task contexts allow to test the direct impact of reward and punishment on effort mobilization in goal pursuit.

As proposed by Wright's integration (Wright, 1996, 2008; Wright & Kirby, 2001) of motivational intensity theory (Brehm and Self, 1989) and Obrist's(1981) active coping approach, effort mobilization in active coping situations is proportional to the sympathetic activation of the heart. Pre-ejection period (PEP), the time interval between the onset of left ventricular excitation and the opening of the heart's left ventricular valve, is a direct measure of the sympathetically determined force of myocardial contraction. Systolic blood pressure (SBP) is also systematically influenced by myocardial contractility, while diastolic blood pressure (DBP) is mainly determined by total peripheral resistance and heart rate (HR) is determined by both sympathetic and parasympathetic activation (Papillo and Shapiro, 1990). A large number of studies have confirmed the predictions of motivational intensity theory by using cardiovascular reactivity (see Gendolla et al., 2012 for review). Importantly, findings from tasks with unclear difficulty have demonstrated increased cardiovascular reactivity during reward anticipation in comparison to a neutral condition (Richter and Gendolla, 2006, 2007, 2009). These studies showed that healthy participants mobilized more effort when a reward was at stake for successful performance.

2. The present study

As outlined above, the literature consistently demonstrates reduced sensitivity to reward—and in part also to punishment—in depression and dysphoria. However, only a few studies have addressed the question as to whether depressed or dysphoric individuals indeed mobilize less effort when incentives are anticipated (Brinkmann et al., 2009; Brinkmann and Franzen, 2013). Specifically, only one study has demonstrated reduced cardiovascular reactivity to a monetary punishment, which was delivered on an all-or-nothing basis. What is more, this study did not find results on the primary cardiovascular measure, which is PEP

(Brinkmann et al., 2009, Study 1). Finally, all of these studies have focused only on physiological measures and did not simultaneously take behavioral measures into account.

The present study aims to close these gaps in the literature by investigating not only reward but also punishment responsiveness from a motivational point of view, using cardiovascular reactivity as an operationalization of effort mobilization during the anticipatory phase of reward and punishment processing (i.e., wanting). PEP reactivity, our primary measure of sympathetic impact on the myocardium (Kelsey, 2012), as well as SBP, DBP, and HR reactivity were assessed during performance of a cognitive task with unfixed difficulty, that is, a task where incentives directly determine effort mobilization (Brehm and Self, 1989; Wright and Kirby, 2001). Moreover, in order to link effort-related cardiovascular reactivity to previous research on reward and punishment insensitivity in depression and dysphoria (Henriques and Davidson, 2000), monetary rewards and punishments in the present study were delivered on a trial-by-trial basis. Finally, to take into account both physiological and behavioral levels, a recognition memory task similar to previous behavioral studies (Henriques and Davidson, 2000) was chosen for the present study.

Based on previous research with healthy participants (Richter and Gendolla, 2009), we hypothesized that nondysphoric participants would show an increase in cardiovascular reactivity if they could win a monetary reward or if they could avoid a monetary loss, compared to a neutral condition without hedonic consequence. In contrast, we expected a blunted cardiovascular response to both reward and punishment anticipation in dysphoria (e.g., Eshel and Roiser, 2010). Specifically, we hypothesized that dysphoric participants would show no increase in cardiovascular reactivity in the incentive conditions but have a cardiovascular response similar to the one in the neutral condition. Moreover, we hypothesized the same pattern for the behavioral measure, expecting that in the incentive conditions nondysphoric participants would show stronger reward maximization behavior than dysphoric individuals, whereas behavioral responses of the two groups would be similar in the neutral condition (Henriques and Davidson, 2000). Furthermore, we hypothesized that nondysphoric individuals would use the negative feedback after an unsuccessful trial in the punishment condition to perform better in the subsequent trial, whereas dysphoric participants would not (Elliott et al., 1997; Eshel and Roiser, 2010). Finally, we expected that dysphoric individuals would report lower reward attractiveness, lower punishment aversion, and lower success importance than nondysphoric individuals.

3. Method

3.1. Participants and experimental design

The study was run in a 2 (dysphorics vs. nondysphorics) x 3 (neutral vs. reward vs. punishment) between-persons design and was approved by the appropriate local ethics committee. Participants were University students recruited from an introductory psychology course and by announcement at the University blackboards and received 15 Swiss Francs (about 15 USD) for participation. The final sample consisted of 107 students, composed of 87 women and 20 men aged from 19 to 35 years (see Table 1 for sample characteristics).

Dysphoric and nondysphoric participants were randomly assigned to one of the three experimental conditions.

Preceding the experimental session, participants first answered the Center for Epidemiologic Studies – Depression Scale (CES-D; Radloff, 1977) as part of a questionnaire session. Participants scoring in the lower or in the upper quartiles of the CES-D score distribution were then invited via an anonymous code to participate in the experimental session. Of the 126 students who participated in the experimental session, only those participants whose CES-D scores at this second measurement time stayed within the lower (≤ 11) or upper (≥ 15) quartile of the CES-D were retained for analyses. Of the 116 remaining participants, nine had to be excluded due to bad signal quality of the impedance measure during habituation or task (five participants) or due to extremely high PEP reactivity of more than 2.5 *SD*s above overall means (four participants: one participant in the nondysphoric-reward condition, two participants in the dysphoric-neutral condition, and one participant in the dysphoric-reward condition). Finally, six participants had to be excluded due to bad signal quality of the SBP and DBP measures during habituation or task. The final sample for these two measures thus consisted of 101 participants.

3.2. Procedure

The present study was divided into two parts, a questionnaire session and an experimental session. Participants answered the CES-D in the questionnaire session, and were invited for the experimental session about 6 months later. Each experimental session was individual and took about 30 min. The experimenter, who was blind to hypotheses and experimental conditions, first welcomed the participant and then asked him or her to take a seat in front of the computer monitor, to answer some biographical questions and to sign an informed consent form. Next, the experimenter applied the sensors for assessment of cardiovascular measures, explained the first part of the experimentation, left the room, and monitored the experiment from an outside control room. For this first part, participants were asked to answer the CES-D and a mood scale, ostensibly for an unrelated questionnaire validation study.

Then, the experimenter reentered the experimental room to start the second part of the study and left the room. For this second part, participants were first asked to read introductory study information. Then, the habituation period started, during which they watched an excerpt of a hedonically neutral documentary film and during which cardiovascular baseline measures were assessed. After this habituation period, participants received instructions for the recognition memory task. Then, participants in the two incentive conditions received information about the incentive structure of the task. After these instructions, participants answered questions about task importance (all participants) and reward attraction or punishment aversion, depending on the experimental condition. Afterwards, the memorization phase started, during which cardiovascular activity was assessed, followed by a color-discrimination distraction task. Then, participants were asked to perform the recognition phase. Finally, the experimenter reentered the room and removed the blood pressure sensor and the electrodes. Participants were thanked and debriefed.

3.3. Self-report measures

The French version of the positive and negative hedonic tone scales of the UWIST mood adjective checklist (Matthews et al., 1990) was used to measure participants' momentary mood. Participants had to indicate their momentary feeling state by scoring eight adjectives on 7-point scales ranging from 1 (*not at all*) to 7 (*very much*). A mood index was calculated by summing all negative and reverse-scored positive items, so that higher scores indicate a more negative mood. In this study, the UWIST showed high internal consistency (Cronbach's α = .89).

The CES-D was used in order to measure dysphoria and to divide participants in two groups. This self-report depression scale aims at identifying the presence of depression and to assess the severity of depressive symptomatology. The French version of this questionnaire was validated by Führer and Rouillon (1989) and consists of 20 items. For each item, participants have to indicate the frequency of the depressive symptom occurrence during the past week on 4-point scales from 0 (*never, very seldom*) to 3 (*frequently, always*). The total score is calculated by summing all items (four reverse-scored items) and can vary from 0 to 60 (Cronbach's α = .93).

Depending on the experimental condition, we assessed participants' perception of reward attractiveness ("To what extent is the gain of money attractive for you?", "To what extent do you want to gain the money?", "To what extent is it interesting for you to obtain the proposed money?") or punishment aversion ("To what extent is the loss of money aversive for you?", "To what extent do you want to avoid losing the money?", "To what extent is it interesting for you not to lose the initial credit?") by means of three questions to be rated on 7-point scales (Cronbach's α = .84 for reward; Cronbach's α = .75 for punishment). In all three conditions, we assessed participants' perception of task importance ("To what extent is it important for you to obtain a good performance in this task?", "To what extent is it important for you to invest effort during this task?") by means of two questions to be rated on 7-point scales (Cronbach's α = .69; $r(72) = .53$). Because it has been shown that task context can have an impact on the relationship between incentives and cardiovascular response (Richter, 2010), all these questions were asked before task performance in order to make the incentives salient.

3.4. Experimental task

The study was computerized using a personal computer and experimental software (Inquisit 3.0, Millisecond Software, Seattle, WA) for all instructions and stimuli presentations. The experimental task was a recognition memory task, which consisted of two parts, a memorization phase and a recognition phase. During the memorization phase, a list of 30 non-words (e.g., "imbose") was presented on the screen during 5 min, and participants were asked to learn as many of those non-words as they could (unfixed or "do your best" task difficulty). Cardiovascular measures were taken throughout this 5-min memorization phase. The non-words had been created by means of an internet site specialized in creating databases according to French language rules (New and Pallier, 2012) using the following criteria: every non-word had to have six letters and these letters were selected by their mean frequency in the French language.

During the recognition phase, 90 trials were presented, randomly composed of 30 target non-words and 60 distractor non-words. For each target, two distractors were created, using the same first and last letters and mixing up the remaining four letters (e.g., for the target “imbose”, the created distractors were “ibsome” and “ibosme”). This construction was chosen to make the stimuli recognition ambiguous. During each recognition trial, a non-word was presented in the center of the screen. Participants had to decide whether or not they had seen the non-word during the memorization phase by pressing one of two specified keys before the next non-word appeared. There was no time limit for responding in the recognition phase. In the reward and punishment conditions, the incentive structure was inspired by Henriques and Davidson (2000). In the reward condition, participants got 0.30 Swiss Francs (about 0.30 USD) for each correct identification of a target non-word, which could accumulate to a maximum gain of 9 Swiss Francs (about 9 USD). For each correct identification, participants received a feedback indicating that the response was correct, how much they won on the current trial, and what were their current cumulative earnings. In the punishment condition, an initial credit of 9 Swiss Francs was given to the participants and they lost 0.30 Swiss Francs for each omission of a target non-word. In this situation, participants received a feedback indicating that the response was wrong, how much they lost on the current trial, and what was their current remaining credit. At the end of the recognition phase, participants in the neutral condition received information about their total number of correct responses. Participants in the incentive conditions received information about their cumulative credit (example: “You won 6.60 Swiss Francs.”).

To make a break between the memorization and recognition phases and thus to increase the difficulty of the recognition memory task, a 3-min color-discrimination distraction task was administered. Participants had to count the number of blue squares among a series of squares of different colors.

3.5. Cardiovascular measures

Cardiovascular measures were assessed during a habituation phase and during the memorization phase of the recognition memory task. All measures were directly transferred to and stored on a computer drive so that both experimenter and participants were ignorant of these values. PEP and HR were measured noninvasively with electrocardiogram (ECG) and impedance cardiogram (ICG) signals using a Cardioscreen® 1000 haemodynamic monitoring-system (medis, Ilmenau, Germany) (for a validation study see Scherhag et al., 2005). Four dual gel-pad sensors (medis-ZTECT™) were placed on each side of the base of the participant’s neck and on each side of the thorax along the mid axillary line at the level of the xiphoid. Data were sampled with 1000 Hz. SBP and DBP were measured noninvasively by applanation tonometry using a Vasotrac® APM205A monitor (MEDWAVE®, St. Paul, MN) (for a validation study see Belani et al., 1999). A pressure sensor was placed on the wrist on top of the radial artery of the participants’ nondominant arm and a blood pressure measure was obtained every 12 to 15 heart beats.

3.6. Data reduction

For PEP measures (in ms), the ICG's first derivative (ICG dZ/dt signal) was ensemble averaged over 60-s time intervals and synchronized with the ECG signal. The ECG R-onset and the ICG B-point were automatically detected by a LabVIEW-based software (National Instruments, Austin, TX) developed in our laboratory (Richter, 2009). R-onset and B-point were then visually inspected by two independent raters and modified if necessary (see Sherwood et al., 1990). PEP was then calculated as the interval between ECG R-onset and ICG B-point (Berntson et al., 2004). Because inter-rater reliability was high, ICC(2,1) = .99 (Shrout and Fleiss, 1979), we used the averaged PEP values from both raters for analyses. HR (in beats per min [bpm]) was determined by means of the same software that detects and counts R-peaks in the ECG signal.

PEP, HR, SBP, and DBP baseline scores were created by averaging the last 4 minutes of the habituation period (Cronbach's αs > .97). Means of measures assessed during the 5-min memorization phase were used as PEP, HR, SBP, and DBP task performance scores (Cronbach's αs > .98). Cardiovascular reactivity scores were calculated as the difference of task scores minus respective baseline scores (see Kelsey et al., 2007; Llabre et al., 1991).

In order to assess reward and punishment responsiveness on the behavioral level, we calculated a sensitivity index and a response bias index from participants' responses during the recognition phase based on signal detection theory (see Snodgrass and Corwin, 1988): We calculated hit rate by dividing the number of correctly identified targets by the total number of targets (30). False alarm rate was calculated by dividing the number of incorrectly identified distractors by the total number of distractors (60). Then, we calculated sensitivity—a discrimination index of participants' performance—by subtracting false alarm rate from hit rate. Finally, response bias—an index of participants' proneness to choose the incentive maximizing option—was computed as false alarm rate divided by 1 minus sensitivity.

3.7. Statistical analyses

Cardiovascular baseline measures, mood, and self-reported success importance were tested with 2 (dysphoric vs. nondysphoric) x 3 (neutral vs. reward vs. punishment) between-persons ANOVAs. For self-reported reward attractiveness and punishment aversion, we ran independent samples *t*-tests for each of the incentive conditions. For our main hypotheses about cardiovascular reactivity, we calculated a priori contrasts for PEP, HR, SBP, and DBP reactivity scores, the most appropriate test for the predicted pattern (see Rosenthal and Rosnow, 1985). Contrast weights were -1 for dysphorics in all three conditions and for nondysphorics in the neutral condition (corresponding to the expected reduced responsiveness to both reward and punishment in dysphoria), and +2 for nondysphorics in each incentive condition. We used the same a priori contrasts for our main hypotheses about response bias and sensitivity. Furthermore, in order to test the effect of reward and punishment on participants' behavior in the next trial, we ran independent samples *t*-tests for each incentive condition.

4. Results

4.1. Cardiovascular analyses

Means and standard errors of the cardiovascular baseline scores for PEP, HR, SBP and DBP are presented in Table 2. According to 2 (dysphorics vs. nondysphorics) x 3 (neutral vs. reward vs. punishment) ANOVAs, there were no significant main or interaction effects on PEP and HR baseline measures, *F*s< 2.65, *p*s> .07. Results revealed an interaction effect for SBP, $F(2, 95) = 3.68$, $p = .03$, $\eta_p^2 = .07$, in absence of significant main effects, *F*s< 0.56, *p*s> .45, as well as an interaction effect for DBP, $F(2, 95) = 3.46$, $p = .04$, $\eta_p^2 = .07$, in absence of significant main effects, *F*s< 0.49, *p*s> .56. These interactions suggested that the nondysphoric group in the neutral condition and the dysphoric group in the punishment condition had lower SBP and DBP baseline values than the other groups. Follow-up comparisons with Tuckey's HSD tests showed that these cell differences were, however, not significant, all *p*s> .28.

Cardiovascular reactivity analyses revealed a significant a priori contrast for PEP, our main dependent variable, $F(1, 101) = 4.34$, $p = .04$, η_p^2=.04. Confirming our hypothesis, nondysphorics' PEP reactivity was higher in the incentive conditions (Reward: *M* = -2.33, *SE* = 0.92; Punishment: *M* = -3.68, *SE* = 1.08) than in the neutral condition (*M* = -0.90, *SE* = 1.04). In contrast, dysphorics' PEP reactivity was rather low in all three experimental conditions (Neutral: *M* = -2.03, *SE* = 0.84; Reward: *M* = -0.83, *SE* = 0.71; Punishment: *M* = -1.62, *SE* = 0.88) (see Figure 1).[1]

For HR, analyses also revealed a reliable a priori contrast according to our hypothesis, $F(1, 101) = 5.88$, $p = .02$, η_p^2 =.06. Similar to the PEP pattern, nondysphorics' HR reactivity was higher in the reward condition (*M* = 5.73, *SE* = 1.23) and in the punishment condition (*M* = 6.85, *SE* = 1.55) than in the neutral condition (*M* = 3.39, *SE* = 0.75). In contrast, dysphorics' HR reactivity was similar in the three experimental conditions (Neutral: *M* = 3.74, *SE* = 0.95; Reward: *M* = 4.01, *SE* = 0.85; Punishment: *M* = 5.08, *SE* = 0.88). This HR reactivity pattern is displayed in Figure 2.

The a priori contrasts for SBP and DBP reactivity were not significant, SBP: $F(1, 95) = 0.01$, $p = .91$; DBP: $F(1, 95) = 0.03$, $p = .87$, contrary to our hypothesis of enhanced blood pressure reactivity of nondysphoric participants in the incentive conditions. Means and standard errors of these measures are presented in Table 3.

4.2. Behavioral analyses

In order to assess reward and punishment responsiveness on a behavioral level using signal detection theory, sensitivity (overall *M* = 0.42, *SE* = 0.02) and response bias (overall *M* = 0.60, *SE* = 0.02) were analyzed. Results revealed no significant a priori contrasts for both behavioral measures, *F*s< 1.53, *p*s> .22. These results indicate that nondysphoric participants did not show significantly enhanced performance or incentive maximizing behavior in the incentive conditions.

Concerning the trial-by-trial analyses, *t*-tests showed a marginally significant effect for incorrect responses, that are preceded by punished incorrect responses in the punishment condition, $t(32) = -1.81$, $p = .08$, $\eta_p^2 = .02$. Confirming our hypothesis, nondysphorics made fewer errors following a punishment (*M* = 2.35%, *SE* = 0.61) than dysphorics (*M* = 4.41%, *SE* = 0.96) (see Figure 3). Results for correct responses in the punishment condition and for correct and incorrect responses in the other conditions were not significant, *t*s< 1.43, *p*s>.15, demonstrating no significant impact of performance feedback on subsequent trials in these conditions.

4.3. Self-report measures

For the UWIST analysis, we found a dysphoria main effect, $F(1, 101) = 53.96$, $p < .001$, $\eta_p^2 = .35$, in absence of other effects, *F*s< 1.44, *p*s> .62. This result shows that participants categorized as dysphoric were in a more negative mood (*M* = 25.51, *SE* = 1.10) during the time of the experiment than participants categorized as nondysphoric (*M* = 16.02, *SE* = 0.71).

Analyses for reward attractiveness and punishment aversion revealed no effects, *t*s< 1.13, *p*s> .26, indicating that dysphorics and nondysphorics did not significantly differ regarding their evaluation of reward attractiveness (Dysphorics: *M* = 4.33, *SE* = 0.27; Nondysphorics: *M* = 4.78, *SE* = 0.29) and punishment aversion (Dysphorics: *M* = 4.57, *SE* = 0.32; Nondysphorics: *M* = 4.76, *SE* = 0.29). However, results for success importance showed a marginally significant main effect of dysphoria, $F(1, 101) = 3.77$, $p = .055$, $\eta_p^2 = .04$, in absence of other significant effects, *Fs*< 0.79, *ps*> .46. This finding confirms our hypothesis that across the three conditions dysphorics (*M* = 5.26, *SE* = 0.16) tended to evaluate success as less important than did nondysphorics (*M* = 5.63, *SE* = 0.12).

5. Discussion

Previous behavioral and neuroimaging studies have demonstrated that dysphoric and depressed individuals show a hyposensitivity to reward and in part to punishment (see Eshel and Roiser, 2010, for a review) but the question remained open as to whether they would also mobilize less effort when anticipating a positive or negative incentive to follow goal pursuit. The present study thus aimed at closing these gaps in the literature by investigating reward and punishment responsiveness in dysphoria (i.e., subclinical depression) from a motivation point of view. Specifically, the aim of this study was to use not only incentive maximization behavior like in previous behavioral studies (e.g., Henriques et al., 1994; Henriques and Davidson, 2000) as an indicator of reward and punishment sensitivity, but also cardiovascular measures as an indicator of effort mobilization for obtaining a monetary gain or avoiding a monetary loss.

Using a recognition memory task with an unfixed task difficulty, the results of the present study confirm our main physiological hypothesis. As expected, the a priori contrast revealed that nondysphoric participants showed indeed an increase in PEP reactivity—our primary measure of sympathetic impact on the heart—in both reward and punishment conditions. In contrast, dysphoric participants did not show an increase in PEP reactivity in the incentive conditions, and PEP responses were similar to the neutral condition. These findings demonstrate that nondysphoric participants mobilized more effort for obtaining the reward or avoiding the punishment, whereas dysphoric participants showed blunted effort mobilization independent of incentives. The expected pattern was also found for HR reactivity but not for SBP and DBP reactivity.

The fact that HR reactivity mirrors PEP reactivity is not surprising. In his motivational theory, Fowles (1983) postulated an association between reward and cardiovascular response. Specifically, Fowles and colleagues demonstrated that HR increases when a reward is anticipated and suggested that this increase would reflect the behavioral activation system (Fowles, 1983; Fowles et al., 1982). Furthermore, many studies in the framework of motivational intensity theory (Brehm and Self, 1989) showed effects on HR (e.g., Brinkmann et al., 2009; Brinkmann and Franzen, 2013; Freydefont and Gendolla, 2012). The lack of an effect on DBP reactivity can be explained by the fact that DBP is mostly influenced by total peripheral resistance. Moreover, previous studies run in the context of motivational intensity theory have only inconsistently found DBP effects (see Gendolla et al., 2012, for a review). The absence of an effect on SBP reactivity is more surprising because SBP is systematically influenced by myocardial contractility. Most of the previous studies run with dysphoric and nondysphoric participants and based on motivational intensity theory have shown SBP reactivity effects (e.g., Brinkmann and Gendolla, 2007, 2008). However, other studies based on motivational intensity theory and working specifically with incentives have found PEP and HR effects without accompanying SBP effects (Brinkmann and Franzen, 2013; Freydefont and Gendolla, 2012). Finally, as SBP is determined not only by myocardial contractility but also by total peripheral resistance, it is possible that sympathetic effects on SBP reactivity in the present study have been masked by simultaneous decreases in peripheral resistance (Wright, 1996).

As outlined before, results of PEP reactivity correspond to our expectations. Nevertheless, it is important to further explore this finding because PEP may be driven not only by sympathetic impact on the heart but also by cardiac preload (i.e., left ventricular filling) and afterload (i.e., aortic diastolic pressure) (Sherwood et al., 1990). In order to conclude that the present results show sympathetic influences on the heart, a shortening of the PEP should be accompanied by a stability or an increase of HR and DBP, which are approximations for preload and afterload, respectively (Obrist et al., 1987; Sherwood et al., 1990). As can be seen from the descriptive data, there is a shortening of the PEP in the incentive conditions for nondyphoric participants, which is accompanied by an increase in DBP and HR. This pattern of results thus suggests that PEP reactivity in the present study is driven by sympathetic activation of the heart.

Taken together, the physiological results of the nondysphoric group are in line with previous studies conducted with healthy participants and using an unclear (Richter and Gendolla, 2006, 2007, 2009) or an unfixed (Wright et al., 2002) task difficulty. Moreover, the physiological results of the dysphoric group confirm reduced responsiveness to both reward and punishment. Behavioral and neuroimaging studies have already shown that depression and dysphoria are linked to a reduced responsiveness to reward (e.g., Kunisato et al., 2012; Pechtel et al., 2013; Shankman et al., 2013). The present study expands these previous studies on reduced reward responsiveness in dysphoria and adds important aspects to the literature: With a specific motivational approach in the framework of motivational intensity theory, our results demonstrate that subclinical participants with high depression scores show reduced effort mobilization for obtaining a monetary reward.

Furthermore, the PEP and HR results of the present study clearly show a reduced responsiveness to punishment in dysphoria. They lead to the same conclusions as previous behavioral and neuroimaging studies (Bress et al., 2012; Steele et al., 2007). Moreover, they are in accordance with findings from a previous physiological study (Brinkmann et al., 2009, Study 1), which found that participants with high depression scores had lower SBP reactivity than participants with low depression scores when a monetary punishment was anticipated. Importantly, they expand these previous findings with respect to PEP reactivity and a trial-by-trial incentive structure.

Concerning the behavioral measures, the main results were not significant. Whereas previous behavioral studies found reduced proneness to choose the incentive maximizing option in dysphoria (Henriques et al., 1994) and depression (Henriques and Davidson, 2000), the present study could not replicate these findings. One reason for this could be differences in the experimental design. Because of the cardiovascular measures, we ran the present study in a between-persons design, whereas in the two studies by Henriques et al. and Henriques and Davidson all participants worked on several neutral, reward, and punishment blocks in a within-persons design. However, supplemental analyses showed that nondysphoric participants performed better after a punishment than dysphoric individuals. We can make a link between this behavioral result and the specific impairment in responding to negative feedback information (see Eshel and Roiser, 2010, for a review). As outlined above, depressed persons tend to make more errors after errors, and this abnormal response can be interpreted as a difficulty to use negative feedback to improve future performance. Similar to our results, this interpretation suggests that depressed individuals have difficulties adjusting their behavior in order to reduce the risk of subsequent errors. It thus leads to the assumption of a hyposensitivity to punishment in depression (Eshel and Roiser, 2010).

Concerning self-report measures, we assessed participants’ self-reported feeling states to ensure that dysphorics and nondysphorics differed in terms of momentary mood at the time of the experimental session. Results of the UWIST scale showed a significant difference between the two groups, indicating that dysphorics were in a more negative mood than nondysphorics. Concerning self-reported reward attractiveness, punishment aversion, and success importance, results did not show the expected pattern of lower reward attractiveness and punishment aversion by dysphoric participants in comparison to nondysphorics’ evaluation. However, results about success importance revealed that across all three conditions dysphorics tended to evaluate success as less important than did nondysphorics. Even if further research is needed to make an affirmation, this tendency suggests that reduced reward and punishment responsiveness in dysphoria might be due to the lower evaluation of success importance and thus to impairments in the cognitive evaluation of incentives. These results are in accordance with theoretical considerations proposed by Treadway, Bossaler, Shelton, and Zald(2012), suggesting that anhedonic symptoms result from cognitive deficits. Specifically, the authors suggest that depressed individuals are hyposensitive to reward because they overestimate the costs of obtaining rewards, because they do not integrate cost/benefit information, or because they underestimate the anticipated benefits.

Finally, it is important to acknowledge two limitations of the present study. First, the sample was mainly composed of women. It is of note that previous studies have not revealed gender differences on self-report, behavioral, or neuroimaging measures of reward sensitivity in depression and dysphoria. Therefore, it is unlikely to find gender differences in effort-related cardiovascular reactivity. Moreover, the few men were approximately equally represented in each condition. Nevertheless, future studies including more men are needed. Another limitation of this study concerns the subclinical status of our dysphoric group. Following the perspective of a dimensional approach of psychopathology, which refers to a continuum from no depression to severe depression, results from subclinical analogue samples can reveal important insights for the understanding of clinical states (Ruscio and Ruscio, 2000). Nevertheless, future studies with clinical samples are needed to generalize our results.

In summary, the results of the present study confirm that dysphorics show an altered behavioral response to punishment and that they tend to attribute relatively less importance to success in the cognitive task than nondysphorics. On the physiological level, the present study demonstrates reduced responsiveness to reward in dysphoria with respect to cardiovascular measures, indicating that participants with high depression scores mobilize less effort to obtain a reward than participants with low depression scores. Moreover, our study also confirms this reduced responsiveness during punishment anticipation.

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Footnotes

[1] As suggested by an anonymous reviewer, we have tested three alternative contrasts that test the same main hypothesis. The first one tested the prediction that PEP reactivity would be stronger for nondysphoric than dysphoric participants in the two incentive conditions (contrast weights +1 for nondysphorics in the incentive conditions, -1 for dysphorics in the incentive conditions, 0 for the no-incentive conditions). The results showed a marginally significant effect, $F(1, 101) = 3.66$, $p = .055$. The second contrast tested the prediction that PEP reactivity would be stronger in the incentive conditions than in the neutral condition among nondysphoric participants (contrast weights 0 for all dysphorics, -2 for nondysphorics in the non-incentive condition, +1 for nondysphorics in both incentive conditions). This contrast was also marginally reliable, $F(1, 101) = 3.64$, $p = .06$. The third contrast tested the same effect as the second contrast among dysphoric participants (same contrast weights as the second contrast, but inversed for dysphorics and nondysphorics). As expected, this contrast was not significant ($F<1$). Taken together, these results lend further support to our main hypothesis.

Table 1
Sample characteristics

	N			CES-D		Age	
	Total	Men	Women	*M*	*SD*	*M*	*SD*
Nondysphorics	**56**	**9**	**47**	**6.07**	**3.20**	**22.46**	**3.12**
Neutral	19	4	15	5.84	3.56	22.00	2.31
Reward	20	4	16	7.10	2.63	22.25	2.81
Punishment	17	1	16	5.12	3.22	23.24	4.13
Dysphorics	**51**	**11**	**40**	**23.15**	**7.03**	**23.51**	**3.79**
Neutral	17	4	13	23.00	7.26	22.47	3.59
Reward	17	3	14	23.35	7.07	24.41	4.30
Punishment	17	4	13	23.12	7.18	23.65	3.37

Note. CES-D = Center for Epidemiologic Studies – Depression Scale

Table 2

Means and Standard Errors of Cardiovascular Baselines

	M				*SE*			
	PEP	HR	SBP	DBP	PEP	HR	SBP	DBP
Nondysphorics								
Neutral	101	75	125	73	2.33	2.03	2.82	2.01
Reward	99	76	129	76	3.46	2.00	4.14	2.97
Punishment	99	76	133	78	2.67	2.51	5.07	3.84
Dysphorics								
Neutral	93	82	134	79	2.57	3.75	4.07	2.88
Reward	99	71	137	78	2.14	2.86	5.06	3.94
Punishment	105	74	124	70	2.78	3.91	2.49	2.04

Note. SBP and DBP are indicated in millimeters of mercury, HR is indicated in beats per minute, and PEP is indicated in milliseconds. Please note that the blood pressure values are quite high. This is due to the application of the blood pressure sensor at the wrist, which systematically is at a lower level than the conventional blood pressure cuff applied at the upper arm. This effect consistently concerns baseline and task periods and is thus unproblematic for the interpretation of the change scores.

Table 3
Means and Standard Errors of Systolic and Diastolic Blood Pressure Reactivity

	M		*SE*	
	SBP	DBP	SBP	DBP
Nondysphorics				
Neutral	5.63	3.96	1.76	1.56
Reward	6.81	5.11	1.83	1.47
Punishment	7.30	5.19	1.97	1.73
Dysphorics				
Neutral	7.64	4.62	2.15	1.42
Reward	8.81	7.44	3.04	2.58
Punishment	5.27	3.65	2.62	1.80

Note. SBP and DBP are indicated in millimeters of mercury.

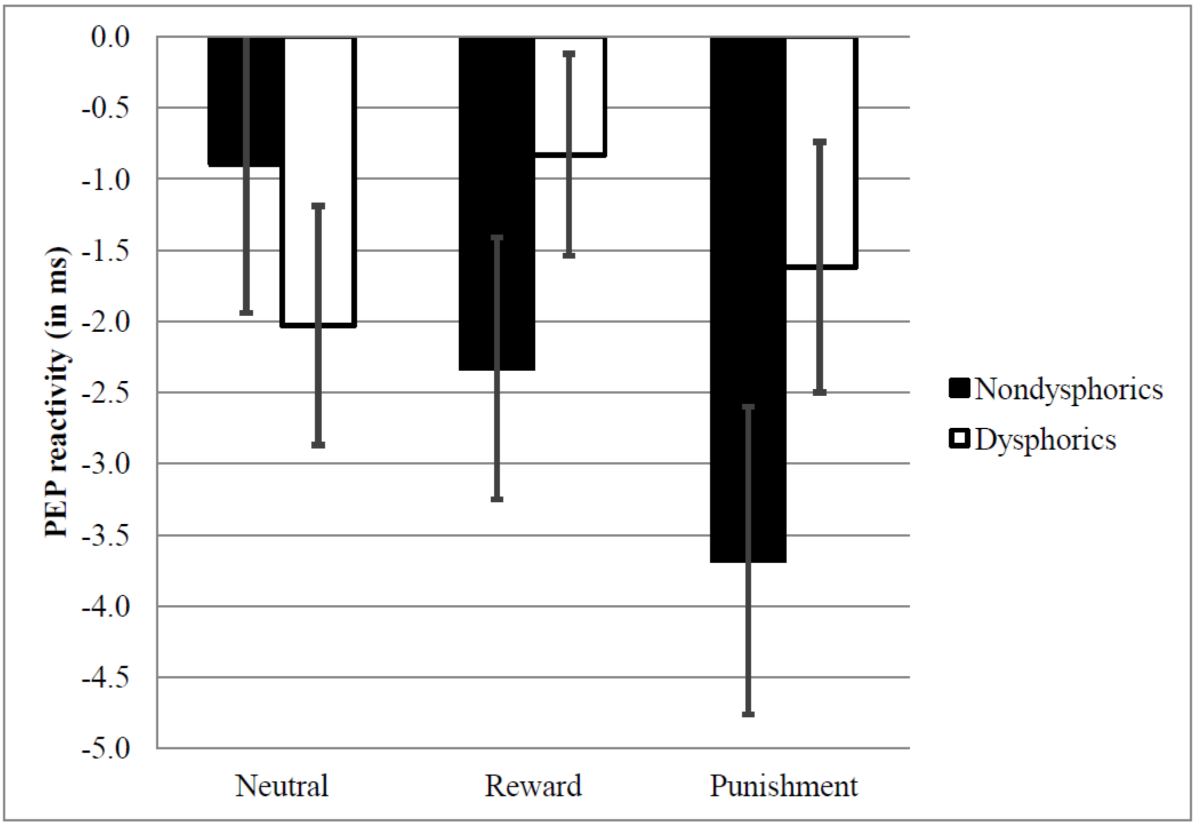

***Figure 1*. Means and Standard Errors of Pre-Ejection Period Reactivity**

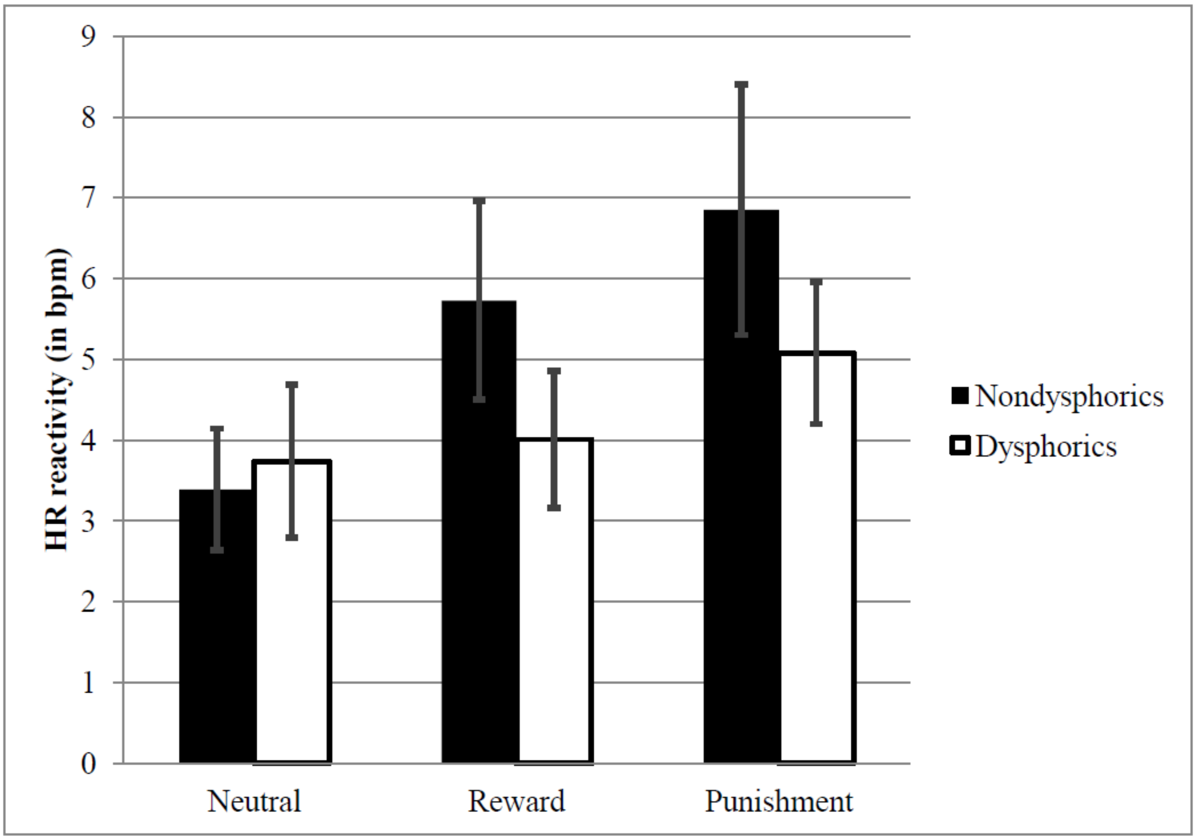

Figure 2. **Means and Standard Errors of Heart Rate Reactivity**

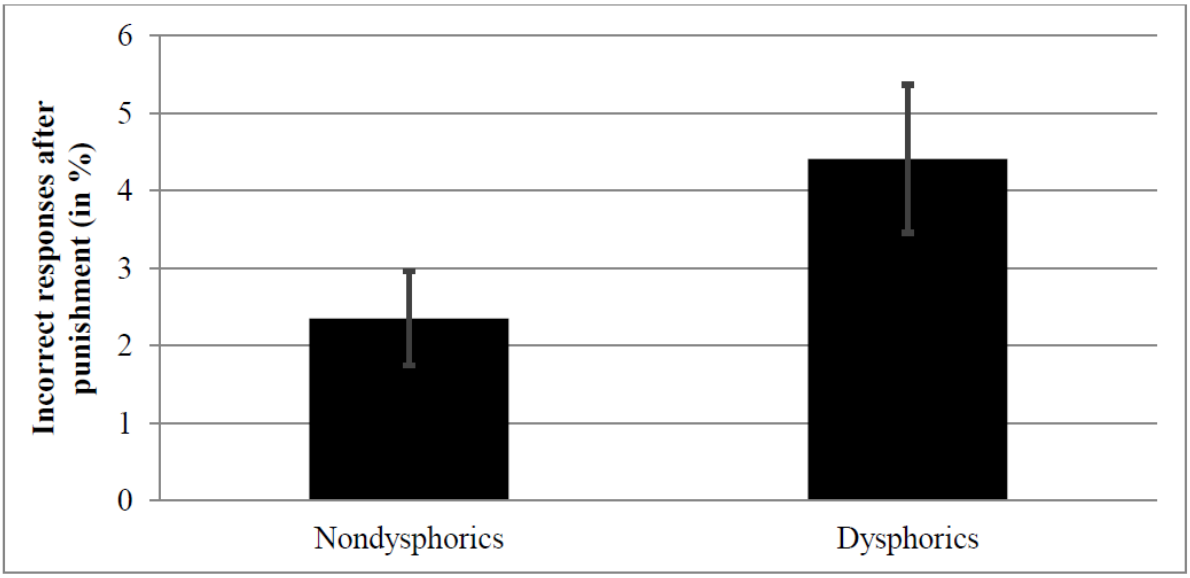

Figure 3. **Means and Standard Errors of Incorrect Responses after Punishment**